Taylor & Francis
Taylor & Francis Group

Journal of Plastic Surgery and Hand Surgery

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/iphs20

Is conservative management of partial zone II flexor tendon laceration possible? A systematic literature review and meta-analysis

Young Woong Mo, Da Hye Ryu, Gyo-Young Cho & Jong Won Hong

To cite this article: Young Woong Mo, Da Hye Ryu, Gyo-Young Cho & Jong Won Hong (2023) Is conservative management of partial zone II flexor tendon laceration possible? A systematic literature review and meta-analysis, Journal of Plastic Surgery and Hand Surgery, 57:1-6, 46-53, DOI: 10.1080/2000656X.2022.2117704

To link to this article: https://doi.org/10.1080/2000656X.2022.2117704

Published online: 19 Oct 2022.

JOURNAL OF PLASTIC SURGERY AND HAND SURGERY
2023, VOL. 57, NOS. 1–6, 46–53
https://doi.org/10.1080/2000656X.2022.2117704

ARTICLE

OPEN ACCESS Check for updates

Is conservative management of partial zone II flexor tendon laceration possible? A systematic literature review and meta-analysis

Young Woong Mo[a,b], Da Hye Ryu[a,b], Gyo-Young Cho[c] and Jong Won Hong[a,b]

[a]Department of Plastic and Reconstructive Surgery, Severance Hospital, Yonsei University College of Medicine, Seoul, Republic of Korea; [b]Institute for Human Tissue Restoration, Yonsei University College of Medicine, Seoul, Republic of Korea; [c]Department of Statistics, Kyungpook National University, Daegu, Republic of Korea

ABSTRACT

Background: There is still no consensus on managing zone II level partial flexor tendon lacerations, and the management of zone II partial flexor tendon injuries is controversial. No reliable large cohort studies or metaanalysis papers on partial flexor tendon laceration management are available in PubMed or Embase.

Methods: We searched PubMed, Embase, Cochrane Library, Insight, Scopus, and Web of Science databases for primary research articles investigating outcomes of patients with partial flexor tendon injuries. The initial search was limited to human studies that were published from 1970–2021 and indexed as randomized controlled or clinical trials or observational, cross-sectional, or cohort studies. We used statistical package R version 4.1.2 for this meta-analysis.

Results: The Standardised mean difference (SMD) of the common effects model was 2.020 (95% CI; 1.583–2.457; $P < 0.0001$), indicating that the results of conservative treatment without surgical intervention are similar to surgical intervention or better in some articles. The SMD of the random effect model was 7.093 (95% CI; 1.090–13.096; $P < 0.0206$), indicating the same result. Higgins' I2 value was 97.6%, indicating serious heterogeneity.

Conclusions: In this first meta-analysis on flexor zone II conservative treatment, five papers with publication bias were analyzed. It is meaningful to verify the result of conservative treatment statistically. Even though this is a heterogeneous paper, conservative treatment seems to have a lot of benefits for the patient, including offering a fairly solid longterm prognosis with very few complications.

ARTICLE HISTORY
Received 17 May 2022
Accepted 21 August 2022

KEYWORDS
Partial; flexor tendon; tendon laceration; meta-analysis

Introduction

How do you manage zone II level partial flexor tendon lacerations? In particular, at this level of damage, each hand surgeon has different techniques for operation, indications for surgery, and protocols of rehabilitation. In other words, there is still no consensus on this point, and the management of zone II partial flexor tendon injuries is controversial.

A sensational review paper including animal experiments without meta-analysis [1] was previously published in *Plastic and Reconstructive Surgery (PRS)* in 2018 and suggested that indications for exploration and treatment include concern for complete injury, triggering of the involved digit, or entrapment of the tendon. This systemic review asserts that 'partial tendon lacerations involving 90% of the cross-sectional area can be safely treated without surgical repair and immediate protected active motion'. We have always had doubts, and, when the opportunity arose, we thought that we should locate all papers related to flexor zone II management according to the standards and conduct a meta-analysis and systemic review that considered them both quantitatively and qualitatively. Although there has been systemic review of this topic, no study has performed a meta-analysis by collecting these papers based on a certain standard. After all, evidence-based medicine has recently been in the spotlight, and the trend is to follow this standard. We really wanted to objectively analyze whether this trend is consistent with what the paper published in *PRS* previously mentioned above and relating similar papers are claiming, and we also tried to study how accurate it is quantitatively if possible.

In the 1990s, a large survey of 1000 members of the American Society for Surgery of the Hand was undertaken to determine the methods by which clinicians currently treat partial lacerations of flexor tendons. Results from 591 respondents showed that most surgeons use a modified Kessler technique and begin protected mobilization within the first 48 h [2]. In addition, in this study, 75% of hand surgeons answered that >50% of the flexor tendon cross-section is damaged before tendon repairs are performed [2]. Since then, there have been various studies on whether to conduct surgery according to the degree of tendon damage, and the results of these investigations are very diverse. Some reported treatment options range from repair of all partial injuries to nonsurgical treatment with an early active motion therapy protocol for injuries involving ≤95% of the tendon cross-sectional area [3–6]. However, not only the indications for tendon reconstruction surgery performed according to this cross-sectional area but also

CONTACT Jong Won Hong hsaturn@hanmail.net Department of Plastic and Reconstructive Surgery, Severance Hospital, Yonsei University College of Medicine, 50-1 Yonsei-ro, Seodaemun-gu, Seoul 03722, Republic of Korea

the techniques used for tendon reconstruction and the protocols used for rehabilitation regimens of patients postoperatively varied [6–12]. According to Wray et al., 85% of partial flexor tendon lacerations were treated by not suturing the tendon and by early mobilization of the digit, resulting in excellent outcomes. These partial tendon lacerations varied from 25 to 95% of the cross-sectional area [6].

No reliable large cohort studies or meta-analysis papers on partial flexor tendon laceration management are available in PubMed or Embase. In order to retain the same degree of maximal flexion function as that seen before the injury without complications, including postoperative adhesions, in the functionally very important hand injury, we aimed to analyze big data by a systemic literature review and meta-analysis to find the 'correct' and 'uniform' surgical indications and surgical methods, thus creating a decision-making support guideline. This review is important as it helps hand surgeons to choose the most appropriate procedure decision based on the best-available evidence derived by analyzing the available big data regarding zone II level flexor tendon lacerations.

Methods

A systematic review of the literature was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses guideline and was registered in the National Institute for Health Research database Prospective Register of Systematic Reviews (identification no. CRD42022316096) [13]. It is available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022316096.

Search strategy

We searched the PubMed, Embase, Cochrane Library, Insight, Scopus and Web of Science databases for primary research articles investigating the outcomes of patients with partial flexor tendon injuries. Reference lists of all available primarily studied were reviewed to identify additional relevant citations. The search strategy was developed using the following terms: 'partial', 'flexor', 'tendon', 'injury', 'tendon injuries' and 'laceration' as text words and Medical Subject Headings (i.e. MeSH and Emtree) (Figure 1). A professor of department of statistics at a National University of South Korea assisted with the development of appropriate search terms and algorithms. The search was performed in March 2022. Our complete search strategy and the algorithm is provided. The identified abstracts for all published English language studies from 1970 to 2021 were screened for evaluation of biomechanical strength, complications and outcomes after partial tendon injury.

Study design and inclusion criteria

The initial search was limited to human studies published from 1970 to 2021 and indexed as randomized controlled or clinical trials or observational, cross-sectional, or cohort studies; however, additional references were included if deemed necessary for discussion. Studies were excluded if their full text was inaccessible or they were published in a language other than English, as the study quality could not be evaluated. The detailed inclusion and exclusion criteria are displayed in Table 1. Evidence ratings were not assigned to studies with inadequately described methods and/or worrisome biases or to references included for discussion purposes only (e.g. narrative reviews). Case reports, meta-analyses

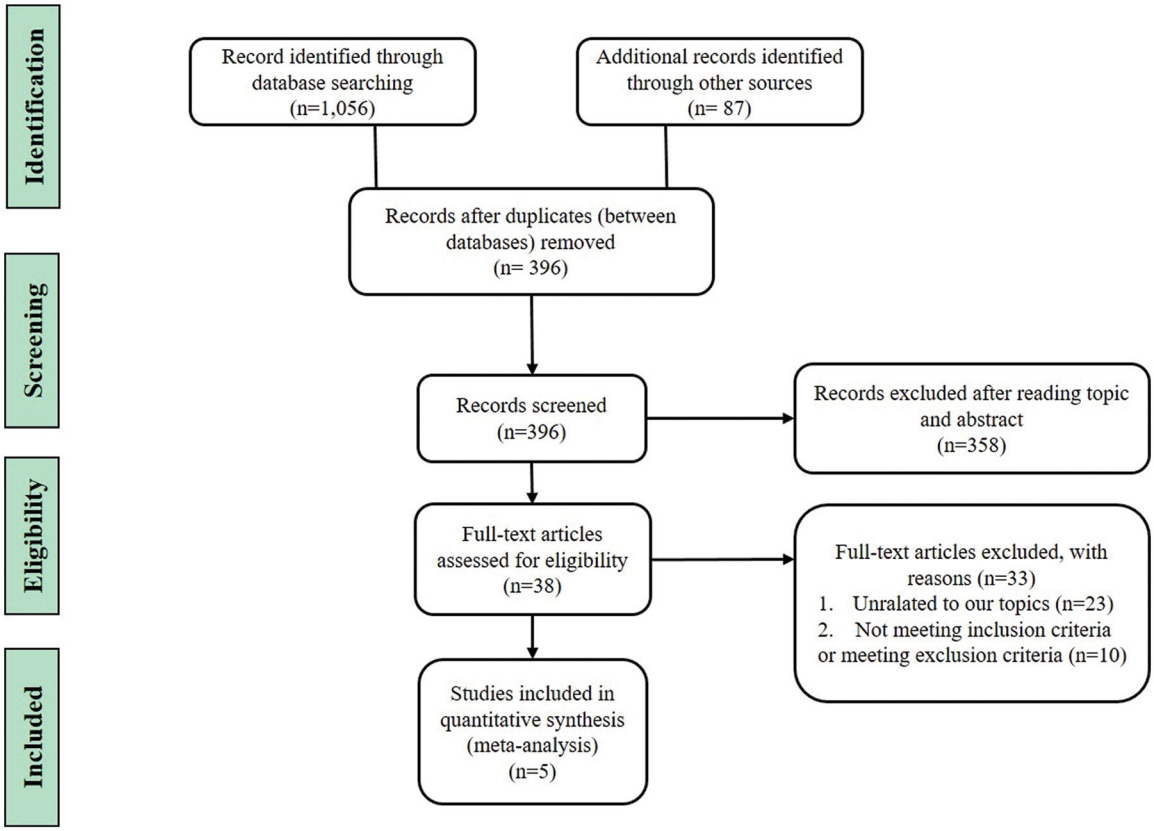

Figure 1. Search strategy. From Moher D, Liberati A, Tetzlaff J, Altman DG. The PRISMA group. Preferred Reporting Items for Systematic Reviews and Meta-analyses: the PRISMA statement. PLoS Med. 2009;6:e1000097. For more information, visit www.prisma-statement.org.

Table 1. Inclusion and exclusion criteria.

Inclusion criteria
1. Articles published until 2021 with no limitation on the start of the publication year
2. Articles written in English
3. Original articles and randomized controlled or clinical trials or observational, cross-sectional, or cohort studies
4. A full-text version of the article is available
5. Studies included a sample population of children who can obey to rehabilitation protocol (age ≥6 years)
6. Studies included a sample population of participants diagnosed with zone II flexor tendon laceration
7. Studies including ≥1 of the following outcome measures:
   - Total arc of motion angle measurement
   - Final outcome of the capability of touching the distal palmar crease in composite flexion (i.e. total active flexion)
   - Active flexion angles of each finger at each joint were measured, and the lack of normal extension in degrees was subtracted from the flexion.
   - The range of motion for the distal interphalangeal, proximal interphalangeal and metacarpophalangeal joints were added together to give the total active motion.
8. Studies had a sample size of ≥10
9. Studies included the number of participants lost to follow-up

Exclusion
1. Articles published after December 2021
2. Articles written in a language other than English
3. Studies that were not an original article or randomized controlled trial
4. Review articles, discussions or abstracts
5. Studies that included participants aged <6 years, cadavers, or animals
6. Studies that included treatments for other conditions (i.e. other than partial zone II flexor tendon injury)
7. Studies with a sample size of <10
8. Studies did not include information regarding the individual treatment groups
9. Studies did not specify the number of participants lost to follow-up
10. Meta-analyses and reviews

and reviews were excluded. Studies meeting the inclusion criteria were read by two of the authors, and the references of the selected articles were reviewed to capture any studies missed during the database query process.

Statistical analysis

We used the R version 4.1.2 statistical package (R Foundation for Statistical Computing, Vienna, Austria) for this meta-analysis. The Cochrane bias ROBINS-1 tool was also used. We assessed the heterogeneity of each study using the I^2 test, which measures the percentage of total variation across studies [14]. The I^2 value was calculated as follows: I^2 (%)$=100\times(Q - \mathrm{df})/Q$, where Q is Cochrane's heterogeneity statistic and df is the number of degrees of freedom. We then computed the 95% confidence interval (CI) of each treatment option using both random- and fixed-effects models. We confirmed those results using the I^2 test, with significance set at a value of $p < 0.05$ in both models. We established forest plots to illustrate the effect of study size and funnel plots to look for evidence of publication bias.

Weighted standardized mean difference (SMD) and 95% CI values were calculated using random-effects models to pool results in each publication and assess the effect of conventional tenorrhaphy (core suture with or without epitenon suture) versus conservative treatment without surgical intervention and the length of therapy. Additionally, the degree of the range of motion from baseline was compared between the two groups using odds ratio (OR) and 95% CI values. Outcomes were measured using a continuous variable.

The Chi-squared test was used to statistically assess heterogeneity. However, regardless of the heterogeneity assessment, the more conservative random-effects model for sensitivity analyses was used. If a study did not report the standard deviation for a treatment group with respect to a particular endpoint, the study was not included in the meta-analysis for that endpoint since it could not contribute to the overall effect of the treatment for that outcome. All analyses were performed using the RevMan version 5.3 software program (The Cochrane Collaboration, 2014, The Nordic Cochrane Centre, Copenhagen, Denmark).

The statistical validity of this study was reviewed, proofread and certified by statisticians in the Department of Statistics at a National University.

Assessment of methodologic quality

A methodologic quality assessment of studies for diagnostic accuracy was performed according to criteria from the Quality Assessment of Diagnostic Accuracy Studies. These criteria assess the quality of included studies in terms of the risk of bias and concerns regarding applicability over four domains.

Results

Study characteristics

We identified a total of 1143 articles. Among them, 38 were identified through title and abstract screenings as eligible for a thorough full-text review. After inclusion and exclusion criteria were applied, five articles with a total of 88 patients and 108 partially injured zone II level flexors were included (Figure 1). Of these five articles, four were observational studies involving a total of 90 partially divided zone II flexors, and the remaining study was a cohort study with a total of 22 flexor tendons. The mean reported age across studies was 24.61 ± 11.78 years; only two of the five studies reported the proportions of male and female patients.

No randomized controlled trials were found. Most studies were excluded while screening the titles and abstracts because they studied locations other than the flexor zone II level, they did not have full-text articles available, or they included <10 lacerated flexor tendons treated by surgery. All included studies were rated as low to very low quality mostly due to having a retrospective study design and a low number of patients and injured flexor tendons due to being restricted only to the flexor zone II level.

Table 2. Treatment characteristics, outcome measures and corresponding results, including complications.

Author, year, country	No. of patients (M/F)	No. of partially lacerated tendon	Age (year, range)	CSA < 50%	50 ≤ CSA < 75%	CSA ≥ 75%	Mean cross sectional area of partially lacerated tendon (%)	Study type	Outcome	Complications	Mean follow-up, months (range)
Wray and Weeks [12] USA	26	34	NR	6	17	11	60	Observational study	Excellent 24 Good 1 Fair 0 Poor 0	Only 1 complication: mild triggering finger which resolved spontaneously over 2 months	NR
McGeorge and Stilwell [10], England	14	18	28.3	6	12	0	54	Cohort study	Excellent 14 Good 0 Fair 0 Poor 0	No complications	22.2 (2.5–40)
Stahl et al. [11], Israel	12 (8/4)	19	7.4	13	6	0	40	Observational study	Excellent 11 Good 1 Fair 0 Poor 0	Only 1 complication: mild local infection	18.3
al-Qattan [15], Saudi Arabia	15 (13/2)	17	35.0	0	7	10	71	Observational study	Excellent 14 Good 1 Fair 0 Poor 0	No complications	26
Wray et al. [6], U.S.A	17	20	25.0 (10–46)	3	11	6	60	Observational study	Excellent 16 Good 0 Fair 1 Poor 0	No complications	NR

NR: not recorded.

Treatment characteristics, outcome measures and corresponding results are presented in Table 2.

Study quality

All of the included studies had a moderate to high risk of bias. According to the ROBINS-I tool, two of the five non-randomized controlled trials would be considered to have a high risk of bias. The potential magnitude of bias on the outcome of flexor rehabilitation may be considered low, as the patients could not be blinded to the intervention (conservative treatment with early rehabilitation). The observational studies had a mean Methodological Index for Non-randomized Studies (MINORS) score of 10.5 out of 16 points (range, 9–12 points) (Table 3) [16]. The overall quality of included observational studies was at a moderate risk of bias. There were some notable limitations of the included literature. Only two of the five studies described the patient exclusion criteria explicitly, and the majority of studies did not calculate effect size or statistical power prospectively.

Individual study outcomes

Outcomes results from individual studies are listed in Table 2. None of the studies examined all endpoints established for this meta-analysis. There were variances in which endpoints were measured as well as the way the endpoints were reported between studies.

McGeorge and Stilwell counted separately for each finger at the zone II level, FDS and FDP, and the repaired group and the conservatively treated group were also divided and averaged according to the area of each cross-section area. However, unlike in other papers, no standard deviation was recorded in any of the statistics [10]. In the non-repaired group, all oblique flap lacerations were trimmed to prevent entrapment and ensure smooth gliding. In the article, the power and grip strength of the group in which the tendon was repaired and in the group treated with conservative treatment without surgical intervention were only quantitatively quantified and compared. Contrary to the expectation that both grip strength and pinch grip would increase in the repaired group, the pinch grip was instead 110% higher than the contralateral normal value in the non-repaired group and decreased to 67% in the repaired group ($p < 0.05$).

Stahl et al. analyzed the youngest patient group (average age, 7.4 years). Since their age for inclusion was ≥5 years, this study was included in the current analysis [11]. In the non-repaired group, the lacerated edges were trimmed to ensure smooth gliding and prevent triggering without tenorrhaphy.

The study by al-Qattan et al. [15] is the only prospective study on this topic. The mean follow-up length was 26 months. In addition to the fact that this paper reports a prospective study, it methodologically defined and sorted each case much more precisely and clearly, unlike previous studies, and the results are also clearly presented by distinguishing the steps. For example, when calculating the cross-section of the cut tendon, the authors clearly calculated the percentage of the cut width from the total width based on the width and reported it using 5% intervals (i.e. 55, 60 and 65%), and the points where excellent, good, fair and poor cases could be stratified were based on 150°, 125° and 90° using the Strickland and Glogovac method [17]. This study was restricted to including tidy wounds of fingers in zone II, and surgical exploration was performed under digital block. The flexor tendons were observed as the patient fully extended and flexed the finger. If there was no visible triggering, the sheath was repaired

Table 3. The revised and validated version of MINORS [16].

Methodological items for non-randomized studies	Score[a]
1. A clearly stated aim: the question addressed should be precise and relevant in the light of available literature.	
2. Inclusion of consecutive patients: all patients potentially fit for inclusion (satisfying the criteria for inclusion) have been included in the study during the study period (no exclusion or details about the reasons for exclusion).	
3. Prospective collection of data: data were collected according to a protocol established before the beginning of the study.	
4. Endpoints appropriate to the aim of the study: unambiguous explanation of the criteria used to evaluate the main outcome which should be in accordance with the question addressed by the study. Also, the endpoints should be assessed on an intention-to-treat basis.	
5. Unbiased assessment of the study endpoint: blind evaluation of objective endpoints and double-blind evaluation of subjective endpoints. Otherwise the reasons for not blinding should be stated.	
6. Follow-up period appropriate to the aim of the study: the follow-up should be sufficiently long to allow the assessment of the main endpoint and possible adverse events.	
7. Loss to follow up less than 5%: all patients should be included in the follow up. Otherwise, the proportion lost to follow up should not exceed the proportion experiencing the major endpoint.	
8. Prospective calculation of the study size: information of the size of detectable difference of interest with a calculation of 95% confidence interval, according to the expected incidence of the outcome event, and information about the level for statistical significance and estimates of power when comparing the outcomes.	
Additional criteria in the case of comparative study	
9. An adequate control group: having a gold standard diagnostic test or therapeutic intervention recognized as the optimal intervention according to the available published data.	
10. Contemporary groups: control and studied group should be managed during the same time period (no historical comparison).	
11. Baseline equivalence of groups: the groups should be similar regarding the criteria other than the studied endpoints. Absence of confounding factors that could bias the interpretation of the results.	
12. Adequate statistical analyses: whether the statistics were in accordance with the type of study with calculation of confidence intervals or relative risk.	

[a]The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate). The global ideal score being 16 for non-comparative studies and 24 for comparative studies.

with interrupted 6–0 Prolene sutures (Ethicon, Edinburgh, UK) and the skin was closed. In the end, excellent results were obtained for all the fingers except for one case with a good result. It is unique in that most of the studies on flexor tendons that were cut by ≥50% in a prospective manner yielded excellent results.

Meta-analysis outcomes

Looking at the overall effect size of all five studies, the SMD of the common effects model was 2.020 (95% CI, 1.583–2.457; $p < 0.0001$), indicating that the results of conservative treatment without surgical intervention are similar to surgical intervention or better than surgical intervention in some articles. The SMD of the random-effects model was 7.093 (95% CI, 1.090–13.096; $p < 0.0206$), indicating the same result. Statistics were entered into the R version 4.1.2 statistical package to analyze the results of subgroups, but the number of patients in each of the five studies was too small to analyze, and the number of cases included in the entire cohort was small, so the results could not be derived.

When it comes to the heterogeneity of the entire study, τ^2 (tau square)=45.4196 [15.1891; 395.0150] and τ (tau)=6.7394 [3.8973; 19.8750] were calculated. Additionally, I^2=97.6% [96.1%; 98.5%] and $H = 6.41$ [5.07; 8.11], and, for the heterogeneity, Higgins' I^2 value was 97.6%, which indicates serious heterogeneity. The result of the forest plot of the above studies belonging to continuous data in order to make it easy to visually recognize the above overall effect size and to easily understand the intra-study and inter-study variations by presenting the effect size of individual studies graphically is shown in Figure 2. Finally, to explore the publication bias in Figure 3, a visually funnel plot with asymmetry between studies was presented (Figure 3).

Finally, a meta-regression analysis was performed to identify the cause of heterogeneity, and 'method.tau = REML (restricted maximum-likelihood estimator)' was used. As a result, based on the random-effects model, τ^2 (estimated amount of total heterogeneity)=45.420 (SE = 33.162), $\tau = 6.739$, I^2 (total heterogeneity/total variability)=99.31% and H^2 (total variability/sampling variability)=144.07. The test for heterogeneity was $Q(df = 4)=164.598$, and $p < 0.001$.

Complications

All five studies included in this study reported on whether complications occurred. In three studies, there were no complications, while, in the other two studies, one complication was a mild triggering finger, which resolved spontaneously over 2 months, and the other was a mild infection. In the end, out of the 108 tendon cases included in the study, only two developed very mild complications, which resolved spontaneously, and the rest had no major problems. When looking only at the types of complications, there was only one case (mild triggering finger) that was caused by the mechanical process of the tendon, and even this spontaneously improved [11,12].

Discussion

Following the Wray paper published in the 1970s, until the 2000s, research on this topic was not actively conducted to the extent that a paper presented the results of conservative treatment for partial tendon tears at only four flexor zone II levels. Looking at all available published studies, the number of patients was so small that the largest number of patients was <30 (34 tendons). We think that it must have been difficult to collect data because the tendon is sutured surgically rather than conservatively due to the existing belief that suturing is beneficial when the tendon is damaged by >50%. This is because, as there is less tendon remaining after trauma, if conservative treatment is performed, the remaining tendon cannot withstand the tendon tension of gliding movement and may be cut totally. Rather, conservative treatment without surgical intervention to the injured tendon even after the exploration may cause a loss of appropriate time to suture the tendon.

In fact, the 'tendon' itself is literally 'a string or a cord that transmits power'. As the muscle rises from the proximal bone and goes to the distal bone, it transits to the musculotendinous

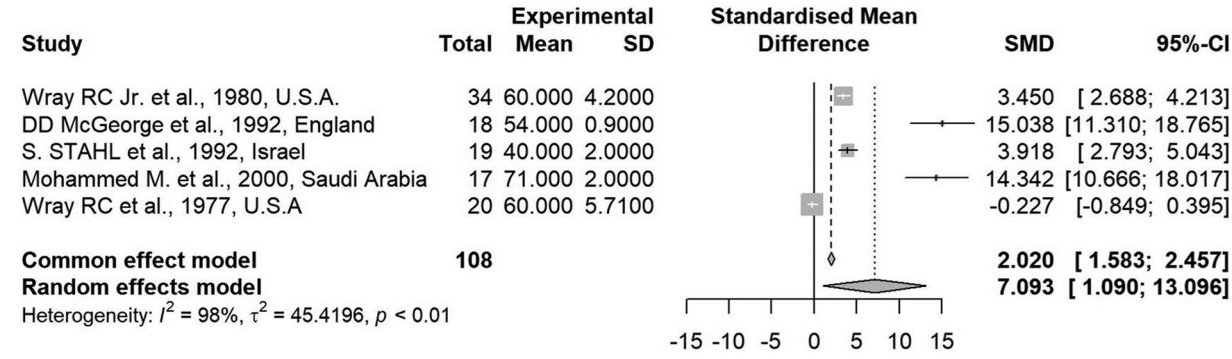

Figure 2. The forest plot of included studies. It can be seen that the large intra-study variance is the paper published in 1992 by DD McGeorge and Stilwell and the paper published in 2000 by al-Qattan et al., and the large inter-study variance is the paper published in 1992 by McGeorge and Stilwell and the paper published in 1977 by Wray et al.

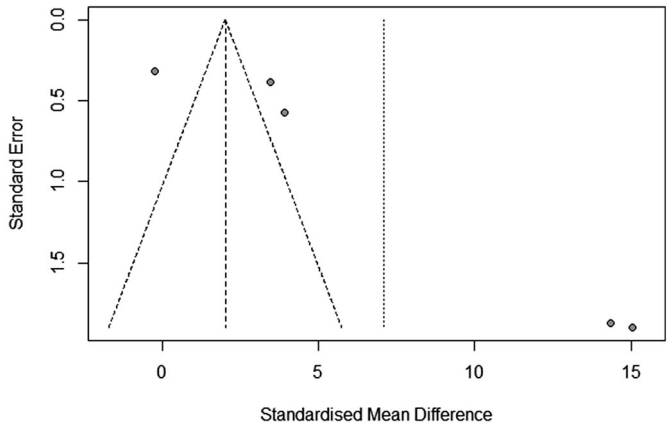

Figure 3. The funnel plot. In general, small-scale studies are distributed widely at the bottom, and large-scale studies are distributed narrowly at the top of the funnel. In this plot, there are one distribution to the left and four distributions to the right outside the funnel.

junction and finally is connected to the tendon. In the tendon part, unlike in the muscle belly, contraction and relaxation of the structure do not occur by itself; only the force created by the muscle movement is transmitted to enable the function at the inserting part.

Depending on where the tendon is attached, the finger or wrist can be flexed, extended, abducted, adducted or opposed. In the volar zone II level, which we were interested in for this current study, the FDS and FDP pass together, and, especially in zone IIc, the FDS tendon is bifurcated and divided into two strands, rendering the structure and the mechanics of the tendon gliding much more complicated. This area is also where the A2 pulley is located. That is to say, too many structures are glued together in the volar zone II area. Hence, in the end, if there is damage to this part, it is true that it is much more difficult to obtain the fine results of surgery or rehabilitation when reconstructed than in other parts. Due to these reasons, the volar zone II level is also called 'no man's land.'

Although there are a small number of papers, we found five papers to be analyzed by assessing the papers filtered by our precise inclusion criteria, and the most scientific and statistical analysis of these papers is the result of our study. When evaluating the overall effect size of all five studies, the SMD of the common-effects model was 2.020 (95% CI, 1.583–2.457; $p < 0.0001$), indicating that the results of conservative treatment without surgical intervention, which we were curious about in the current study, were statistically significantly improved compared to those for surgical treatment. In a general meta-analysis, there are several methods of calculating the SMD. The most basic method is Cohen's *d*, which divides the effect size by the common standard deviation. It is preferable to use the *g* of Hedges that corrects, so this also was used in the current study (method.smd=='Hedges' or 'Cohen').

A limitation in our study is that it did not derive results between subgroups, which proves that the number of papers included in this study is small because the scope of a study conducted in flexor zone II, which is the focus of this paper, is too limited. The number of cases included in the entire cohort was small, so the results could not be derived. In the random-effects model, more informative conclusions could not be drawn if the heterogeneity of differences according to subgroups was known, but information on subgroups could not be obtained.

When it comes to the heterogeneity of the entire study. I^2=97.6% [96.1%; 98.5%], and $H = 6.41$ [5.07; 8.11]. For the heterogeneity, Higgins' I^2 was a value obtained by subtracting the degree of freedom from the Cochrane *Q* statistic and dividing it by the Cochrane *Q* statistic to quantify the heterogeneity consistently, and this result was 97.6%, which indicates serious heterogeneity. In other words, it can be concluded that severe heterogeneity exists. Therefore, the overall model should take precedence over the random-effects model.

As for the heterogeneity of the meta-analysis we analyzed, we tested significant moderator variables and judged that there was heterogeneity (Figure 3). The causes of this heterogeneity will be very diverse, ranging from chance to differences in research design, research environment and demographic factors of the sample group. As shown in the results, in our study, one and four studies were distributed to the left and right, respectively, outside the funnel, and it can be judged that there is a publication bias visually. As heterogeneity was suspected from the heterogeneity value using Higgins' I^2, a meta-regression analysis was performed to statistically verify the cause.

In order to assert that surgery, which has been originally actively and invasively performed in medical studies, especially clinical studies, is not really necessary, conservative treatment should be gradually adopted as long as it does not harm the patient. The fact that it already has been performed under a low threshold of indication is a very burdensome aspect. Conservative treatment was used in anticipation that it would be okay after seeing a few cases. In conclusion, if the results and prognosis are poor, this is because conservative treatment after exploration is an act that ultimately harms the patient. These reasons explain why the number of patients in the group that underwent

conservative treatment was small in all of the papers we analyzed in accordance with the inclusion criteria.

The ability to restore functional ability following treatment of flexor tendon injuries in the hand has been greatly improved by the development of better suture techniques and rehabilitation protocols. In spite of these improvements, however, the outcome of surgical repair is often less than desirable [18]. Researchers using barrier and chemical techniques have reported some degree of adhesion reduction in laboratory and clinical studies of tendon repair [19–26]. In spite of these findings, these methods are not widely used in clinical practice. This suggests that none of them have been demonstrated to be effective in most clinical settings.

Of course, there are limitations to this study. There were five papers included in our analysis, and this is not many papers for a meta-analysis, even though a meta-analysis is possible if there are $\geq$3 papers. However, in flexor zone II, where tendon suturing is the most difficult, only cases managed without tendon suturing were enrolled using strict criteria in the current study, so it is true that there were almost no cases until recently. Of the five papers analyzed, four were published before 2000 and are very old studies. Since then, various materials have been developed over time, and the trend of postoperative rehabilitation treatment has changed from the modified Kleinert method to early active and passive motion. In addition, materials to prevent adhesions after tendon suturing have been developed and improved, which helps a lot in gliding of the tendon after surgery. A specific quantitative study on how much tension occurs during finger rehabilitation depending on what proportion of the tendon cross-section is left should be attempted.

We thought about why there are only a few papers from such a long time ago, and why the research on conservative treatment of tendon research has not been active. Finally, we concluded, including the cases of the papers included in the analysis, to determine the degree of damage to the tendon, hand surgeons must perform an exploration first. In this context, if there is damage to the tendon, it is uncomfortable to let it be, so the tendon is sutured before exiting the operation room. Patients who were injured and then had delayed rupture were those patients who eventually suffered partial injuries of tendons. Hence, when going to the exploration surgery and coming out with all the partial damage mitigated as defensively as possible with tenorrhaphy, there would be few papers that involved comparative studies or conservative treatment; as a result, there were not many papers that could be included in our study.

In fact, when looking for related papers, most of them were written based on the results of animal experiments rather than actual clinical trials or were even studies of patients who have actually undergone conservative treatment; even if the number of patients is large, individual studies analyzing about 30 patients from a single institute were published as papers. Regarding this topic, there were no papers that systematically analyzed papers by reviewing them or analyzed or compared phenomena quantitatively and qualitatively based on the basis of calculating the bias or effect size by grouping similar papers.

Of course, these studies are only applicable to flexor zone II management, as the original purpose of this paper, and it is important to consider that, in this area, FDS and FDP pass at the same time, so the mechanism is very limited and more dynamic than in other areas. When comparing studies on only this area, suturing the partially lacerated tendon at each narrow digit to strengthen the tendon force is a better way to transcend complications (i.e. difficulty in gliding, adhesion, rehabilitation delay). When comparing the advantages and disadvantages, the above conclusion is reached.

In conclusion, five papers with publication bias were analyzed in the first meta-analysis on flexor zone II conservative treatment. It is meaningful to verify our findings statistically and quantitatively, and, as a result, even though this is a heterogeneous paper, conservative treatment seems to have a lot of benefits for the patient, offering a fairly solid and long-term prognosis with very few complications, albeit only in the case of flexor zone II management. However, the purpose of our study was not to praise conservative treatment but to more objectively and quantitatively analyze existing papers that claim conservative treatment is good even for partial tendon damage, as stated at the beginning. If there come about many related studies involving a large number of patients in the future, and if the publication bias can be reduced, it is more meaningful if such papers are also included in the study and analyzed, and data could be analyzed separately by subgroup, assisting hand surgeons in making flexor zone II trauma treatment decisions. This extension of the present analysis will be able to guide the suggestion of more progressive and wise decisions about treatment.

Acknowledgements

The authors would like to thank Kyungpook National University Department of Statistics for their statistical review.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022316096

References

[1] Lineberry KD, Shue S, Chepla KJ. The management of partial zone II intrasynovial flexor tendon lacerations: a literature review of biomechanics, clinical outcomes, and complications. Plast Reconstr Surg. 2018;141(5):1165–1170.

[2] McCarthy DM, Boardman ND 3rd, Tramaglini DM, et al. Clinical management of partially lacerated digital flexor tendons: a survey [corrected] of hand surgeons. J Hand Surg Am. 1995;20(2):273–275.

[3] Balk ML, Sotereanos DG. Partial flexor digitorum profundus lacerations. Oper Tech Orthop. 1998;8(2):67–72.

[4] Bastian DA, Kusnezov N, Dunn JC, et al. Subclinical partial attritional rupture of the flexor digitorum profundus as an etiology of atraumatic trigger finger. Case Rep Orthop. 2017;2017:8769369.

[5] Schlenker JD, Lister GD, Kleinert HE. Three complications of untreated partial laceration of flexor tendon – entrapment, rupture, and triggering. J Hand Surg Am. 1981;6(4):392–398.

[6] Wray RC Jr, Holtman B, Weeks PM. Clinical treatment of partial tendon lacerations without suturing and with early motion. Plast Reconstr Surg. 1977;59(2):231–234.

[7] Bishop AT, Cooney WP 3rd, Wood MB. Treatment of partial flexor tendon lacerations: the effect of tenorrhaphy and early protected mobilization. J Trauma. 1986;26(4):301–312.

[8] Grewal R, Saw SS, Bastidas JA, et al. Passive and active rehabilitation for partial lacerations of the canine flexor digitorum profundus tendon in zone II. J Hand Surg Am. 1999;24(4):743–750.
[9] Gulihar A, Hajipour L, Dias JJ. Comparison of three different peripheral suturing techniques for partial flexor tendon lacerations: a controlled in-vitro biomechanical study. Hand Surg. 2012;17(2):155–160.
[10] McGeorge DD, Stilwell JH. Partial flexor tendon injuries: to repair or not. J Hand Surg Br. 1992;17(2):176–177.
[11] Stahl S, Kaufman T, Bialik V. Partial lacerations of flexor tendons in children. Primary repair versus conservative treatment. J Hand Surg Br. 1997;22(3):377–380.
[12] Wray RC Jr, Weeks PM. Treatment of partial tendon lacerations. Hand. 1980;12(2):163–166.
[13] Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med. 2009;151(4):264–269, W264.
[14] Whiting PF, Rutjes AWS, Westwood ME, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Ann Intern Med. 2011;155(8):529–536.
[15] al-Qattan MM. Conservative management of zone II partial flexor tendon lacerations greater than half the width of the tendon. J Hand Surg Am. 2000;25(6):1118–1121.
[16] Slim K, Nini E, Forestier D, et al. Methodological Index for Non-randomized Studies (MINORS): development and validation of a new instrument. ANZ J Surg. 2003;73(9):712–716.
[17] Strickland JW, Glogovac SV. Digital function following flexor tendon repair in zone II: a comparison of immobilization and controlled passive motion techniques. J Hand Surg Am. 1980;5(6):537–543.
[18] Beredjiklian PK. Biologic aspects of flexor tendon laceration and repair. J Bone Joint Surg Am. 2003;85(3):539–550.
[19] Moran SL, Ryan CK, Orlando GS, et al. Effects of 5-fluorouracil on flexor tendon repair. J Hand Surg Am. 2000;25(2):242–251.
[20] Khan U, Occleston NL, Khaw PT, et al. Single exposures to 5-fluorouracil: a possible mode of targeted therapy to reduce contractile scarring in the injured tendon. Plast Reconstr Surg. 1997;99:465–471.
[21] Salti NI, Tuel RJ, Mass DP. Effect of hyaluronic acid on rabbit profundus flexor tendon healing *in vitro*. J Surg Res. 1993;55(4):411–415.
[22] Kulick MI, Smith S, Hadler K. Oral ibuprofen: evaluation of its effect on peritendinous adhesions and the breaking strength of a tenorrhaphy. J Hand Surg Am. 1986;11(1):110–120.
[23] Kapetanos G. The effect of the local corticosteroids on the healing and biomechanical properties of the partially injured tendon. Clin Orthop Relat Res. 1982;163:170–179.
[24] Hanff G, Hagberg L. Prevention of restrictive adhesions with expanded polytetrafluoroethylene diffusible membrane following flexor tendon repair: an experimental study in rabbits. J Hand Surg Am. 1998;23(4):658–664.
[25] Siddiqi NA, Hamada Y, Ide T, et al. Effects of hydroxyapatite and alumina sheaths on postoperative peritendinous adhesions in chickens. J Appl Biomater. 1995;6(1):43–53.
[26] Austin RT, Walker F. Flexor tendon healing and adhesion formation after sterispon wrapping: a study in the rabbit. Injury. 1979;10(3):211–216.