SCIENTIFIC ARTICLE

Flexor Tendon Repair Rehabilitation Protocols: A Systematic Review

Harlan M. Starr, MD, Mark Snoddy, MD, Kyle E. Hammond, MD, John G. Seiler III, MD

Purpose To systematically review various flexor tendon rehabilitation protocols and to contrast those using early passive versus early active range of motion.

Methods We searched PubMed and Cochrane Library databases to identify articles involving flexor tendon injury, repair, and rehabilitation protocols. All zones of injury were included. Articles were classified based on the protocol used during early rehabilitation. We analyzed clinical outcomes, focusing on incidence of tendon rupture and postoperative functional range of motion. We also analyzed the chronological incidence of published tendon rupture with respect to the protocol used.

Results We identified 170 articles, and 34 met our criteria, with evidence ranging from level I to level IV. Early passive motion, including both Duran and Kleinert type protocols, results included 57 ruptures (4%) and 149 fingers (9%) with decreased range of motion of 1598 tendon repairs. Early active motion results included 75 ruptures (5%) and 80 fingers (6%) with decreased range of motion of 1412 tendon repairs. Early passive range of motion protocols had a statistically significantly decreased risk for tendon rupture but an increased risk for postoperative decreased range of motion compared to early active motion protocols. When analyzing published articles chronologically, we found a statistically significant trend that overall (passive and active rehabilitation) rupture rates have decreased over time.

Conclusions Analyzing all flexor tendon zones and literature of all levels of evidence, our data show a higher risk of complication involving decreased postoperative digit range of motion in the passive protocols and a higher risk of rupture in early active motion protocols. However, modern improvements in surgical technique, materials, and rehabilitation may now allow for early active motion rehabilitation that can provide better postoperative motion while maintaining low rupture rates. *(J Hand Surg 2013;38A:1712–1717. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Early active motion, flexor tendon repair, postoperative care, rehabilitation.

Additional material is available online.

Before the 1970s, most flexor tendon repair rehabilitation protocols focused on immobilization during the first 3 weeks following repair, as research had shown tendon tensile strength to be low with most ruptures occurring during this time period.[1] However, in the mid-1970s, Duran and Houser reported their protocol involving controlled passive motion and stated that 3 to 5 mm of tendon excursion was sufficient to prevent restrictive adhesions following tendon repair.[2] Around the same time, Lister and Kleinert re-

From the Department of Orthopaedics, Emory University, Atlanta, GA; Georgia Hand, Shoulder and Elbow, Atlanta, GA.

Received for publication January 20, 2013; accepted in revised form June 26, 2013.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

Corresponding author: Harlan M. Starr, MD, Department of Orthopaedics, Emory University, 59 Executive Park Drive South, Atlanta, GA 30329; e-mail: hmstarr3@gmail.com.

0363-5023/13/38A09-0007$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2013.06.025

ported encouraging results with immediate passive mobilization using an orthosis that allowed active digit extension to produce recoil on an attached rubber band, with resulting passive flexion.[3,4] Since that time, progressive modifications in orthosis and rehabilitation design, along with advancement in surgical materials and technique, have allowed flexor tendon repair rehabilitation to continue to evolve toward early mobilization.[5] However, despite flexor tendon repair rehabilitation being a widely studied topic, a range of early mobilization protocols are used without an identified, optimal model. Most would agree that the ideal protocol would allow enough excursion to prevent adhesion formation without creating stress that would compromise the repair. Although rehabilitation methods such as the Kleinert, Duran, and active place-and-hold are popular, many surgeons and therapists are modifying these techniques or using combined techniques to improve outcomes.[6] With the wide variety of rehabilitation techniques for flexor tendon repair injuries, it is necessary to analyze the treatment methods and compare reported data of patient outcomes.

Other groups have attempted systematic literature reviews of rehabilitation protocols following flexor tendon repair. Chesney et al reviewed rehabilitation of flexor tendon injuries in zone II. They determined that early motion protocols were superior to static splinting and that no significant difference existed between early active and early passive protocols.[7] In 2004, another group attempted to broaden the spectrum of study by analyzing rehabilitation of flexor tendon injuries in all zones of the hand. This study was withdrawn due to insufficient evidence from randomized, controlled trials.[8] The object of this systematic review was to analyze results from articles of all levels of evidence, including all zones of flexor tendon injury, to determine an optimal rehabilitation protocol. We paid specific attention to early active versus early passive range of motion protocols and their complication rates, including rupture and decreased postoperative range of motion. Secondarily, we analyzed chronological trends over the past 25 years to determine whether advancements in surgical technique and materials have led to increased repair strength and, thus, decreased rate of repair failure.

MATERIALS AND METHODS

We used the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines as a template for our systematic review. These guidelines are an evidence-based minimum set of items aimed to help authors improve the reporting of systematic reviews and meta-analyses. The review process started with a search of PubMed and Cochrane databases to identify articles on flexor tendon injury, repair, and rehabilitation protocol. Two independent reviewers assessed all articles and references and agreed on which articles should be included. A third, senior reviewer was available for final decision making if an article was disputed. To prevent selection bias during review, abstracts from the search were numbered and pasted into a document after deleting the publication journal, author, and institution. The initial search included keywords "flexor tendon repair" and "rehabilitation," which returned 282 results. Due to the high variation of relevant articles and anatomical locations, the search was modified to included "hand," which produced 170 results after duplicate articles were identified and discarded. The term "hand" was chosen over "finger" because it produced more results and included all flexor tendon zones of injury. The search returned articles published from 1980 to 2011. We included English-language clinical studies that provided a description of the flexor tendon repair technique, rehabilitation protocol, and an assessment of functional clinical outcomes, including final digit motion and complications. Exclusion criteria included no results reported (3 articles), biomechanical study only (10 articles), no surgical technique (23 articles), no rehabilitation protocol (29 articles), not about flexor tendons (14 articles), studies only on flexor pollicis longus tendon repairs (3 articles), review articles (34 articles), studies on animals or cadavers (9 articles), and studies not in English (22 articles). A total of 23 articles meeting our criteria were identified through the search process. Also, a secondary search was conducted by reviewing references cited in the selected articles. An additional 11 articles were identified that met the inclusion criteria. Thus, 34 articles met the criteria and were analyzed (Fig. 1). Two independent reviewers determined each article's level of evidence, as outlined by the *Journal of Hand Surgery American,* with a third reviewer available for dispute resolution.

Attention was focused on the protocol used during the critical, early stage (first 3 weeks) of rehabilitation. For comparison, early stage protocols were divided into immobilization, passive motion (including both Kleinert and Duran type protocols), active motion, and continuous motion. Data were compiled from all qualifying studies, with specific attention to outcomes measures, including functional results, total active motion, and tendon rupture. The Fisher's exact test was used to test the association between complications, ruptures, and decreased range of motion between early passive and

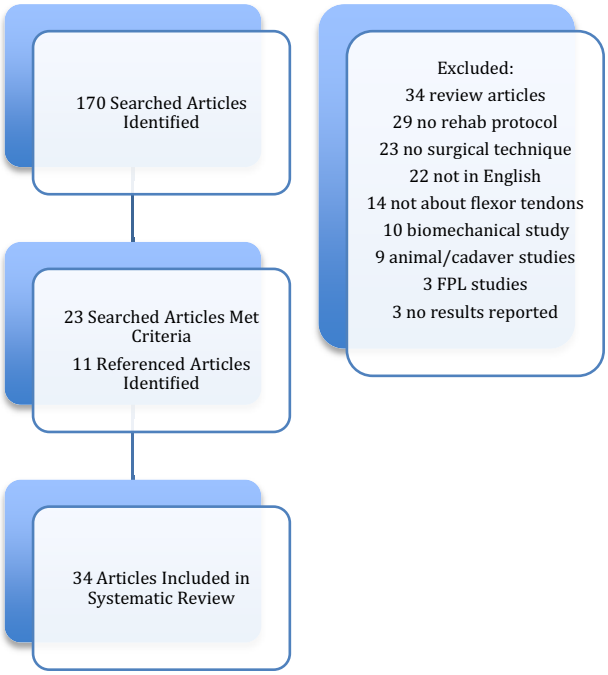

FIGURE 1: Method of article selection.

early active range of motion protocols. In addition, published rupture data were analyzed in 5-year intervals over a period of 25 years (1987–2011) to determine whether advancement in technique, surgical material, and rehabilitation protocols has led to an overall decreased rate of rupture. Publication date was chosen instead of surgery date because not all articles reported data collection dates, and publication date portrays advancements in flexor tendon injury treatment through accomplishments in published research. The 25-year period was chosen because it included all articles meeting our search criteria, except for one paper published by Strickland et al in 1980, and allowed comparison of data in 5-year intervals. Strickland's paper was considered to be in an outlying year, but if included, its 4% rupture rate with passive rehabilitation would not have significantly affected the data analysis.[9] Rupture data were also analyzed in 10-year intervals over the past 20 years to determine whether results would differ. A left-sided, Cochran-Armitage trend test was used to evaluate the chronologic interval rupture data. A Fischer's exact test was also used to test the association between rupture and 2-strand versus 4-strand and 6-strand core suture repair. A biostatistician facilitated the statistical analysis of the reported results, and data were considered significant if the P value was $< .05$.

RESULTS

In the 34 articles reviewed, the rehabilitation protocols most commonly used were early mobilization with passive motion alone (53%), early mobilization with active motion alone (32%), and studies comparing passive motion versus early active motion (15%). Other methods included immobilization and continuous motion. The majority of studies attempted to find the ideal balance between achieving early tendon excursion without compromising repair and to determine the appropriate amount of time and motion needed for rehabilitation.

The level of evidence in the studies ranged from level I to level IV. Two papers were high-quality, randomized, prospective controlled trials (level I evidence). Two other randomized, controlled trials were of moderate quality and were classified as level II evidence. Also, 7 prospective, comparative studies were considered level II evidence and 1 comparative study was level III. The remaining 22 papers included level IV evidence and consisted of retrospective and prospective case series.

Surgical techniques included 2-strand, 4-strand, and 6-strand core suture repairs, and all but one article used an epitendinous stitch. Suture material included core suture of polypropylene, nylon, polydioxanone, or braided polyester with sizes of 3-0 or 4-0 (2-0 in one study), In several instances, suture size or material varied within a study. Epitendinous suture used was 5-0 or 6-0 nylon or polypropylene. Surgical timing was described in 15 of 34 articles and varied from within 6 hours of injury to 21 days, even within each study. Postoperative orthoses were used in every study, with wrist flexion varying from 0°- to 30°, metacarpophalangeal joint flexion varying from 50° to 90°, and the interphalangeal joints typically allowed to achieve full extension. Time splinted ranged from 3 to 6 weeks in all studies except one, in which the splint was worn for 12 weeks. Some studies noted differences in patient participation with prescribed therapy, but all reported results only on those who had participated to some extent. These results, along with functional results and complications reported in the articles meeting inclusion criteria, are summarized in Appendix A (available on the *Journal's* Web site at www.jhandsurg.org).

The most commonly reported complication was tendon rupture. Studies also reported joint contractures, adhesions, noteworthy loss of motion to a joint, and extensor lag. For purposes of comparison, these were all grouped into "decreased range of motion." All studies reporting decreased range of motion as a complication considered an extension lag of 15° or joint contracture of 20° to be noteworthy. The overall complication rate of patients with immobilization was 16%, with all complications from rupture. Continuous passive motion

TABLE 1. Complications Reported Per Rehabilitation Protocol

Rehabilitation	Passive (22 articles)	Active (16 articles)	Immobilization (1 article)	Continuous Motion (2 articles)
Total tendons	1,598	1,412	25	83
Total complications (%)	206 (13%)	155 (11%)	4 (16%)	2 (2%)
Ruptures (%)	57 (4%)	75 (5%)	4 (16%)	2 (2%)
Decreased range of motion (%)	149 (9%)	80 (6%)	0	0

TABLE 2. Early Passive Versus Early Active Range of Motion in Flexor Tendon Rehabilitation

	Odds Ratio (Passive vs Active)	*P* Value
Total complications	1.20 (0.96–1.50)	.12
Ruptures	0.66 (0.46–0.94)	.02
Decreased range of motion	1.71 (1.29–2.27)	< .01

protocols produced 2 tendon ruptures, for an overall complication rate of 2%. In passive motion rehabilitation, the overall complication rate was 13%, with 4% from rupture and 9% from decreased motion. Active motion rehabilitation showed an overall 11% complication rate, with 5% from ruptures and 6% from decreased motion. The findings are summarized in Table 1. Multiple flexor tendon repairs on the same hand were described in 10 papers. Two of these papers noted overall worse functional motion, one noted better motion, and one noted equivocal motion. The remainder of papers noted that good–excellent versus fair–poor results were patient specific and consistent with each finger on the hand (Appendix A; available on the *Journal's* Web site at www.jhandsurg.org).

A Fisher's exact test was used to compare total complications, ruptures, and decreased range of motion between early active and passive rehabilitation protocols. Overall, there was not a statistically significant difference when comparing total complications between passive versus active protocols. However, passive protocols had a statistically significant lower risk of rupture but a significantly higher risk of decreased postoperative range of motion compared to early active motion protocols. The findings are detailed in Table 2.

When analyzing published rupture data in 5-year intervals, we discovered a trend for decreasing rupture rates that neared statistical significance ($P = .056$, left-sided, Cochran-Armitage trend test) (Table 3). In addition, when the data are analyzed in 10-year intervals over the past 20 years, there is a statistically significant trend for decreased rupture risk, with a 5.4% active rehabilitation rupture rate and 5.0% overall rupture rate from articles published from 1992 to 2001 compared to 4.0% active rehabilitation rupture rate and 3.4% overall rupture rate from articles published from 2002 to 2011 ($P = .038$, left-sided, Cochran-Armitage trend test) (Table 4). When analyzing early-active-motion articles, we found that the risk for tendon rupture in 4-strand repairs compared to 2-strand repairs (odds ratio 0.38, $P = .106$, Fisher's exact test) and in 6-strand repairs compared to 2-strand repairs (odds ratio 0.23, $P = 0.26$, Fisher's exact test) revealed no statistically significant difference (Table 4).

DISCUSSION

The purpose of this review is to analyze published results of rehabilitation protocols following flexor tendon repair in the hand. Our specific search terms were designed to fully evaluate this topic while limiting the return of irrelevant literature. By supplementing our primary search with a secondary search of the pertinent literature reference lists, we feel that we were able to capture a complete, yet focused, literature review of rehabilitation following flexor tendon repair in the hand. Our search strategy was limited by the exclusion of non-English literature that might have met our inclusion criteria.

Many of the papers in our review described how active motion protocols aim to increase early tendon excursion to prevent adhesion formation and to produce increased motion.[10–13] This was reinforced by Trumble et al, who produced level I evidence directly comparing active place-and-hold therapy with passive motion. The study showed greater interphalangeal joint motion, significantly smaller flexion contractures, and higher patient satisfaction with early active motion without increased risk for repair rupture.[13] In addition, numerous other, lesser-quality active motion studies found a high percentage of good–excellent functional results and improved interphalangeal joint motion with low com-

TABLE 3. Published Rupture Rates Over the Past 25 Years

Publication Date (5-Year Interval)	Passive Ruptures/Total Tendons (%)	Active Ruptures/Total Tendons (%)	Overall Ruptures/Total Tendons (%)
1987–1991	13/403 (3%)	14/230 (6%)	27/633 (4%)
1992–1996	17/410 (4%)	27/486 (6%)	44/896 (5%)
1997–2001	5/100 (5%)	24/451 (5%)	29/551 (5%)
2002–2006	10/121 (8%)	10/229 (5%)	20/350 (6%)
2007–2011	9/484 (2%)	2/71 (3%)	11/555 (2%)

TABLE 4. Rupture Rates in Early Active Range of Motion Compared with Number of Core Strand Sutures

No. Strand Repair	Two (11 Articles)	Four (4 Articles)	Six (1 Article)
Total Tendons	1,245	131	36
Ruptures (%)	72 (6%)	3 (2%)	0 (0%)

plication rates.[5,11,14–18] In general, patients with improved joint motion stated that they had better hand function and, thus, also had higher patient satisfaction scores.[13]

Analyzing all flexor tendon zones and literature of all levels of evidence, our study showed a higher risk of rupture in the various early active motion protocols and a higher risk of decreased digit range of motion in the passive protocols. Only 1 immobilization article and 2 continuous passive motion articles met inclusion criteria, making data too sparse to draw notable conclusions with regard to these protocols. In studies reporting hands with multiple-digit tendon repairs, all patients seemed to have similar results in each finger of the hand, although these results varied from good–excellent to fair–poor among patients and articles (Appendix A; available on the *Journal's* Web site at www.jhandsurg.org). Many of the articles conclude that multiple-digit results were directly related to the patient's rehabilitation effort. Multiple-digit injuries are included in our complications reported (Table 1) and may represent a confounding variable that increases the combined frequency reported for both good and poor postoperative functional digit range of motion.

A number of factors could contribute to the disparity in active motion ruptures reported throughout the literature (Appendix A; available on the *Journal's* Web site at www.jhandsurg.org). These include patient compliance, variations of active motion protocols, and differing surgical technique and materials. Many studies inconsistently report patient noncompliance ruptures, which may provide a false representation of complications for the given protocol. For example, in the article by Peck, the active motion protocol resulted in tendon rupture of 46%, a percentage much higher than all other active motion protocols reviewed.[19] The authors explained that 7 of the 12 ruptures were due to noncompliance and activities such as fighting, arrest by police, or gripping a towel. The authors discussed that the digit freedom of motion, compared to an orthosis with elastic band traction, may lead to inadvertent overactivity.[19] In another study by Small showing higher rates of rupture (9%), noncompliance was not addressed.[12]

Another factor that makes direct comparison difficult is variations and modifications in rehabilitation protocols. We divided the papers based on what rehabilitation activities were occurring during the critical initial 3 weeks after surgery. Although we categorized early-stage protocols to a best-fit classification of active or passive motion, there was great variation between protocols within each category. For example, Trumble used an active place-and-hold method that resulted in a 3% rupture rate.[13] In comparison, Small applied an active motion protocol based on achieving a specific degree of flexion over a specific time and reported a 9% rupture rate.[20] These 2 studies also differed in that Trumble used a 4-strand core suture repair technique compared to Small's 2-strand repair. Although these 2 protocols were categorized together, there was certainly variation in the postoperative strain applied to the tendon and in the inherent strength of the repair.[13,20] Many of the articles also included tendon injuries in several different zones of injury, but all used the same rehabilitation protocol for each tendon within the article, regardless of the injury zone.

Our analysis found a trend for decreased overall rupture rate (passive and active protocols) over time when data were analyzed in 5–year and 10-year intervals by publication date. We recognize that one flaw in this methodology is that data collection time periods

and time to publication varied among studies. However, we could not use surgical date because it was not reported in 8 studies, and publication date portrays advancements in flexor tendon injury treatment as accomplished by published research. We believe that the trend for decreased rupture rate is likely due not only to improvements in rehabilitation protocols but also to advancements in surgical materials and techniques. Although we found a trend that early active motion articles using a 4-strand core suture repair technique had a lower risk for rupture (2%) compared to those using a 2-strand technique (6%), this did not reach statistical significance. Our meta-analysis may not have had sufficient power to support this analysis, as only 4 articles described 4-strand repairs and early active motion rehabilitation. Three of these 4 articles were published within the last 10 years (2 within the last 5 years), and we believe this may represent advancement in surgical technique; this should be studied further with regard to active rehabilitation.[13,21–23] The one study using a 6-strand repair reported zero tendon ruptures, but it did report a complication related to decreased digit motion in 5 of 36 (14%) repairs.[10] Core suture material and size can also affect repair strength and ranged from 2–0 to 4–0 and monofilament to braided suture in our review. Given that the suture varied, even within single articles without correlation of results, statistical analysis could not be performed in our study. Overall, our systematic review provides evidence that, with improved strength of surgical repair, early active motion protocols can likely be tolerated and used to improve range of motion.

Determination of the optimal rehabilitation method through a systematic analysis of a majority of level IV literature is difficult due to the multitude of article variables, including patient population, injury pattern, surgical technique and materials, and rehabilitation modifications. Other aspects of treatment such as surgeon and therapist experience and patient access and compliance may also contribute.[24] In addition, multiple classification systems have been used to report functional results, and other reported outcomes measures are variable throughout the literature, making comparison difficult. Standardizing the method for reporting data would assist researchers in determining the individual influence of the various factors contributing to improved functional outcomes of rehabilitation protocols.

REFERENCES

1. Mason ML, Allen HS. The rate of healing of tendons. An experimental study of tensile strength. *Ann Surg.* 1941;113(2):424–459.
2. Duran R, Houser R, Coleman C, et al. A preliminary report in the use of controlled passive motion following flexor tendon repair in zones II and III. *J Hand Surg Am.* 1976;1( ):79.
3. Lister GD, Kleinert HE, Kutz JE, et al. Primary flexor tendon repair followed by immediate controlled mobilization. *J Hand Surg Am.* 1977;2(6):441–451.
4. Werntz JR, Chesher SP, Breidenbach WC, et al. A new dynamic splint for postoperative treatment of flexor tendon injury. *J Hand Surg Am.* 1989;14(3):559–566.
5. Edinburg M, Widgerow AD, Buddulph SL. Early postoperative mobilization of flexor tendon injuries using a modification of the Kleinert technique. *J Hand Surg Am.* 1987;12(1):34–38.
6. Chow JA, Thomes LJ, Dovelle S, et al. A combined regimen of controlled motion following flexor tendon repair in "no man's land." *Plast Reconstr Surg.* 1987;79(3):447–455.
7. Chesney A, Chauhan A, Kattan A, et al. Systematic review of flexor tendon rehabilitation protocols in zone II of the hand. *Plast Reconstr Surg.* 2011;127(4):1583–1592.
8. Thien TB, Becker JH, Theis JC. Withdrawn: Rehabilitation after surgery for flexor tendon injuries in the hand. *Cochrane Database Syst Rev.* 2010;6(10):CD003979.
9. 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.
10. Savage R, Risitano G. Flexor tendon repair using a "six strand" method of repair and early active mobilization. *J Hand Surg Br* 1989;14(4):396–399.
11. Bainbridge LC, Robertson C, Gillies D, et al. A comparison of post-operative mobilization of flexor tendon repairs with "passive flexion-active extension" and "controlled active motion" techniques. *J Hand Surg Br.* 1994;19(4):517–521.
12. Silfverskiold K, May E. Flexor tendon repair in zone II with a new suture technique and an early mobilization program combining passive and active flexion. *J Hand Surg Am.* 1994;19(1):53–60.
13. Trumble TE, Vedder NB, Seiler JG III, et al. Zone-II flexor tendon repair: a randomized prospective trial of active place-and-hold therapy compared with passive motion therapy. *J Bone Joint Surg Am.* 2010;92(6):1381–1389.
14. Cullen KW, Tolhurst P, Lang D, et al. Flexor tendon repair in zone 2 followed by controlled active mobilization. *J Hand Surg Br.* 1989;14(4):392–395.
15. Elliot D, Moiemen NS, Flemming AF, et al. The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen. *J Hand Surg Br.* 1994;19(5):607–612.
16. Baktir A, Türk CY, Kabak S, et al. Flexor tendon repair in zone 2 followed by early active mobilization. *J Hand Surg Br.* 1996;21(5):624–628.
17. Braga-Silva J, Kuyven CR. Early active mobilization after flexor tendon repairs in zone two. *Chir Main.* 2005;24(3–4):165–168.
18. Bal S, Oz B, Gurgan A, et al. Anatomic and functional Improvements achieved by rehabilitation in zone II and zone V flexor or tendon injuries. *Am J Phys Med Rehabil.* 2011;90(1):17–24.
19. Peck FH, Bücher CA, Watson JS, et al. A comparative study of two methods of controlled mobilization of flexor tendon repairs in zone 2. *J Hand Surg Br.* 1998;23(1):41–45.
20. Small JO, Brennen MD, Colville J. Early active mobilisation following flexor tendon repair in zone 2. *J Hand Surg Br.* 1989;14(4):383–391.
21. Gerard F, Garbuio P, Obert L, et al. Immediate active mobilization after flexor tendon repairs in Verdan's zones I and II. A prospective study of 20 cases. *Chir Main.* 1998;17(2):127–132.
22. Klein L. Early active motion flexor tendon protocol using one splint. *J Hand Ther.* 2003;16(3):199–206.
23. Yen CH, Chan WL, Wong JW, et al. Clinical results of early active mobilisation after flexor tendon repair. *Hand Surg.* 2008;13(1):45–50.
24. Gelberman RH, Nunley JA II, Osterman AL, et al. Influences of the protected passive mobilization interval on flexor tendon healing. A prospective randomized clinical study. *Clin Orthop Relat Res.* 1991;264:189–196.

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Strickland J, et al[1] "Digital function following flexor tendon repair in zone II: a comparison of immobilization and controlled passive motion techniques" 1980	Level II—prospective, comparative 37 patients, 50 digits	Zone II	Group 1: immobilization—25 digits Group 2: passive motion—25 digits	Not described Group 1: wrist positioned in moderate flexion and digits in a balanced position—no other details Group 2: dorsal orthoplast splint with wrist in moderate flexion and digits in a balanced position—no other details 5.5 wk Follow-up averaged 4.5 mo	FDP: modified Kessler with epitenon running sutures—no suture type mentioned FDS: horizontal mattress 2-strand repair	ASSH Group 1: 12% good–excellent Group 2: 56% good–excellent	Group 1: 4 ruptures Group 2: 1 rupture
Chow JA, et al.[2] "A combined regimen of controlled motion following flexor tendon repair in 'no man's land.'" 1987	Level IV—prospective, case series 37 patients, 44 digits	Zone II	Washington regimen: active extension against rubber band, passive flexion combined with controlled passive flexion/extension	15 fingers repaired within 8 h of injury, 29 fingers had delayed primary repair Thermoplastic dorsal splint—no splint specifics described 6 wk Follow-up range, 6–40 mo	FDP: modified Kessler or Tajima suture—3-0 or 4-0 braided synthetic suture with 6-0 nylon epitendinous FDS: horizontal mattress 2-strand repair	Strickland: 98% good–excellent	3 ruptures 6 extension deficits 6 patients with multiple-digit injuries (2 or 3 digits). All digits rated good–excellent

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Edinburg M, et al[3] "Early postoperative mobilization of flexor tendon injuries using a modification of the Kleinert technique" 1987	Level IV—retrospective, case series 36 patients, 99 digits	Zones I–V	Modified Kleinert	Repaired within 24 h, with the majority of injuries repaired within 12 h (article does not state whether time is from presentation or from injury) Dorsal splint with wrist at 60° flexion, MCPs in 40° to 60° flexion, and IPs at neutral 6 wk Follow-up averaged 3.2 mo	Modified Kessler—3-0 Ticron or 3-0 Ethibond and 6-0 nylon epitendinous 2-strand repair	Buck-Gramcko: 61% good-excellent	2 ruptures
Chow JA, et al[4] "Controlled motion rehabilitation after flexor tendon repair and grafting" 1988	Level IV—prospective, case series 66 patients, 78 digits	Zone II	Washington regimen: active extension against rubber band, passive flexion combined with controlled passive flexion/extension	32 fingers repaired within 8 h of injury, 46 fingers had delayed primary repair Thermoplastic dorsal splint—no splint specifics described 6 wk Follow-up ranged from 6 mo to 5 y	FDP: Modified Kessler or Tajima suture—3-0 or 4-0 braided synthetic suture with 6-0 nylon epitendinous FDS: horizontal mattress 2-strand repair	Strickland: 98% good–excellent	3 ruptures
Bunker TD, et al[5] "Continuous passive motion following flexor tendon repair" 1989	Level IV—prospective, case series 20 patients, 35 digits	Zones I–V	Toronto Mobilimb Continuous motion machine for 4.5 wk	Repaired within 12 h of injury Dorsal slab with wrist in 30° flexion, MCP joints flexed to 70° 6 wk Follow-up averaged 10.6 mo	Modified Mason Allen—4-0 Ethibond sutures with 6-0 Ethilon epitendinous 2-strand repair	Buck-Gramcko: 85% good–excellent Kleinert criteria: 70% good–excellent	2 ruptures

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Cullen KW, et al[6] "Flexor tendon repair in zone II followed by controlled active mobilization" 1989	Level IV—prospective, case series 27 patients, 31 digits 56 tendons	Zone II	Controlled active mobilization: 4 active and 2 passive every 4 h	Not described Dorsal slab with wrist in minus 30° full flexion and MCPs flexed to 90° 4 wk Follow-up averaged 10.2 mo	Modified Kessler—3-0 Ticron and 6-0 Prolene epitendinous 2-strand repair	Strickland: 77% good–excellent	2 ruptures 2 adhesions 1 contracture 4 patients had 2-digit injuries—both fingers on each patient had excellent results
Savage R, et al[7] "Flexor tendon repair using a 'six strand' method of repair and early active mobilization" 1989	Level IV—prospective, case series 36 tendons	Zones I, II, III, V	Early active mobilization	Repaired within 24 hours of injury Dorsal plaster splint with wrist at 0°, MCPs at 90°, and IPs at full extension 3–4 wk Follow-up at 3 mo	Three grasping stitches in each tendon end and 6 strands of 4-0 Ethibond, with 6-0 Prolene epitendinous 6-strand method	Buck-Gramcko: 100% good–excellent in zone I 69% good–excellent in zone II	2 adhesions 3 extension deficits
Small JO, et al[8] "Early active mobilisation following flexor tendon repair in zone II" 1989	Level IV—prospective, case series 114 patients, 138 tendons	Zone II	Early active mobilization	Not described Dorsal splint with wrist at midflexion, MCPs at 90° flexion, and IPs in full extension 6 wk Follow-up at 6 mo	FDP: Kessler-Mason-Allen core suture—4/0 monofilament and 6-0 Prolene epitendinous FDS: 5-0 or 6-0 monofilament, horizontal mattress 2-strand repair	ASSH: 77% good–excellent	11 ruptures

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Gelberman RH, et al[9] "Influences of the protected passive mobilization interval on flexor tendon healing. A prospective randomized clinical study" 1991	Level II—randomized, controlled trial 51 patients, 102 tendons	Zones I–V	Passive motion: Group 1: greater intervals of passive motion with continuous passive-motion device—75 h/wk with 12,000 cycles (48 tendons) Group 2: traditional early passive motion—4 h/wk with 1,000 cycles (54 tendons)	Not described Group 1: dorsal block splint with wrist flexed to 30° and MCPs flexed to 45° Group 2: dorsal block splint with wrist flexed to 30°, MCPs flexed to 60° to 70°, and IPs in neutral 6 wk Follow-up at 6 mo	Kessler and Missim techniques—4-0 braided Dacron sutures and 6-0 nylon epitendinous 2-strand repair	Strickland: Group 1 ROM: 138° ± 6° Group 2 ROM: 119° ± 8°	Group 1: 0 ruptures Group 2: 1 rupture Group 1: Three patients with 2 digits injured—2 patients had both digits achieve fair results, and the third patient had good results for both digits Group 2: Four patients with 2 digits injured—1 had a good and a fair digit, 1 had a fair and a poor digit, 1 had 2 good digits, 1 had 2 excellent digits. One patient had 3 digits injured—2 digits had poor results, and 1 had fair results
Gerbino PG II, et al[10] "Complications experienced in the rehabilitation of zone I flexor tendon injuries with dynamic traction splinting" 1991	Level IV—retrospective, case-series 20 tendons	Zone I	12-wk rehabilitation protocol: controlled active extension against passive flexion by rubber band and controlled passive extension and flexion	Not described Modification of Kleinert's splint with wrist flexed to 30° and MCP flexion at 45°, but increased flexion of DIPs 6 wk Follow-up range, 6–42 mo	Modified Kessler—3-0 Ethibond and 6-0 nylon epitendinous 2-strand repair	Strickland: 65% good–excellent	1 rupture 7 adhesions

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Saldana MJ, et al[11] "Further experience in rehabilitation of zone II flexor tendon repair with dynamic traction splinting" 1991	Level IV—retrospective, case-series 57 patients, 60 digits	Zone II	12-wk protocol from United States military, combined regimen of controlled motion: active extension against rubber band with passive flexion, passive extension with passive flexion	Not described Thermoplastic dorsal splint—no splint specifics described 6 wk Follow-up at 12–48 mo	FDP: modified Kessler—3-0 braided synthetic suture with 6-0 nylon epitendinous FDS: horizontal mattress sutures 2-strand repair	Strickland: 93% good–excellent	3 ruptures
May EJ, et al[12] "Controlled mobilization after flexor tendon repair in zone II: a prospective comparison of three methods" 1992	Level II—prospective, comparative 140 patients, 159 digits	Zone II	Group 1: modified Kleinert—54 digits Group 2: combination modified Kleinert and passive movement—51 digits Group 3: dynamic flexion traction, short splint with free IP joints, and nighttime extension splint—54 digits	Not described Group 1: dorsal plaster splint with wrist in 30° to 45° flexion, MCPs in 50° to 70° flexion, and IPs fully extended. At night, fingers rested in flexed position Group 2: dorsal plaster splint with wrist in 30° to 45° flexion, MCPs in 50° to 70° flexion, and IPs fully extended. At night, fingers rested in flexed position Group 3: dorsal plaster splint extending to the PIPs, with wrist in 30° to 45° flexion, MCPs in 50° to 70° flexion, and IPs fully extended. At night, digits splinted in full extension 4 wk Follow-up at 6 mo and 1 y	FDP: modified Kessler—4-0 braided polyester with 6-0 epitendinous stitch FDS: mattress sutures of 4-0 braided polyester 2-strand repair	Strickland: Group 1: 72% good-excellent Group 2: 62% good-excellent Group 3: 83% good-excellent	Group 1: 2 ruptures 15 extension deficits Group 2: 1 rupture 14 extension deficits Group 3: 2 ruptures 3 extension deficits Multiple-digit injuries did worse than single-digit injuries in both passive and 4-finger groups

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
May EJ, et al[13] "The correlation between controlled range of motion with dynamic traction and results after flexor tendon repair in zone II" 1992	Level IV—prospective, case series 48 patients, 51 digits	Zone II	Early controlled mobilization with dynamic traction via pulley—active extension with passive flexion	39 tendons repaired within 24 h of injury; 12 tendons with delayed repair Dorsal plaster splint with wrist in 30° to 45° flexion, MCPs in 50° to 70° flexion, and IPs in full extension 4 wk Follow-up at 6 mo and 1 y	FDP: modified Kessler—4-0 braided polyester with 6-0 epitendinous stitch FDS: mattress sutures of 4-0 braided polyester 2-strand repair	Strong correlation between tendon excursion and DIP and PIP controlled ROM and active ROM during rehabilitation	2 ruptures Lists 6 of the 51 digits were involved in multiple digit injuries but does not describe them specifically
Bainbridge LC, et al[14] "A comparison of postoperative mobilization of flexor tendon repairs with 'passive flexion-active extension' and 'controlled active motion' techniques" 1994	Level II–prospective, comparative Group 1: 52 patients, 68 digits Group 2: 56 patients, 67 digits	Zones I, II	Group 1: passive flexion–active extension Group 2: controlled active motion	Not described Group 1: dorsal splint with wrist in 30° flexion, MCPs in 90° flexion, and IPs in neutral Group 2: dorsal splint with wrist in 30° flexion, MCPs in 90° flexion, and IPs in full extension 6 wk Follow-up at 4 mo	FDP: modified Kessler suture of 3-0 or 4-0 Prolene with epitendinous 6-0 nylon or Prolene FDS: 4-0 or 5-0 horizontal mattress sutures of either nylon or Prolene 2-strand repair	Buck-Gramcko: Group 1: zone I: 90% good–excellent zone II: 50% good–excellent Group 2: zone I: 89% good–excellent zone II: 90% good–excellent	Group 1: 2 ruptures 27 extensor deficits Group 2: 5 ruptures 7 extensor deficits
Elliot D, et al[15] "The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen" 1994	Level IV—prospective, case series 233 patients, 317 tendons	Zones I, II	Controlled active motion	Repaired within 24 h of hospital presentation Thermoplastic dorsal splint with 30° wrist flexion, 30° MCP flexion, and IPs in neutral 4 wk Follow-up at 3 mo	FDP: Tajima using 3-0 or 4-0 Prolene and 6-0 Prolene or nylon epitendinous FDS: horizontal mattress of 4-0 or 5-0 nylon 2-strand repair	Strickland: 77% good–excellent	18 ruptures

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Silfverskiold K, et al[16] "Flexor tendon repair in zone II with a new suture technique and an early mobilization program combining passive and active flexion" 1994	Level IV—prospective, case series 46 patients, 55 digits	Zone II	Active extension and passive/active flexion	48 digits repaired within 24 h of injury, 7 digits had delayed repair Dorsal plaster splint extending to PIPs, with wrist at 0°, MCPs in 50° to 70° flexion, and IPs fully extended 6 wk Follow-up at 6 wk and 6 mo	FDP: modified Kessler—4-0 braided polyester and 6-0 polypropylene epitendinous 2-strand repair	DIP and PIP had 82% and 88% of ROM compared to other hand, respectively	2 ruptures
Adolfsson L, et al [17] "The effects of a shortened postoperative mobilization program after flexor tendon repair in zone 2" 1996	Level II—randomized, controlled trial 82 patients, 91 digits	Zone II	First 6 wk: passive flexion–active extension Next 6 wk: randomized into full activity after 8 wk or full activity after 10 wk	Repair within 24 h of injury Dorsal splint that extends to PIPs with wrist in 30° flexion, MCPs in > 70° flexion, and IPs in neutral position 6 wk Follow-up at 6 mo	Modified Kessler—4-0 Maxon with epitendinous 6-0 Prolene 2-strand repair	Louisville: Group A: 71% good–excellent Group B: 67% good–excellent Tsuge: Group A: 77% good–excellent Group B: 73% good–excellent Buck-Gramcko: Group A: 91% good–excellent Group B: 91% good–excellent No significant difference in functional results, grip strength, or subjective assessment. Absence from work was reduced by 2.1 wk with shorter mobilization program	6 ruptures No significant difference in rupture rates

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Baktir A, et al[18] "Flexor tendon repair in zone 2 followed by early active mobilization" 1996	Level II—prospective, comparative 71 patients, 88 tendons	Zone II	Group 1: 33 patients: Kleinert rubber band passive flexion/active extension method Group 2: 38 patients: early active mobilization	58 tendons repaired within 12 h, 13 tendons repaired within 2 wk (does not state whether hours from injury or from presentation) Group 1: dorsal splint with wrist in 30° to 40° flexion, MCPs in 70° to 90° flexion, and IPs in full extension Group 2: dorsal splint with wrist in 0° flexion, MCPs in 70° to 90° flexion, and IPs in full extension 6 wk Follow-up at 1 y	FDP: modified Kessler—4-0 braided polyester and epitendinous 6-0 Prolene FDS: horizontal mattress sutures—4-0 braided polyester 2-strand repair	Strickland: Passive flexion group: 78% good–excellent and 84% mean grip strength Active mobilization group: 85% good–excellent and 90% mean grip strength	2 ruptures in each group Extensor deficit: 10 in Kleinert 5 in early active mobilization No difference in results from multiple tendon injuries in same hand or whether FDP or both FDP and FDS tendons were injured
Gerard F, et al[19] "Immediate active mobilization after flexor tendon repairs in Verdan's zones I and II. A prospective study of 20 cases" 1998	Level IV—prospective, case series 20 repairs	Zones I, II	Early active mobilization—"patient encouraged to actively and synchronously flex all fingers as many times as possible starting day 5"	Repaired within 6 h of injury Dorsal splint with wrist flexed to 30°, MCPs in 90° flexion, and IPs in neutral 4 wk	FDP: double-loop suture of Tsuge with 4-0 PDS with 6-0 Prolene epitendinous FDS: Tsuge with 4-0 PDS or X-shaped 6-0 Prolene 4-strand repair	Strickland: Mean active mobility 70% for zone I and 85% for zone II	0 ruptures
Kitsis CK, et al[20] "Controlled active motion following primary flexor tendon repair: a prospective study over 9 years" 1998	Level IV—prospective, case series 130 patients, 339 tendons	Zones I–V	Active motion combined with modified Kleinert dynamic traction splint	Repaired within 4 wk of injury Modified Kleinert splint worn continuously—no details are provided 5–6 wk Follow-up at 6 mo	Modified Kessler—4-0 Ethibond with Halsted peripheral running stitch of 5-0 nylon 2-strand repair	Strickland: 92% good–excellent	6 ruptures 17 adhesions

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Peck FH, et al[21] "A comparative study of two methods of controlled mobilization of flexor tendon repairs in zone II" 1998	Level II—prospective, comparative 52 patients, 52 digits, 92 tendons	Zone II	Group 1: controlled active motion—26 patients Group 2: modified Kleinert regime—26 patients	Repaired within 24 h of injury Group1: thermoplastic dorsal splint with wrist in 40° flexion, MCPs in 60° flexion, and IPs in neutral Group 2: thermoplastic dorsal splint with wrist in 40°flexion, MCPs in 60° flexion, and IPs in neutral 6 wk Follow-up at 12 wk	FDP: modified Kessler—3-0 Prolene and 6-0 nylon or Prolene epitendinous FDS: horizontal mattress with 6-0 Prolene. 2-strand repair	Strickland: Group 1: 85% good–excellent Group 2: 69% good–excellent	Group 1: 12 ruptures Group 2: 2 ruptures
Cetin A, et al[22] "Rehabilitation of flexor tendon injuries by use of a combined regimen of modified Kleinert and modified Duran techniques" 2001	Level IV—prospective, case series 37 patients, 74 digits	Zones I–V	Controlled mobilization: combined modified Kleinert and modified Duran techniques—Kleinert splint with a palmar pulley	Not described Dorsal splint with wrist at 30° to 35° flexion and MCP joints flexed to 50° to 60° 4 wk Follow-up averaged 12.9 wk	Modified Kessler—4-0 Prolene with 6-0 nylon epitendinous 2-strand repair	Buck-Gramcko: 97% good–excellent	1 rupture 13 extensor deficits Number of injured digits had a positive correlation with improved total active motion
Hatanaka H, et al[23] "Aggressive active mobilization following zone II flexor tendon repair using a two-strand heavy-gauge locking loop technique" 2002	Level IV—prospective, case series 7 digits	Zone II	Active mobilization	Not described Dorsal splint with wrist and MCPs at 20° flexion and IPs fully extended 5 wk Follow-up at 6 mo	FDP: 2-stranded locking loop using heavy 2-0 braided polyester suture with 6-0 Prolene epitendinous FDS: Tang technique using 4-0 looped nylon with 6-0 monofilament epitendinous 2-strand repair	Strickland: 86% good–excellent	1 rupture

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Klein L[24] "Early active motion flexor tendon protocol using one splint" 2003	Level IV—retrospective, case-series 40 digits	Zones I–III	Active motion—dorsal blocking splint with fingers in rubber band traction for 5 wk	Not described Thermoplastic dorsal splint with wrist in neutral, MCPs in 50° to 70° flexion, and IPs allowed full extension 5 wk Follow-up at 12 wk	Various 4-strand types: Tajima, modified Kessler, modified Kessler, and mattress with 3-0 or 4-0 braided synthetic suture, with all adding a simple running epitendinous 6-0 nylon 4-strand repair	Strickland: 95% good–excellent in zone II 88% good–excellent in zones I, III	1 rupture
Braga-Silva J, et al[25] "Early active mobilization after flexor tendon repairs in zone 2" 2005	Level IV—retrospective, case-series 82 patients, 136 tendons	Zone II	Early active mobilization	Repaired between 7 and 21 d from injury Not described 3 wk Follow-up range, 12–36 mo	Modified Kessler—3-0 nylon with 5-0 epitendinous 2-strand repair	IFSSH and Strickland criteria: Long fingers: 98% good–excellent (Strickland); 82% good (IFSSH) Thumb: 96% good–excellent (Strickland); 96% good–excellent (IFSSH)	5 ruptures
Chai SC, et al[26] "Dynamic traction and passive mobilization for the rehabilitation of zone II flexor tendon injuries: a modified regime" 2005	Level IV—retrospective, case-series 8 patients, 15 digits 28 tendons (only 25 of 28 tendons repaired—3 not repaired due to bulkiness that could prevent tendon gliding)	Zone II	Dynamic traction and passive motion	Not described Dorsal blocking splint with wrist in 0° to 30° flexion, MCPs in 60° to 90° flexion, and IPs in full extension 6 wk Follow-up at 3 mo	Supramid 6-strand technique (9 tendons) 6-strand repair Modified Kessler using Prolene (16 tendons) 2-strand repair	Strickland: 93% good–excellent Grip strength 50% of uninjured hand	0 ruptures 2 patients with multiple tendon lacerations who were compliant with therapy session attendance achieved excellent results, and one patient with multiple tendon lacerations who was less compliant with therapy attendance had limited ROM after therapy

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Hung LK, et al[27] "Active mobilization after flexor tendon repair: comparison of results following injuries in zone 2 and other zones" 2005	Level IV—prospective, case series 32 patients, 46 digits	Zones I, II, III, V	Early active mobilization: passive flexion, then active flexion	Not described Thermoplastic dorsal splint with wrist in 40° flexion, MCPs in 70° flexion, and IPs in neutral 3 wk Follow-up at 3, 6, 9, and 12 wk	Modified Kessler—4-0 nylon with 6-0 nylon epitendinous 2 strand repair	ASSH: 71% good–excellent in zone II 77% good–excellent in other zones Pinch grips were similar between groups, with 95% that of uninjured hand	2 zone II ruptures 1 ruptures in other zones
Su BW, et al[28] "Device for zone-II flexor tendon repair. A multicenter randomized, blinded, clinical trial." 2005	Level I—randomized, controlled trial 67 patients, 85 digits	Zone II	Modified Kleinert with active flexion starting at 4 wk after surgery	Repaired within 14 d of injury Dorsal splint with wrist in 30° flexion, MCPs in 60° flexion, and IPs in full extension 6 wk Follow-up at 6 mo	34 digits treated with TenoFix—2 intratendinous, stainless steel anchors joined by multifilament 2-0 stainless steel suture, 1-strand repair and 6-0 nylon epitendinous 51 digits with 4-stranded cruciate suture repair—3-0 or 4-0 Prolene and 6-0 nylon epitendinous Control group 4-strand repair	Strickland: 67% good–excellent in TenoFix 70% good–excellent in control No difference in ROM, DASH, grip strength, pain, swelling, or neurologic recovery	TenoFix: 0 ruptures Control: 9 ruptures

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Chan TK, et al[29] "Functional outcomes of the hand following flexor tendon repair at the 'no man's land'" 2006	Level IV—retrospective, case series 16 patients, 21 digits	Zone II	7-wk rehabilitation: 3 wk active extension/passive flexion, 2 wk active flexion without resistance, 2 wk active flexion with resistance	Repaired within 24 h of hospital presentation Kleinert splint with wrist flexion at 30°, MCPs flexed to 45°, and IPs at neutral 3 wk Follow-up at 130 d	FDP: modified Kessler—4-0 nylon with 6-0 nylon epitendinous FDS: horizontal mattress sutures 2-strand repair	Buck-Gramcko: 81% good-excellent	1 rupture 3 patients with multiple digits injured. Two patients injuring 2 digits achieved excellent results. One patient who injured 4 digits achieved poor results (patient noted to have poor compliance with rehabilitation protocol)
Yen CH, et al,[30] "Clinical results of early active mobilisation after flexor tendon repair" 2008	Level III—Prospective, comparative cohort 20 patients	Zone II	Active extension, active place-and-hold—10 patients Kleinert method—10 patients	Not described Dorsal splint with wrist in 30° flexion, MCPs in 70° flexion, and IPs in full extension 6 wk Follow-up at 4 mo	4-0 Prolene core sutures plus 6-0 Prolene circumferential sutures 4-strand repair	Mayo Wrist Score: Active motion: 70% good–excellent Kleinert splint: 0% good–excellent	Active place and hold: 0 complications Kleinert splint: 1 rupture
Kitis PT, et al[31] "Comparison of two methods of controlled mobilisation of repaired flexor tendons in zone 2" 2009	Level II—prospective, comparative 192 patients, 263 digits	Zone II	Group 1: modified Kleinert (Washington regimen)—137 digits) Group 2: controlled passive movement—126 digits	Repaired within 24 h of hospital presentation Group 1: 6 wk in Kleinert splint with wrist at minus 20° full flexion, MCPs at 10° to 20°flexion, and IPs at neutral Group 2: 5 wk in dorsal splint with wrist at 20° flexion, MCPs at 50° flexion, and IPs fully extended Follow-up range, 6–20 mo	Modified Kessler—4-0 nylon with 6-0 nylon epitendinous 2-strand repair	Buck-Gramcko: Group 1: 87% excellent total active movement, 89% grip strength, DASH 30 Group 2: 75% excellent total active movement, 81% grip strength, 42 DASH	Group 1: 16 extension deficits 0 ruptures Group 2: 26 extension deficits 1 rupture

(Continued)

APPENDIX A. Articles Meeting Inclusion Criteria for Systematic Review, Arranged Chronologically (Continued)

Study Publication Year	Level of Evidence, Number of Patients	Flexor Zones	Rehabilitation Method(s)	Time From Injury to Surgery Splint Type Total Time Splinted Follow-Up	Core Suture Repair Method—Suture Size and Material No. Strand Repair	Functional Results (Classification System)	Complications Comments on Complications in Multiple-Digit vs Single-Digit Injuries
Saini N, et al[32] "Outcome of early active mobilization after flexor tendons repair in zones II-V in hand" 2010	Level IV—prospective, case series 75 digits	Zones II–V	Modified Kleinert's regimen and Silfverskiold regimen: active extension with initial active flexion and later passive flexion	26 fingers repaired within 6 to 8 h of injury, 49 fingers had delayed repair Dorsal splint with the wrist in 0° to 5° flexion, MCPs in 70° flexion, and IPs in full extension 12 wk Follow-up at 14 wk	Modified Kessler—3-0 or 4-0 polypropylene core suture and epitendinous stitch 2-strand repair	Louisville: 82% good–excellent	2 ruptures 2 contractures
Trumble TE, et al[33] "Zone-II flexor tendon repair: a randomized prospective trail of active place-and-hold therapy compared with passive motion therapy" 2010	Level I—randomized, controlled trial 103 patients, 119 digits	Zone II	Passive motion—51 patients with 58 digits Active motion with place-and-hold—52 patients with 61 digits	Repaired within 48 h of injury No splint details 6 wk Follow-up at 6, 12, 26, and 52 wk	FDP: Strickland method—2 core sutures of 3-0 polyester and 6-0 Prolene epitendinous FDS: simple Kessler with 3-0 polyester 4-strand repair	Strickland: Active motion: IP joint motion was 156° ± 25°, with 94% good–excellent Passive motion: IP joint motion was 128° ± 22°, with 62% good–excellent	Passive motion: 2 ruptures Active motion: 2 ruptures Six patients with multiple-digit injuries included in each group. Patients with multiple-digit injuries had overall worse outcomes in both groups
Bal S, et al[34] "Anatomic and functional improvements achieved by rehabilitation in zone II and zone V flexor tendon injuries" 2011	Level II—prospective, comparative 31 patients, 78 digits	Zone II, V	Modified Kleinert protocol	Not described Dorsal splint with wrist in 45° flexion, MCPs in 30° flexion, and IPs in full extension 3 wk Average follow-up at 52 wk for zone II and 55 wk for zone V	Modified Kessler—3-0 Prolene with epitendinous 5-0 Prolene 2-strand repair	ASSH: 52% good–excellent in zone II 83% good–excellent in zone V Grip strength: 71%, zone II 53%, zone V	2 zone II ruptures 1 zone V rupture

FDS, flexor digitorum superficialis; FDP, flexor digitorum profundus; ASSH, American Society for Surgery of the Hand; MCP, metacarpophalangeal; IP, interphalangeal; ROM, range of motion; DIP, distal interphalangeal; PDS, polydioxanone; IFSSH, International Federation of Societies for Surgery of the Hand; DASH, Disabilities of the Arm, Shoulder, and Hand.

REFERENCES

1. 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.
2. Chow JA, Thomes LJ, Dovelle S, et al. A combined regimen of controlled motion following flexor tendon repair in "no man's land." *Plast Reconstr Surg.* 1987;79(3):447–455.
3. Edinburg M, Widgerow AD, Buddulph SL. Early postoperative mobilization of flexor tendon injuries using a modification of the Kleinert technique. *J Hand Surg Am.* 1987;12(1):34–38.
4. Chow JA, Thomes LJ, Dovelle S, et al. Controlled motion rehabilitation after flexor tendon repair and grafting. A multi-centre study. *J Bone Joint Surg Br.* 1988;70(4):591–595.
5. Bunker TD, Potter B, Barton NJ. Continuous passive motion following flexor tendon repair. *J Hand Surg Br.* 1989;14(4):406–411.
6. Cullen KW, Tolhurst P, Lang D, et al. Flexor tendon repair in zone 2 followed by controlled active mobilization. *J Hand Surg Br.* 1989;14(4):392–395.
7. Savage R, Risitano G. Flexor tendon repair using a "six strand" method of repair and early active mobilization. *J Hand Surg Br* 1989;14(4):396–399.
8. Small JO, Brennen MD, Colville J. Early active mobilisation following flexor tendon repair in zone 2. *J Hand Surg Br.* 1989;14(4):383–391.
9. Gelberman RH, Nunley JA II, Osterman AL, et al. Influences of the protected passive mobilization interval on flexor tendon healing. A prospective randomized clinical study. *Clin Orthop Relat Res.* 1991;264:189–196.
10. Gerbino PG II, Saldana MJ, Westerbeck P, et al. Complications experienced in the rehabilitation of zone I flexor tendon injuries with dynamic traction splinting. *J Hand Surg Am.* 1991;16(4):680–686.
11. Saldana MJ, Chow JA, Gerbino PG II, et al. Further experience in rehabilitation of zone II flexor tendon repair with dynamic traction splinting. *Plast Reconst Surg.* 1991;87(3):543–546.
12. May EJ, Silfverskiöld KL, Sollerman CJ. Controlled mobilization after flexor tendon repair in zone II: a prospective comparison of three methods. *J Hand Surg Am.* 1992;17(5):942–952.
13. May EJ, Silfverskiöld KL, Sollerman CJ. The correlation between controlled range of motion with dynamic traction and results after flexor tendon repair in zone II. *J Hand Surg Am.* 1992;17(6):1133–1139.
14. Bainbridge LC, Robertson C, Gillies D, et al. A comparison of post-operative mobilization of flexor tendon repairs with "passive flexion-active extension" and "controlled active motion" techniques. *J Hand Surg Br.* 1994;19(4):517–521.
15. Elliot D, Moiemen NS, Flemming AF, et al. The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen. *J Hand Surg Br.* 1994;19(5):607–612.
16. Silfverskiold K, May E. Flexor tendon repair in zone II with a new suture technique and an early mobilization program combining passive and active flexion. *J Hand Surg Am.* 1994;19(1):53–60.
17. Adolfsson L, Soderberg G, Larsson M, et al. The effects of a shortened postoperative mobilization program after flexor tendon repair in zone 2. *J Hand Surg Br.* 1996;21(1):67–71.
18. Baktir A, Türk CY, Kabak S, et al. Flexor tendon repair in zone 2 followed by early active mobilization. *J Hand Surg Br.* 1996;21(5):624–628.
19. Gerard F, Garbuio P, Obert L, et al. Immediate active mobilization after flexor tendon repairs in Verdan's zones I and II. A prospective study of 20 cases. *Chir Main.* 1998;17(2):127–132.
20. Kitsis CK, Wade PJ, Krikler SJ, et al. Controlled active motion following primary flexor tendon repair: a prospective study over 9 years. *J Hand Surg Br.* 1998;23(3):344–349.
21. Peck FH, Bücher CA, Watson JS, et al. A comparative study of two methods of controlled mobilization of flexor tendon repairs in zone 2. *J Hand Surg Br.* 1998;23(1):41–45.
22. Cetin A, Dincer F, Keçik A, et al. Rehabilitation of flexor tendon injuries by use of a combined regimen of modified Kleinert and modified Duran techniques. *Am J Phys Med Rehabil.* 2001;80(10):721–728.
23. Hatanaka H, Kojima T, Mizoguchi T, et al. Aggressive active mobilization following zone II flexor tendon repair using a two-stranded heavy-gauge locking loop technique. *J Orthop Sci.* 2002;7(4):457–461.
24. Klein L. Early active motion flexor tendon protocol using one splint. *J Hand Ther.* 2003;16(3):199–206.
25. Braga-Silva J, Kuyven CR. Early active mobilization after flexor tendon repairs in zone two. *Chir Main.* 2005;24(3–4):165–168.
26. Chai SC, Wong CW. Dynamic traction and passive mobilization for the rehabilitation of zone II flexor tendon injuries: modified regime. *Med J Malaysia.* 2005;60 Suppl C:59–65.
27. Hung LK, Pang KW, Yeung PL, et al. Active mobilization after flexor tendon repair: comparison of results following injuries in zone 2 and other zones. *J Orthop Surg (Hong Kong).* 2005;13(2);158–163.
28. Su BW, Solomon M, Barrow A, et al. Device for zone-II flexor tendon repair. A multicenter, randomized, blinded clinical trial. *J Bone Joint Surg Am.* 2005;87(5):923–935.
29. Chan TK, Ho CO, Lee WK, et al. Functional outcome of the hand following flexor tendon repair at the 'no man's land.' *J Orthop Surg (Hong Kong).* 2006;14(2):178–183.
30. Yen CH, Chan WL, Wong JW, et al. Clinical results of early active mobilisation after flexor tendon repair. *Hand Surg.* 2008;13(1):45–50.
31. Kitis PT, Buker N, Kara IG. Comparison of two methods of controlled mobilisation of repaired flexor tendons in zone 2. *Scand J Plast Reconstr Surg Hand Surg.* 2009;43(3):160–165.
32. Saini N, Kundnani V, Patni P, et al. Outcome of early active mobilization after flexor tendons repair in zones II-V in hand. *Indian J Orthop.* 2010;44(3):314–321.
33. Trumble TE, Vedder NB, Seiler JG III, et al. Zone-II flexor tendon repair: a randomized prospective trial of active place-and-hold therapy compared with passive motion therapy. *J Bone Joint Surg Am.* 2010;92(6):1381–1389.
34. Bal S, Oz B, Gurgan A, et al. Anatomic and functional Improvements achieved by rehabilitation in zone II and zone V flexor or tendon injuries. *Am J Phys Med Rehabil.* 2011;90(1):17–24.