ABSTRACT:

Purpose: Despite an abundance of literature, there is no consensus on the optimal rehabilitation protocol following flexor tendon repair. This systematic review compares results of various protocols, following repair in all zones of injury, and specifically contrasts early passive vs. early active range of motion.

Methods: Pubmed and Cochrane Library databases were searched to identify articles involving flexor tendon injury, repair, and rehabilitation protocol published from 1980-2011. All zones of injury were included. Exclusion criteria included studies not in English and those without documented surgical technique, rehabilitation protocol or clinical results. Articles were classified based on the protocol employed during early rehabilitation. Clinical outcomes were analyzed focusing on incidence of tendon rupture and postoperative functional range of motion. Secondarily, the chronological incidence of tendon rupture was analyzed with respect to protocol employed.

Results: 170 articles were identified. 34 articles met our criteria with evidence ranging from Level I-IV. Early passive range of motion, including both Duran’s and Kleinert’s type protocols, results included 57 ruptures (3.57%) and 149 fingers with decreased range of motion (9.32%) out of 1598 total tendon repairs. Early active range of motion results included 75 ruptures (5.3%) and 80 fingers with decreased range of motion (5.67%) out of 1412 total tendon repairs. Early passive range of motion protocols had an overall decreased risk for tendon rupture but increased risk for decreased range of motion compared to early active motion protocols. Articles published over the past 5 years reported a lower rate or rupture in both the early active and passive motion protocols.

Discussion: There is a lack of high-level evidence regarding flexor tendon repair rehabilitation and no consensus on optimal protocol. Improvements in surgical technique may allow for early active motion rehabilitation that can provide better functional postoperative motion. A set of guidelines is needed for reporting clinical results following flexor tendon repair and rehabilitation.

Type of Study/Level of Evidence: Therapeutic IV

INTRODUCTION:

Since the early 1970’s, advancement in surgical materials and technique, along with improvements in rehab program design, has allowed flexor tendon repair rehabilitation to shift from immobilization to early mobilization (1), However, despite flexor tendon repair rehabilitation being a widely studied topic, there is a range of early mobilization protocols utilized without a single optimal model identified. 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 Kleinert’s, Duran’s and active place and hold are popular, there are many surgeons and therapist modifying these techniques or using combinations of both to improve outcomes (2). 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 review on rehabilitation protocols following flexor tendon repair. Chesney et al has reviewed rehabilitation of flexor tendon injuries in zone II of the hand. They determined early motion protocols were superior to static splinting and that no significant difference existed between early active and early passive protocols (3). In 2004, another group out of the Netherlands 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 (4). The object of this systematic review is to analyze results from articles of all levels of evidence, including all zones of flexor tendon injury, to determine an optimal rehabilitation protocol. We pay specific attention to early active vs. early passive range of motion protocols and their complication rates including rupture and decreased digit range of motion. Secondarily, we analyze chronological trends in the literature over the past 25 years to determine if enhancements in surgical technique and materials have led to increased repair strength and thus decreased rate of repair failure.

MATERIALS AND METHODS:

The Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) guidelines were used as a template for our systematic review. 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 agreeing upon 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 publication journal, author & 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” as it produced more results and included all flexor tendon zones of injury. The search returned articles published from 1980-2011. We included English 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 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. A total of 34 articles met the criteria and were analyzed (Figure 1). Two independent reviewers determined each article’s level of evidence, as outlined by the *Journal of Hand Surgery America*, with a third reviewer available for dispute.

Attention was focused on the protocol employed during the critical early stage of rehabilitation (1st 3 weeks). Early stage protocols were divided into immobilization, passive motion (including both Kleinert’s and Duran’s type protocols), active motion, and continuous motion for comparison purposes. Data were compiled from all qualifying studies with specific attention to outcomes measures including functional results, total active motion, and post-operative tendon rupture. Additionally rupture data were analyzed in 5-year intervals over a period of 25 years (1987-2011) to determine if advancement in technique, surgical material, and rehab protocols has led to an overall decreased rate of rupture. The 25-year period was chosen as it included all articles meeting our search criteria, except for 1 paper published by Strickland et al in 1980, and allowed comparison of data in 5 year intervals. Strickland’s paper was considered an outlying year, but if included, its 4% rupture rate with passive rehabilitation would not have significantly affected the data analysis. A biostatistician was consulted to facilitate statistical analysis of the reported results. An odds ratio was calculated comparing complication rates between early passive and early active range of motion.

RESULTS:

In the 34 articles reviewed, the rehabilitation protocols most commonly used were early mobilization with passive motion and early mobilization with active motion. Other methods utilized in the studies include immobilization and continuous motion. The majority of papers 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 form 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, seven prospective, comparative studies were considered level II evidence. Finally, the remaining 23 papers were level IV evidence and consisted of retrospective and prospective case-series. The suture repair and rehabilitation methods, functional results, and complications reported in the articles meeting inclusion criteria are summarized in Table 1.

The most commonly reported complication was tendon rupture. Studies also reported joint contractures, adhesions, significant loss of motion to a joint, and extensor lag. For purposes of comparison these were all grouped into ‘decreased range of motion.’ The overall complication rate of patients with immobilization was 16%, with all complications from rupture. Continuous passive motion protocols produced 2 tendon ruptures for an overall complication rate of 2.4%. In passive motion rehabilitation, the overall complication rate was 12.9%, with 3.57% from rupture and 9.32% from decreased ROM. Active motion rehabilitation showed an overall 11.0% complication rate, with 5.31% from ruptures and 5.67% from decreased ROM. The findings are summarized in Table 2.

Statistical analysis was used to compare total complications, ruptures, and decreased range of motion between early active and passive rehabilitation protocols. Overall, passive range of motion protocols had an increased risk for complications compared to active protocols but this did not reach statistical significance (odds ratio 1.20, p value 0.12). Passive protocols had a lower risk of rupture (odds ratio 0.66, p value 0.02) but a significantly higher risk of decreased post-operative range of motion compared to early active motion protocols (odds ratio 1.71, p value <0.01). The findings are summarized in Table 3. When analyzing rupture data further, it was noticed that articles published over the last 5 years reported a lower rate of rupture in both active and passive protocol groups (Table 4). Additionally, if analyzed in 10-year intervals over the past 20 years, there continues to be a trend for decreased rupture risk with a 5.4% active rehabilitation rupture rate and 5.0% overall rupture rate from 1992-2001 compared to 4.0% active rehabilitation rupture rate and 3.4% overall rupture rate from 2002-2011. These findings are summarized in Table 4.

DISCUSSION:

Many of the papers in our review discuss how active motion protocols aim to increase early tendon excursion thus preventing adhesion formation and producing final outcomes of increased functional motion (5,10,31,32,36). This was reinforced by Trumble et al, who has produced the only 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. Additionally, numerous other lesser quality active motion studies have found a high percentage of good-excellent functional results and improved interphalangeal motion with low complications rates (1,5,6,9,10,11,17,18).In general, patients with improved joint motion subjectively state they have better hand function and thus also have higher patient satisfaction scores (5).

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 (p=0.02) and a higher risk of decreased digit range of motion in the passive protocols (p<0.01). Only one immobilization and two continuous passive motion articles met inclusion criteria making data too sparse to draw significant conclusions with regards to these protocols (Table 2).

A number of factors could contribute to the disparity in active motion ruptures reported throughout the literature (Table 1). 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. The authors explain the etiology of the ruptures, with 7 of the 12 ruptures due to noncompliance and activities such as fighting, arrest by police, or gripping a towel. The authors discuss that the digit freedom of motion, compared to a splint with elastic band traction, may lead to inadvertent over activity (28). In another study by Small showing higher rates of rupture (9.4%), noncompliance was not addressed (33).

Another factor that makes direct comparison difficult is variations and modifications in rehabilitation protocols. Our group divided the papers based on what rehabilitation activities were occurring during the critical initial three weeks post-operatively. While 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, the Trumble paper uses an active motion ‘place and hold’ method and resulted in a 3.3% rupture rate. In comparison, the Small paper applies an active motion protocol based on achieving a specific degree of flexion over a specific time and reported a 9.4% rupture rate. These two studies also differed in that Trumble used a 4-strand core suture repair technique compared to Small’s 2-strand. While these 2 protocols were categorized together, there was certainly variation in the post-operative strain applied to the tendon and inherent strength of the repair.

Our analysis also found a decrease in the number of tendon ruptures reported over the past 5 years in both passive and active protocols. This finding was compiled from data of 6 different patient cohorts of passive protocols and 2 cohorts of early active motion protocols (4,5,9,23,29). Both recent early active motion articles by Trumble and Yen used a four-strand core suture repair technique reporting a rupture rate of 3.3% and 0% respectively. This multi-strand technique was also utilized in several earlier articles with the majority reporting very low rupture rates with active motion (Table 1) (19,25,31). This is significant as some earlier active range of motion articles used a 2-strand core suture and reported much higher rupture rates (28,33). Overall, our systematic review results provide evidence that through improved strength of surgical repair, early active motion protocols can likely be tolerated and utilized to improve functional outcomes including digit range of motion.

Determination of the optimal rehabilitation method via 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 (8). Additionally, as noted in Table 1, multiple different classification systems have been used to report functional results and other reported outcomes measures are variable throughout the literature making comparison difficult.

In order to provide statistically significant comparative evidence for a superior rehabilitation method, a set of standards must be developed for reporting flexor tendon repair data. This set of standards should include repair technique, time of follow up, a single method of reporting objective and subjective functional outcomes, rating of patient compliance, patient satisfaction, and reported complications, like ruptures, adhesions, joint contracture, and extensor lag. As discussed by Trumble, the frequently used Disabilities of the Arm, Shoulder, and Hand (DASH) may not be an adequate test to determine functional hand and digit outcomes following flexor tendon repair as many of the questions focus on carrying large objects or gross motor function (5). Instead, a patient questionnaire focusing mainly on hand and finger dexterity with fine motor movements should be employed. This questionnaire should not just evaluate activities such as pinch or grip but should also assess fine motor function of the injured digit through questions evaluating such activities as typing or playing a musical instrument. Patient satisfaction should be reported in every study and will likely increase with improved digit motion (5). By standardizing the method for reporting data, it will assist researchers in determining the individual influence of the various factors contributing to improved functional outcomes of rehabilitation protocols.

References:

1. Edinburg M, Widgerow A, Buddulph S. Early postoperative mobilization of flexor tendon injuries using a modification of the Kleinert technique. *J Hand Surg Am* 1987; 12:34-38.

2. Chow J, Thomaes L, Dovelle S, Milnor W, Seyfer A, Smith A. A combined regimen of controlled motion following flexor tendon repair in ‘no man’s land’. *Plast Reconstr Surg* 1987 Mar; 79(3):447-455.

3. Chesney A, Chauhan A, Kattan A, Farrokhyar F, Thoma A. Systematic review of flexor tendon rehabilitation protocols in zone II of the hand. *Plastic and Reconstructive Surgery* 2011 127(4):1583-1592.

4. Thien T, Becker J, Theis S. Withdrawn: Rehabilitation after surgery for flexor tendon injuries in the hand. Cochrane Database Syst Review Oct, 2010.

5. Trumble T, Vedder N, Seiler J, Hanel D, Diao E, Pettrone S. 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;92:1381-1389.

6. Baktir A, Turk C, Kabak S, Sahin V, Kardas Y. Flexor tendon repair in zone 2 followed by early active mobilization. *J Hand Surg Br* 1996;21:624-628.

7. Adolfsson L, Soderberg G, Larsson M, Karlander L. The effects of a shortened postoperative mobilization program after flexor tendon repair in zone 2. *J Hand Surg Br* 1996;21:67-71.

8. Gelberman R, Nunley J, Osterman A, Breen T, Dimick M, Woo S. Influences of the protected passive mobilization interval on flexor tendon healing. A prospective randomized clinical study. *Clin Orthop Relat Res* 1991;264:189-196.

9. Bal S, Oz B, Gurgan A, Memis A, Damirdover C, Sahin B, Oztan Y. Anatomic and functional improvements achieved by rehabilitation in zone II and zone V flexor or tendon injuries. *Am J Phys Med Rehabilitation* 2011;90:17-24.

10. Bainbridge L, Robertson C, Gillies D, Elliot D. 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 Aug; 19(4):517-521.

11. Braga-Silva J, Kuyven C. Early active mobilization after flexor tendon repairs in zone two. *Chir Main* 2005;24:165-168.

12. Bunker T, Potter B, Barton N. Continuous passive motion following flexor tendon repair. *J Hand Surg Br* 1989;14:406-411.

13. Cetin, A, Dincer F, Kecik A, Cetin M. Rehabilitation of flexor tendon injuries by use of a combined regimen of modified Kleinert and modified Duran Techniques. *Am J Phys Med Rehabil* 2001 Oct;80(10):721-728.

14. Chai S, Wong C. Dynamic traction and passive mobilization for the rehabilitation of zone II flexor tendon injuries: modified regime. *Med J Malaysia* 2005;60:59-65.

15. Chan T, Ho C, Lee W. Functional outcome of the hand following flexor tendon repair at the ‘no man’s land’. *J Ortho Surg* 2006;14:178-183.

16. Chow J, Thomas L, Dovelle, S, Monsivais J, Milnor W, Jackson J. Controlled motion rehabilitation after flexor tendon repair and grafting. *J Bone Joint Surg Br* 1988;70:591-595.

17. Cullen K, Tolhurst P, Lang D, Page R. Flexor tendon repair in zone 2 followed by controlled active mobilization. *J Hand Surg Br* 1989 Nov;14(4):392-395.

18. Elliot D, Moiemen N, Flemming A, Harris S, Foster A. The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen. *J Hand Surg Br* 1994;19:607-612.

19. Gerard F, Garbuio P, Obert L. Immediate active mobilization after flexor tendon repairs in Verdan’s zones I and II. A prospective study of 20 cases. *Chir Main* 1998;17:127-132.

20. Gerbino, P, Saldana M, Westerbeck P, Schacherer T. Complications experienced in the rehabilitation of zone I flexor tendon injuries with dynamic traction splinting. *J Hand Surg Am* 1991;16:680-686.

21. Hatanaka H, Kojima T, Mizoguchi T, Ueshin Y. Aggressive active mobilization following zone II flexor tendon repair using a two-stranded heavy-gauge locking loop technique. *J Orthop Sci* 2002;7:457-461.

22. Hung L, Pang K. Active mobilization after flexor tendon repair: comparison of results following injuries in zone 2 and other zones. *J Ortho Surg* 2005;13;158-163.

23. Kitis A, Buker N, Kara IG. Comparison of two methods of controlled mobilization of repair flexor tendons in zone 2. *Scand J Plast Reconstr Surg Hand Surg* 2009;43:160-165.

24. Kitsis C, Wade P, Krikler S, Parsons N, Nicholls L. Controlled active motion following primary flexor tendon repair: a prospective study over 9 years. *J Hand Surg Br* 1998;23:344-349.

25. Klein L. Early active motion flexor tendon protocol using one splint. *J Hand Ther* 2003;16:199-206.

26. May, E, Silfverskiold K, Sollerman C. Controlled mobilization after flexor tendon repair in zone II: a prospective comparison of three methods. *J Hand Surg Am* 1992;17:942-952.

27. May E, Silfverskiold K, Sollerman C. The correlation between controlled range of motion with dynamic traction and results after flexor tendon repair in zone II. *J Hand Surg Am* 1992 Nov;17(6):1133-1139.

28. Peck F, Bucher C, Watson J, Roe A. A comparative study of two methods of controlled mobilization of flexor tendon repairs in zone 2. *J Hand Surg Br* 1998;23:41-45.

29. Saini, N, Kundnani V, Patni P, Gupta S. Outcome of early active mobilization after flexor tendons repair in zones II-V in hand. *Indian J Orthop* 2010;44:314-321.

30. Saldana M, Chow J, Gerbino P, Westerbeck P, Schacherer T. Further experience in rehabilitation of zone II flexor tendon repair with dynamic traction splinting. *Plast Reconst Surg* 1991;87:543-546.

31. Savage R, Risitano G. Flexor tendon repair using a “six strand” method of repair and early active mobilization. *J Hand Surg Br* 1989;14:396-399.

32. 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;19:53-60.

33. Small J, Brennen M, Colville J. Early active mobilization following flexor tendon repair in zone 2. *J Hand Surg Br* 1989;14:383-391.

34. Strickland J, Glogovac S. Digital function following flexor tendon repair in zone II: a comparison of immobilization and controlled passive motion techniques. *J Hand Surg Am* 1980 Nov;5(6):537-543.

35. Su B, Solomon M, Barrow A, Senoge M, Gilberti M, Lubbers L, Diao E, Quitkin H, Rosenwasser M. Device for zone-II flexor tendon repair. A multicenter, randomized, blinded clinical trial. *J Bone Joint Surg Am* 2005;87:923-935.

36. Yen C, Chan W, Wong J, Mak K. Clinical results of early active mobilization after flexor tendon repair. *Hand Surgery* 2008;13:45-50.

Figure Legends Page:

Figure 1: Method of Article Selection