**Postoperative Treatment after Extensor Tendon Repair:**

**A Systematic Review of the Literature**

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**Introduction:**

In contrast to flexor tendon injuries, considerably less emphasis has been devoted to extensor tendon healing and repair in the literature. (Blue, Elliott) There does not seem to be any consensus on the incidence of these injuries. Extensor tendon injuries are still frequently considered simple injuries, which are easy to treat; however, experience has shown that the outcome of extensor tendon injuries is not always good. (Bruner and Kelly) Additionally, younger or less experienced staff often treats these injuries. (Evans) As Doyle noted, the management of extensor tendon lacerations demands the same amount of skill and knowledge required for the care of flexor tendon injuries. (Doyle)

Traditionally, immobilizing the repaired tendons for 4 to 6 weeks has followed surgical treatment of extensor tendon injuries. (Zubovic and Lovett) These static protocols frequently result in significant loss of flexion as well as extension lags of the metacarpophalangeal and interphalangeal joints, caused by tendon adhesions and joint capsule contractures. (Blair and Evans) The extensor tendons are in close proximity to underlying bony structures and some authors have reported the formation of peritendinous adhesions to be more likely to occur after extensor tendon injury than with flexor tendon injury. (Mowlavi) More recently, authors have challenged the notion of static immobilization and reported on early motion, therapy programs, which have demonstrated encouraging results. As early as 1965, Stuart noted the benefits of early dynamic splinting and reported improved functional outcome in patients splinted for 10 days versus 3 weeks. (Stuart)

For some orthopaedic problems in which multiple papers investigate facets of a problem, systematic literature review can help to collate and to clarify treatments by pooling outcome data. Over the past several years, advances in the treatment of extensor tendon injuries have come mostly from changes in postoperative treatment protocols as opposed to modifications of surgical repair techniques.(Bruner) The purpose of this paper was to conduct a systematic review of the literature, in order to determine the optimal method for postoperative treatment of repaired extensor tendons.

**Methods:**

To canvas the literature, a reference librarian was consulted to facilitate database search strategies. Pubmed, and Cochrane database searches were done to identify all English-language clinical papers reporting results on the surgical treatment and rehabilitation of extensor tendon injuries. These searches were supplemented with a secondary search using references cited in the selected articles. Key words used in the search were “extensor tendon repair,” which returned 27 articles in Pubmed when limited to English-language, clinical papers. We used the following exclusion criteria: no results reported (5 articles), biomechanical study only (5 articles), no surgical technique included (2 articles), no detailed rehabilitation program (1 article), not pertaining to extensor tendon repair (1 article), and a review article (1 article). A similar search of the Cochrane Collaboration database returned 7 articles. Two of these articles were excluded for not pertaining to extensor tendon repair, while one article was only a biomechanical study. An additional two of the Cochrane articles were already cited in our pubmed search. After review of the bibliographies of the 14 remaining articles, five additional articles met our criteria for inclusion. A total of 19 articles were used in the final analysis. (References)

**Results:**

We identified three postoperative regimens as the most commonly used after extensor tendon repair: static splinting, dynamic extension splinting, and early active motion. While the majority of the literature involves case series, several larger randomized controlled trials were found, which compared static and dynamic splinting with early active motion programs.

The level of evidence varied between the 19 articles used in this review. Two papers represented high-quality randomized, controlled trials (level I evidence). One article was a lesser-quality randomized, controlled trial, while two papers were prospective, comparative studies (level II). One paper was a retrospective, comparative study (level III). The other 13 articles could be classified as case series or retrospective chart reviews (level IV). Table 1 summarizes the 19 articles reviewed.

Within the 19 papers reviewed, 8 had studied static splinting in their postoperative protocols. Of the 8 papers comparing static splinting, Bulstrode et al had the highest level of evidence, at a level of two. Bulstrode et al prospectively compared 42 patients with simple lacerations involving zones V or VI. They did not report on the amount of time from injury to surgical repair, but did report on their repair method, which in all cases was with 3-0 or 4-0 nylon mattress sutures or a modified Kessler suture – in addition to a 6-0 nylon epitendinous suture. 17 of their patients were completely immobilized in static splints for 4 weeks, allowing no motion. 10 patients were immobilized with the wrist in 30 degrees of extension and the metacarpophalangeal (MCP) joints in extension while leaving the interphalangeal (IP) joints free, and 15 patients were immobilized with the wrist in 45 degrees of extension, the MCP joints in 50 degrees of flexion and the IP joints in neutral while allowing the patient to actively extend the MCP joints. The authors showed that at 4 weeks, total active motion was significantly reduced in the static group (79 degrees versus 165 and 160 degrees, p<0.01), but at 12 weeks there were no differences in motion or outcomes between all 3 groups. At 12 weeks, all groups had achieved a good or excellent outcome according to Kleinert and Verdan’s TAM classification. (Kleinert and Verdan) The only other significant finding between the groups was that at 12 weeks, grip strength between the operative hand and the contra-lateral hand was less in the static group (23kg versus 45kg, p<0.01), but not within the other 2 groups. There was also no statistical difference between time spent with physiotherapists and occupational therapists between the three groups. They reported no complications in their paper. (Bulstrode et al)

Of the 19 papers reviewed, 12 studied dynamic splinting. Chester et al conducted a prospective, randomized, controlled trial (level II) comparing early active motion to dynamic splinting. Tendon injuries were all simple lacerations in zones IV through VIII. The time from injury to repair was not reported, but all the injuries were repaired with either a 3-0 or 4-0 nylon or a 3-0 or 4-0 prolene horizontal mattress suture or modified Kessler technique. Some then received a 6-0 epitendinous suture. 19 patients were given an early active motion, postoperative protocol. 17 patients were placed into a dynamic splinting regimen. All patients were initially (postoperative day #0) placed into a splint with the wrist in 30 degrees of extension, MCP joints at 30 degrees of flexion, and the IP joints in full extension. In the early active motion group, patients were instructed to perform active extension within the splint on postoperative day #1, while the dynamic splinting group did not perform any motion in the splint until postoperative day #5 at which point a dynamic outrigger splint was applied. Hand therapy progression was then implemented over the next 12 weeks, at which point all restrictions were lifted and the patients were allowed to return to work. Splints were completely disregarded at 6 weeks in both groups. Both groups had good or excellent outcomes at final follow-up and neither group had any tendon ruptures. The only statistically, significant findings between the groups were the increased percentage of total active motion in the dynamically splinted group (87% versus 77%, p<0.02) and the smaller amount of flexion deficit (25 degrees versus 45 degrees, p<0.002), which were reported at the 4-week follow-up?????? Both of these findings were in favor of the dynamic splinting group. By the 12-week follow-up there were no statistically significant differences between the two groups; the early active motion groups had a Kleinert and Verdan (reference) median TAM score of 100% and the dynamic group had a median score of 98%.(Chester)

Of the 19 studies reviewed, two randomized, controlled trials reached level I evidence. (Mowlavi and Khandwala) Mowlavi et al evaluated 34 patients with simple, complete tendon lacerations in zones V or VI. The time from injury to repair was not reported, but all patients underwent repair with figure of eight and mattress sutures with 4-0 Tycron suture (Ethicon, Somerville, NJ). 17 patients were enrolled in a dynamic splinting group and 17 patients were enrolled in a static splinting group. Both groups were immobilized for 3-5 days, postoperatively. The dynamic group was then placed into a splint, which allowed 30 degrees of active MCP flexion with passive, rubber band extension. Full, active IP joint motion was allowed. At 2 weeks, 45 degrees of MCP flexion was allowed, at 4 weeks active range of motion was started and splinting was done only at night, and then at 6 weeks the splint was discontinued (unless 15 degrees of extension lag was present). In the static group, the wrist was immobilized in 30 degrees of extension; the MCP joints in 15-20 degrees of flexion and the IP joints were in full extension. At 4 weeks, the patients began an active motion program and splinting was done at night. At 6 weeks, the splints were discontinued just as the other group. The authors found that total active range of motion was significantly increased in the dynamic group at 4 weeks (180 versus 131, p<0.006) and at 6 weeks (239 versus 205, p<0.048), but at 6 months there was no difference (253 versus 250, p<0.562). They also found that the percentage of normal grip strength was greater in the dynamic group at 8 weeks (81 versus 59, p<0.004), but not at 6 months (89 versus 82, p<0.595). Tenolysis was done in one patient in the dynamic group and two patients in the static group.

Table 1: Summary of the 19 studies reviewed: along with their level of evidence, zones of repairs included in study, rehabilitation methods compared, immobilization/splinting time, follow-up period, suture method utilized, functional outcomes if reported, and any complications reported.

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **Study** | **Level of Evidence; # of patients** | **Extensor Zones** | **Rehabilitation Method(s)** | **Total Time Splinted; Follow-Up** | **Suture Repair Method** | **Functional Results** | **Complications** |
| **Zubovic et al** | Level IV (case series); 18 | III-VI | Static splinting then active motion | 3 weeks;  3 months | Augmented (MGH)  Becker 4-strand | Not Reported | None reported |
| **Carl et al** | Level IV (case series); 177 | I-VI | Static splinting then active motion | 6 weeks;  13 months | Double Loop | Not Reported | None reported |
| **Mowlavi et al** | Level I (RCT);  34 | V-VI | Static splinting versus Dynamic Splinting | 6 weeks;  6 months | Figure of 8 + Mattress | Not Reported | Tenolysis (2 in static, 1 in dynamic) |
| **Chow et al** | Level II (Prospective); 86 | IV-VII | Static splinting then active motion versus Dynamic splinting | 3 weeks and 5 weeks;  12-36 months | Modified Kessler or Horizontal Mattress | 71% good – excellent with static then active (Dargan)  100% good – excellent with dynamic (Dargan) | Tenolysis (6 in static),  None reported in Dynamic |
| **Purcell et al** | Level IV (Case series); 33 | I-VIII | Static splinting | 4-8 weeks;  4 months | Standard Kessler or Horizontal Mattress | 95% good – excellent with static (Strickland-Glogovac) | Tenolysis (1), RSD (1), Infection (1) |
| **Russell et al** | Level III (Retrospective); 65 | V-VIII | Static splinting versus Dynamic splinting | 8 weeks and 6 weeks;  3 months | Modified Kessler or Standard Mattress | Not reported | Infection (1 in static), RSD (1 in static) |
| **Newport et al** | Level IV (Case series); 62 | I-VIII | Static Splinting | 3.5 weeks;  60 months | Not Reported | 52% good – excellent with static (Miller) | Repair Failures (4), Tenolysis (1), Infection (2) |
| **Bulstrode et al** | Level II (Prospective); 32 | V-VI | Static splinting versus Active motion | 4 weeks;  3 months | Modified Kessler or Mattress | 100% with static and active motion (Kleinert and Verdan) | None reported |
| **Bruner et al** | Level IV (Case series); 58 | V-VII | Dynamic splinting | 5 weeks;  21 months | Modified Kessler or Horizontal Mattress | 82% good – excellent with dynamic (Geldmacher) | None reported |
| **Crosby et al** | Level IV (Case series); 30 | III-VII | Dynamic Splinting | 4 weeks;  7 months | Modified Kessler or Figure of 8 or Mattress | Not reported | Extensor lag (5) |
| **Ip et al** | Level IV (Case series); 84 | IV-VIII | Dynamic Splinting | 5 weeks;  6 months | Horizontal Mattress | 92% good – excellent with dynamic (Dargan) | Stitch Granuloma (1) |
| **Kerr et al** | Level IV (Case series); 21 | VI-VII | Dynamic Splinting | 6 weeks;  14 months | Not Recorded | Not reported | Extensor lag (1) |
| **Chester et al** | Level II (RCT); 36 | IV-VIII | Dynamic Splinting versus Active Motion | 5 weeks;  3 months | Modified Kessler or Horizontal Mattress | 100% with dynamic (Kleinert and Verdan)  100% with active (Kleinert and Verdan) | Infection (1 in dynamic and 1 in active motion) |
| **Khandwala et al** | Level I (RCT); 100 | V-VI | Dynamic Splinting versus Active Motion | 6 weeks and 4 weeks;  2-4 months | Kirchmayr/Kessler or Horizontal Mattress | 95% with Dynamic (Miller)  93% with active (Miller) | Rupture (1 in dynamic and 2 in active motion), RSD (1 in dynamic) |
| **Browne et al** | Level IV (Case series); 52 | IV-VII | Dynamic Splinting | 5.5 weeks;  2.5 months | Not Reported | 100% Full Fist Flexion | Extensor lag (5) |
| **Hung et al** | Level IV (Case series); 38 | II-VII | Dynamic Splinting | 5.5 weeks;  7 months | Not Reported | Not reported | Extensor lag (3), Button-hole (1) |
| **O’Dwyer et al** | Level IV (Case series); 99 | III-IV | Dynamic Splinting | 8 weeks;  15 months | Not Reported | 88% good – excellent with dynamic (Souter) | Extensor lag (5), Infection (1) |
| **Slater et al** | Level IV (Case series); 22 | V-VIII | Active motion | 6 weeks;  5 months | Multiple | 86% good – excellent with active (Miller) | Infection (1) |
| **Sylaidis et al** | Level IV (Case series); 23 | IV-VII | Active motion | 4 weeks;  2 months | Modified Kessler or Horizontal Mattress | 92 with active (Dargan) | None reported |

Khandwala et al compared dynamic splinting versus early active motion. They enrolled 100 patients in a prospective, randomized, controlled trial. All the patients had simple, complete injuries to their extensor tendons in zones V or VI, which were repaired within 72 hours from the time of injury and placed into static splints for 3-4 days. Both groups underwent repair with a 3-0 or 4-0 polypropylene Kirchmayr/Kessler or horizontal mattress suture, as well as a 5-0 or 6-0 nylon epitendinous running suture. The dynamic group was then splinted to allow active IP joint motion, active MCP joint flexion and passive MCP joint extension, but no synchronous joint motion was allowed for these first 2 weeks. In the second 2 post-operative weeks, the patients were allowed the same motions, but added synchronous joint movements. At 4 weeks, splints were discontinued except for nighttime and at 6 weeks they were discontinued all together. The active group was mobilized in a splint, which held the wrist in 30 degrees of extension, the MCP joints in 45 degrees of flexion and the IP joints free. For the first two weeks, the patient was allowed to actively flex and extend all joints within the limits of the splint and without allowing hyperextension of the MCP joints. At week three, the splint was changed to one which held the MCP joints in 70 degrees of flexion, at this point, MCP joint hyperextension with concurrent IP joint extension was allowed. The splint was discontinued after 4 weeks. The authors found that when comparing Miller’s (Miller) assessment of extensor tendon repairs there were no significant differences between their two groups at follow-up intervals from 8 to 16 weeks: 95% of the patients in the dynamic group and 93% in the active group reported excellent or good outcomes. They also found that total active range of motion did not differ between the two groups: 98% of the dynamic and 95% of the active group reported excellent or good outcomes. Overall, there were three ruptures – one in the dynamic group and two in the active motion group. (Khandwala et al)

Overall, we found a high degree of variability among the articles with respect to which outcomes measures were reported and the manner in which they were reported. The overall complication rate for patients in the static splinting group was 4.1%, including 1.8% of patients requiring a tenolysis and 0.9% rupture rate. The overall complication rate for the dynamic extension-splinting group was 4.3%, including 3.2% of patients experiencing some degree of extensor lag and 0.2% having rupture. The overall complication rate for the early active motion group was 1.7%, including ruptures of 0.8% of tendons. Table 2 summarizes our findings.

Table 2: Summary table demonstrating the total amount of tendons repaired and their complications, derived from all 19 studies identified.

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| --- | --- | --- |
| **Static Splinting** | **Dynamic Splinting** | **Early Motion** |
| **437 total tendons** | 600 total tendons | 240 total tendons |
| **18 total complications; 4.1%** | 26 total complications; 4.3% | 4 total complications; 1.7% |
| **8 requiring tenolysis; 1.8%** | 19 extensor lags; 3.2% | 2 tendon ruptures; 0.8% |
| **4 tendon ruptures; 0.9%** | 1 tendon rupture; 0.2% |  |

**Discussion:**

The postoperative protocol involving extensor tendon repair is one of great variability with multiple publications describing different rehabilitation methods. In addition, the postoperative rehabilitation period is vital to a successful final outcome after extensor tendon repair. Our systematic literature analysis allows the compilation of data reported in 19 articles to help determine the optimal method for postoperative rehabilitation of repaired extensor tendons.

When comparing static splinting, dynamic splinting and early active motion - it was most notable in our analysis that fewer complications presented with those protocols, which involved early active motion. (slater, khandwala, chester) The use of static splinting was not only associated with an increased need for tenolysis,(chow, Purcell, newport) but also included a rate of tendon rupture greater than both dynamic splinting and early active motion programs. (newport) In addition, several comparative studies revealed decreased range of motion and grip strength with static splinting in the early postoperative period although these differences tended to resolve with time. (mowlavi, bulstrode) Chester et al reported increased total active motion (TAM) and less flexion deficit with dynamic splinting versus early active motion in the postoperative period, which resolved by 12 weeks.(Chester) However, our compilation of data ultimately shows a lower total complication rate, 1.7% vs 4.3%, with early active motion compared to dynamic splinting. Most complications reported with dynamic splinting involved extensor lag, (Crosby, kerr, browne, hung, odwyer) which was not seen with any of the early active motion tendon repairs. (slater, khandwala, chester)

The great variability of the articles reviewed makes direct comparison difficult. Differing levels of evidence, zone of extensor tendon injury, repair technique, therapist intervention as well as specifics of rehabilitation protocols hinder this comparison. The variability in reported functional results and methods of collection are other factors that limit our outcome analysis. The issue of patient motivation and compliance, essential to effective rehabilitation, is another variable that undoubtedly affects final outcome and is difficult to compare across our compilation of articles. However, given this importance, it is appropriate to consider effects of dynamic splinting on patient compliance. Cumbersome dynamic splints, and complicated rehabilitation protocols requiring assistance from expert hand therapist, undoubtedly require greater patient motivation and compliance than simpler functional static splinting. Additionally, in an era focused on cost effective medicine, a postoperative regimen involving dynamic splinting may not prove cost effective given the good results with early motion and simple splints seen in our analysis.

Given the abundance of research and publications within the field of hand surgery, it is important to systematically review the literature in order to establish optimal treatment guidelines. This technique allows us to compile years of data across differing cohorts and thus increase the power of our treatment recommendations. However, while our literature analysis provides good data to support fewer complications with early motion protocols following extensor tendon repair, it is hindered by a lack of standard reporting of outcome measures and methods of collection. Efforts to better standardize reporting of functional results, and return to prior levels of activity or work, will aid in future literature reviews attempting to establish optimal treatment guidelines in various areas of hand surgery.

**Conclusion:**

Functional results, when reported, were generally favorable for all three regimens. However, our review indicates that early active motion protocols following extensor tendon repair provide good results with a relatively lower complication rate than other postoperative regimens.