Review Article

Hand Therapy
2018, Vol. 23(1) 3–18

DOI: 10.1177/1758998317729713
journals.sagepub.com/home/hth
SAGE

Optimal early active mobilisation protocol after extensor tendon repairs in zones V and VI: A systematic review of literature

Shirley JF Collocott[1], Edel Kelly[2] and Richard F Ellis[3]

Abstract

Introduction: Early mobilisation protocols after repair of extensor tendons in zone V and VI provide better outcomes than immobilisation protocols. This systematic review investigated different early active mobilisation protocols used after extensor tendon repair in zone V and VI. The purpose was to determine whether any one early active mobilisation protocol provides superior results.

Methods: An extensive literature search was conducted to identify articles investigating the outcomes of early active mobilisation protocols after extensor tendon repair in zone V and VI. Databases searched were AMED, Embase, Medline, Cochrane and CINAHL. Studies were included if they involved participants with extensor tendon repairs in zone V and VI in digits 2–5 and described a post-operative rehabilitation protocol which allowed early active metacarpophalangeal joint extension. Study designs included were randomised controlled trials, observational studies, cohort studies and case series. The Structured Effectiveness Quality Evaluation Scale was used to evaluate the methodological quality of the included studies.

Results: Twelve articles met the inclusion criteria. Two types of early active mobilisation protocols were identified: controlled active motion protocols and relative motion extension splinting protocols. Articles describing relative motion extension splinting protocols were more recent but of lower methodological quality than those describing controlled active motion protocols. Participants treated with controlled active motion and relative motion extension splinting protocols had similar range of motion outcomes, but those in relative motion extension splinting groups returned to work earlier.

Discussion: The evidence reviewed suggested that relative motion extension splinting protocols may allow an earlier return to function than controlled active motion protocols without a greater risk of complication.

Keywords

Extensor tendon, rehabilitation, early active motion, relative motion extension splinting, systematic review

Date received: 19 March 2017; accepted: 10 August 2017

Introduction

Recent systematic reviews have found strong evidence that early mobilisation after hand/wrist extensor tendon repair provided better range of motion (ROM) outcomes compared to immobilisation protocols.[1–4] Early mobilisation needs to be in a controlled manner to optimise the benefits of mobilisation while avoiding the risks related to unrestricted motion.[5–7]

The requirement to balance motion with protection has led to the development of early controlled mobilisation protocols where, during the early post-operative period, motion of the injured digit is allowed while

[1]Department of Hand Therapy, Manukau SuperClinic, Counties Manukau Health, Auckland, New Zealand
[2]School of Clinical Sciences, Faculty of Health and Environmental Sciences, Auckland University of Technology, Auckland, New Zealand
[3]Health and Rehabilitation Research Institute, School of Clinical Sciences, Faculty of Health and Environmental Sciences, Auckland University of Technology, Auckland, New Zealand

Corresponding author:
Shirley JF Collocott, Hand Therapy Department, Module 5, Manukau SuperClinic, PO Box 98743, Manukau City, Manukau 2241, New Zealand.
Email: collocotts@gmail.com

being controlled by a splint.[3,7–11] Early mobilisation protocols for extensor tendon repairs in zones V and VI include those allowing early passive mobilisation (EPM) and those allowing early active mobilisation (EAM) of the repaired tendon.[3,4,12]

Three systematic reviews on extensor tendon repair[2–4] concluded that there was insufficient evidence to determine whether EAM or EPM protocols provided superior outcomes. However, recent systematic reviews on this subject have recommended EAM protocols over EPM protocols[1,4,12] because they provide similar outcomes and the low-profile static splints (usually employed in EAM protocols) are said to be cheaper, quicker to make, and easier for the patient and therapist to manage.[1,4,12–15] Furthermore, EAM protocols may have lower complication rates.[12]

Various EAM protocols have been described for the management of extensor tendon repairs in zone V and VI with differences in splint design and exercise programmes. However, no published trials have investigated the relative benefits of different types of EAM protocols for extensor tendon repairs in zone V and VI, to determine whether any one provides superior outcomes to any other. Although previous systematic reviews have reviewed EPM and EAM protocols,[1–4,12] they have not attempted to specifically examine EAM protocols to identify an optimal approach. Therefore, the objective of this systematic review was to investigate the different types of EAM protocols used after extensor tendon repairs in zone V and VI and to determine whether any EAM protocol provided superior outcomes. This review was structured according to the PRISMA guidelines.[16]

Methods

Search strategy

A search strategy was constructed using keywords and search terms related to EAM protocols for extensor tendon repair. These keywords and search terms were expanded through the use of truncation. The search terms used were: 'extensor tendon injur$' OR 'extensor tendon repair$' OR 'extensor tenorrhaphy' AND 'early motion' OR 'relative motion' OR 'active motion' OR 'splint$' OR 'orthos$' OR 'rehabilitation.'

Utilising the search strategy, a comprehensive search was conducted using the following databases: AMED (Allied and Complementary Medicine) via Ovid, Embase via Ovid, Medline (R) In- Process & Other Non-Indexed Citations, Medline (R) Daily and Medline (R) via Ovid, Cochrane via Wiley, Cochrane via Ovid and CINAHL. Date limitations were set depending on the relative limitation of the database up to search completion on 5 June 2017.

Once articles had been identified, the reference lists were screened by the primary author (SC) to identify additional articles which might meet the inclusion criteria. Those articles that were highlighted following the search were further screened by the primary author (SC) from their title, abstract and/or text using criteria presented in Table 1.

Data extraction

A data extraction form was used with the following data extracted from each study by the primary author (SC): author and date of publication or presentation; type of study; inclusion criteria; zones of injury; intervention groups; sample size; baseline characteristics of participants; results including timing of mobilisation, joint range of motion (ROM), grip strength, time to return to work (RTW), complications, subjective outcomes and amount of hand therapy input.

Assessment of methodological quality

MacDermid's Evaluation Guidelines for Rating the Quality of an Intervention Study[17] was used to assess

Table 1. Inclusion and exclusion criteria for articles for review.

Inclusion criteria
- Studies involving participants with repairs to extensor tendon lacerations of extensor digitorum communis (EDC), extensor indicis (EI) or extensor digiti minimi (EDM) injuries zone V and VI in digits 2–5
- Post-operative rehabilitation regimes allowing active extension of the affected MCP joints within the first week post-operatively, while controlling motion by means of a splint
- Randomised controlled trials (RCT), prospective and retrospective observational studies, cohort studies or case series
- Full text articles

Exclusion criteria
- Studies including thumb extensor tendon repairs only
- Extensor tendon transfers
- Studies describing protocols involving only passive mobilisation or immobilisation of the MCP joints of digits with repaired tendons, or only early active motion of IP joints from the first week post-operatively
- Studies including only extensor tendon repairs in zones other than V or VI
- Description of rehabilitation protocol or splint without description of outcomes of patients treated with this protocol or splint
- Studies involving the lower limb extensor tendons, lateral epicondylitis, tendinopathies or fractures
- Closed injuries to extensor tendons
- Review articles
- Non-English articles
- Case studies

the quality of the included studies. This tool, also known as the SEQES (Structured Effectiveness Quality Evaluation Scale) has been used widely in the assessment of hand therapy and musculoskeletal literature[18–22] and has been shown to have high inter-rater reliability with regard to scoring of studies.[20] The SEQES was designed to evaluate a variety of intervention study designs including randomised controlled trials (RCTs), cohort and retrospective studies[17] and it provides a numerical score that allows comparison of research quality across included studies.

The SEQES tool consists of 24 items divided into seven sections: *Study question* (item 1), *Study design* (items 2–8), *Subjects* (items 9–12), *Intervention* (items 13–15), *Outcomes* (items 16–18), *Analysis* (items 19–23) and *Recommendations* (item 24). Items were scored 2 if completely fulfilled, 1 if partially fulfilled and 0 if not fulfilled or not addressed at all. The maximum score obtainable was 48, and the minimum was 0.[17]

The SEQES was not provided with a classification from the scoring to attribute to methodological quality.[17] From several studies that have used the SEQES, it is apparent that the classification for quantitative interpretation of scores has varied. For example, previous studies reporting the SEQES tool have classified articles as being of 'low' quality if they scored 1–16[21] or 1–20,[22] 'moderate' if scores were between 17 and 32[21] or 21 and 34[22] and 'high' if they were between 33 and 48[21] or 35 and 48.[22] In light of these discrepancies, a decision was made for this systematic review that studies scoring 0–20 were regarded as being of 'low', 21–32 as 'moderate' and 33–48 as 'high' methodological quality. Scoring was carried out independently by two authors (SC and EK). Recommendations for multiple reviewers provided in the original description of the tool were applied.[17] Differences in scoring were discussed; consensus was obtained to within one point of difference in all cases. In the small number of cases where one point of difference remained, the lower score was assigned.

Levels of evidence

The level of evidence of the current systematic review was considered following the evaluation of the included studies. The level of evidence was derived from The Oxford Centre for Evidence-based Medicine 2009 Levels of Evidence 1.[23]

Results

A total of 166 articles were identified through the database search; an additional five articles were identified through review of reference lists of included articles. After inclusion and exclusion criteria had been applied, 12 full text articles were selected for the review (Figure 1). A meta-analysis of the results was not possible due to heterogeneity for EAM protocol design and outcomes used.

Characteristics of included studies

The characteristics of the included studies are detailed in Table 2. The key findings of the included studies are detailed in Table 3. All protocols required the wearing of a splint post-operatively to limit flexion of the digit(s) with repaired tendons. The splint was usually worn full time for four to six weeks. During the first four to six weeks, all protocols except that described by Hirth et al.[24] described an exercise regime to promote tendon glide. Hirth et al.[24] provided no specific home exercises but encouraged patients to use their hands for functional tasks. Interventions to address limited ROM and strengthening were gradually introduced after the full time splinting was discontinued.[13,15,24–28]

Although all protocols used in the studies were classified as EAM, on closer review these could be divided into two groups: 'controlled active motion' (CAM) protocols[13–15,26,27,29–31] and 'relative motion extension splinting' (RMES) protocols.[24,25,28,32] None of the included studies directly compared the outcomes of participants treated with CAM and RMES protocols.

The most important difference between the different EAM protocols was the more restrictive splint design used in the CAM protocols. The CAM protocols made use of a forearm-based splint which included the wrist and all the injured MCP joints, preventing full MCP joint flexion.[13–15,26,27,29–31] In contrast, the RMES protocols used a small 'yoke' splint which included only the MCP joints of the injured digit(s), in relatively more extension than the other digits; the uninjured digits were left free, allowing functional use.[24,25,28,32] This difference between the two types of protocols was even greater in some instances where RMES protocols left the wrist free[24,28] and some CAM protocols additionally included the interphalangeal (IP) joints.[13,27,29–31]

Furthermore, participants treated with CAM protocols were advised to commence light activities at four or six weeks after daytime splinting was discontinued,[13–15,31] with return to work (RTW) at 6–10 weeks[13,14] and full heavy duties from 12 weeks.[13,15] In contrast, participants treated with RMES protocols were encouraged to commence light functional activities immediately from the time of splint application, and were advised to return to heavier tasks earlier. RMES participants were advised to RTW on light duties within the first three weeks[28] and return to heavy tasks whilst wearing the splint by three weeks.[32]

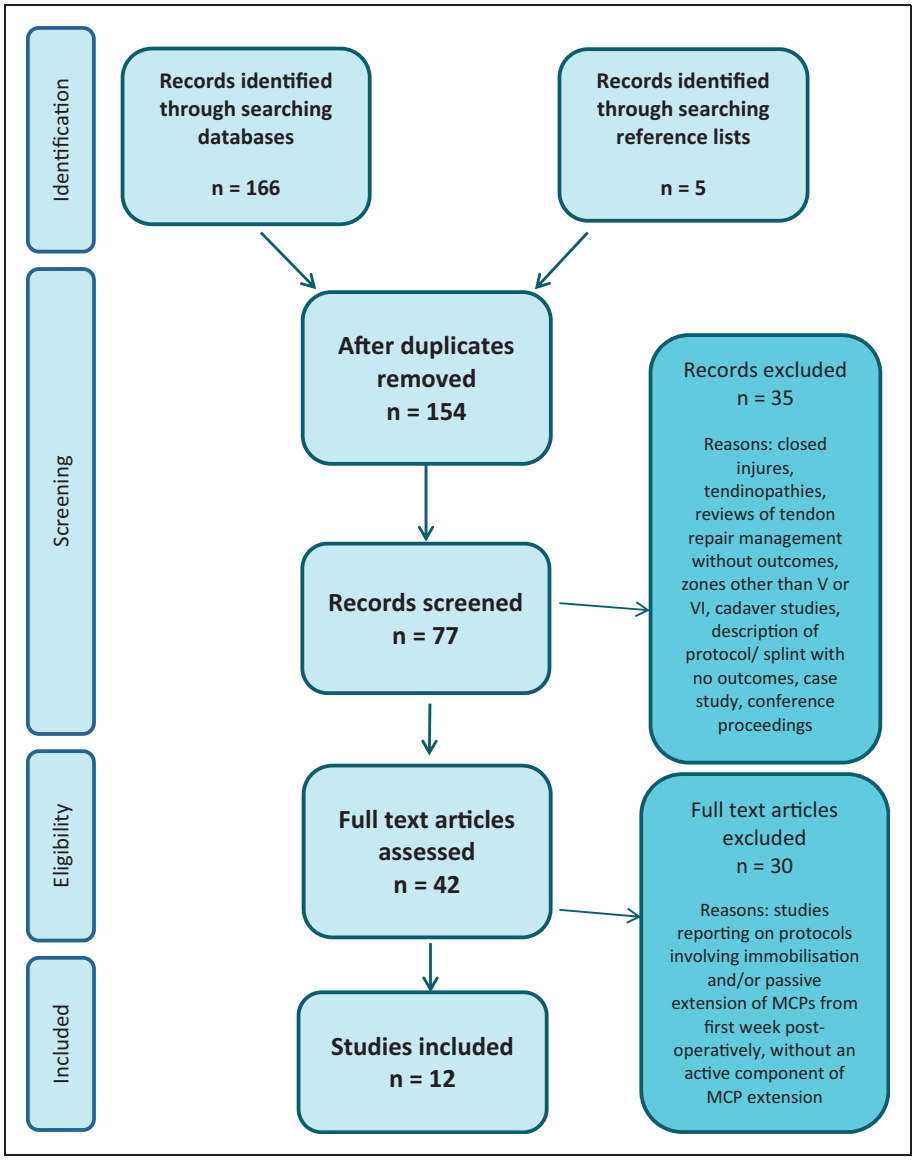

Figure 1. PRISMA flow diagram.

Generally those studies reporting RMES protocols were more contemporary with none published before 2005, in contrast to the CAM studies where half of the studies were published prior to 2005.[13,15,29,30]

Outcome measures reported

Joint ROM was the most frequently reported outcome measure. ROM was reported in various ways including degrees of total active motion (TAM)[14,26,28,29,31] or categorised using a variety of different scales.[13,15,24–28,30,32] High degrees of TAM and high percentages of good and excellent ROM outcomes were reported in all studies in participants treated with both CAM and RMES protocols (Table 4).

Grip strength was the second-equal most frequently reported outcome measure. Mean grip strength at final follow-up was similar for participants treated with a CAM protocol compared to those treated with an RMES protocol. For example, mean grip strength (dynamometer) was 38.9 kg for one CAM group[14] and 36–39 kg for RMES groups.[28]

The time taken for participants to RTW was the second-equal most frequently measured outcome. Participants treated with CAM protocols had a RTW between 6.5 and 10 weeks[30,31] while those treated with RMES protocols had a RTW between 2.6 and 6.7 weeks.[24,28,32]

Subjective outcomes were infrequently reported. In a study reporting on outcomes of RMES protocols,

Table 2. Study characteristics.

Authors	Type of study	Inclusion	Interventions	n = Participants(fingers)	Characteristics
Randomised controlled trials					
Bulstrode et al.[26]	Prospective randomised trial: Immobilisation vs. EAM (CAM) vs. MCP immobilisation with free IPs	Zone V or VI Complete divisions, simple	(a) Immobilisation: splint: wrist 30° extension, MCP and IP extension (b) CAM: splint: wrist 45° extension, MCP 50° flexion, IP neutral; exercises: actively extend MCP and IP joints, then actively extend MCP joints and flex and extend IP joints (c) Immobilisation with free IPs: splint: wrist 30° extension, MCP extension, IP free; exercises: IP flexion/extension (a), (b), (c): splint for 4 four weeks fulltime, then only at risk; scar massage when wound healed; from 4 weeks full active motion + passive extension; passive and resisted flexion from eight weeks	n = 42 (46 tendon divisions) (a) 17 (17 tendons) (b) 10 (13 tendons) (c) 15 (16 tendons) Loss to follow-up: (a) 10, (b) 3, (c) 2	Male: 90% RHD: 32 Age: 35
Chester et al.[13]	Prospective randomised controlled trial: EAM (CAM) vs. EPM	Zone IV to VIII Simple tendon divisions > 50%; no thumb injuries, no associated fracture or palmar injuries, no < 10 yr olds	(a) CAM: splint: wrist 30° ext, MCP 30° flexion, IP full extension; exercises: remove splint, MCP flexion/extension with IP extension, IP flexion/ extension with MCPs extended; (b) EPM: day splint: wrist 30° extension, MCP neutral, IP free; night splint: wrist ° extension, MCP neutral, IP free; night splint: wrist 30° extension, MCP neutral, IP extension; exercises: MCP active flexion/passive extension, IP flexion/ extension in splint (a) + (b) 2 weeks: wrist extension/flexion; 3 weeks fist formation, active extension exercises' scar management; 4 weeks: discontinue splint except night; 4–6 weeks passive flexion MCP, 6–8 weeks: strengthening	n = 54 (a) 30 (b) 24 Loss to follow-up: (a) 11 (b) 7	Male: (a) 75% (b) 89% Age: (a) 31; (b) 33 Dominant injured (a) 72% (b) 55%
Khandwala et al.[15]	Prospective randomised trial: EPM vs. EAM (CAM)	Zone V and VI, complete divisions; simple injuries only; exclude 1 tendon repaired IF/ LF	(a) EPM: splint : wrist neutral, rubber bands holding MCPs in neutral extension; IPs free; exercises: IP flexion/extension, MCP active flexion/ passive extension; splint until 4 weeks; passive flexion/ultrasound after 5 weeks (b) CAM: splint: wrist 30° extension, MCPs 45° flexion, IPs free; exercises: active flexion/extension IP and MCP in splint; MCP extension to neutral; from 2 weeks 70° MCP flexion allowed + hyperextension of MCP with IPs flexed; splint until 4 weeks; passive flexion/ultrasound after 5 weeks	n = 100 (a) 50(78) (b) 50(84) Zone V (a) 39 (b) 52 Zone VI (a) 39) (b) 32 Loss to follow-up: excluded: 6pts disappeared after hospital discharge; 19 pts did not attend follow-up; five pts ruptured before 1st hand therapy appt	Male (a) 96% (b)98% Age: (a) 30 (b) 28

(continued)

Table 2. Continued

Authors	Type of study	Inclusion	Interventions	n = Participants(fingers)	Characteristics
Patil and Koul[31]	Prospective randomised trial: EAM (CAM) vs. immobilisation	Zone V –VII; simple lacerations; exclude complex injuries and IF/ LF if only 1 tendon injured, incomplete injuries	(a) Immobilisation: static splint; wrist 30° extension, finger joints in extension; after 4 weeks IPs free and graded MCP flexion allowed; splint till 6 weeks; splint night until 8 weeks (b) CAM: Splint (only injured fingers); wrist 30° extension, MCPs + IPs in extension; removable wedge to allow 30° flexion/ extension of MCPs for exercise, gradually increased MCP flexion allowed; from 2 weeks IPs free; wedge removed from 4 weeks; splint until 6 weeks	n = 45 (119 tendons) (a)22 (58 tendons) (b)23 (61 tendons) Loss to follow-up: 0 until 12 weeks, 3 at 6 months	'Majority manual workers'
Pilot study					
Hall et al.[14]	Pilot randomised controlled study: Immobilisation vs. EPM vs. EAM (CAM)	Zone V + VI repairs; exclude if unable to comply or if only 1 tendon repaired in IF or LF; include joint capsule damage + infection of interosseous muscle and finger joints	(a) Immobilisation: splint 3/52, wrist 40–45° extension, MCP 0–20°, IP 0°, then graded mobilisation, discontinue splint 6 weeks; (b) EPM: splint: wrist 40–45° extension, MCP 0°, palmar block to allow MCP active flexion to 30–40°, passive extension; exercises: active MCP flexion, passive MCP extension with IP extended; therapist-supervised passive wrist tenodesis + IP motion; palmar block removed 3 weeks, splint discontinued 5 weeks (c) CAM: splint: wrist 30° extension, MCP 45° flexion, IP free; exercises: MCP flexion/extension with IPs extended; composite active flexion/extension in splint; after 3 weeks splint allows 70° MCP flexion, start active hook fists; splint discontinued 5 weeks	n = 27 Results given for n = 18 (24) (a) 4 (b) 5 (c) 9 Loss to follow-up: 9 of 27 prior to 12 weeks	Male (a) 4, (b) 4, (c) 9 Manual occupation (a) 3, (b) 3, (c) 4 Multiple digits (a) 1, (b) 3, (c) 2
Cohort studies: more than one group					
Evans[29]	Prospective cohort study: Immobilisation vs. EPM vs. EAM (CAM)	Zone V – VII and thumb IV and V; simple and complex	(a) Immobilisation: splint: wrist 40° extension, MCP 0°: 3–6 weeks (b) EPM: splint: wrist extension 40°, dynamic slings MCP + IP neutral; palmar block prevent > 30–40° MCP flexion; exercises: active MCP flexion, then passive extension; passive hyper-extension MCP and passive flexion PIP 70–80°; therapist-supervised wrist tenodesis; 3 weeks: volar block removed; 5–6 weeks discontinue splint; 'standard protocols' in weeks 3–6 (c) CAM: splint and exercises as for EPM; addition: therapist supervised exercises: wrist placed 20° flexion, and IP held in extension, active MCP flexion/ extension 0–30°	n = 147 (271) (a) 24 (46 tendons) (b) 100 (184 tendons) (c) 23 (41 tendons) Zone V/VI (a) 14 (24 tendons) (b) 84 (151 tendons) (c) 18 (31 tendons) Loss to follow-up: not noted	Zone V/VI complex (a) 80% (b) 67% (c) 44% No demographics
Hirth et al.[24]	Retrospective cohort:	Zone V and VI, single finger, exclude associated fractures,	(a) Immobilisation: splint: wrist 30° extension, MCP 30° flexion, IP extension; fulltime 4 weeks, then discontinue completely; commence home exercise programme for joint	n = 39 (a) 16 (b) 23	Male: (a) 81.3% (b) 95.7% Age: (a) 39.4 (b)

(continued)

Table 2. Continued

Authors	Type of study	Inclusion	Interventions	*n* = Participants(fingers)	Characteristics
	EAM (RMES) vs. immobilisation	incomplete data set, under 17 years, failure to attend follow-up	stiffness, tendon lag or scar adherence; avoid 'heavy' tasks 8–10 weeks (b) RMES: daytime: yoke only; MCP of injured digit in 15–20° relative extension to other MCP; all 4 fingers included; no wrist immobilisation; night time: splint as for immobilisation group; splint for 4 weeks, thereafter splint for 'heavy' tasks until 8–10 weeks; no specific exercises until 4 weeks, then home exercise programme for joint stiffness, tendon lag or scar adherence	Loss to follow-up: excluded by definition	37.2 Zone V: (a) (13) 81.3% (b) (21) 91.3% Manual workers: (a) 6 (37.8%) (b) 11 (47.8%)
Svens et al.[28]	Prospective cohort two groups EAM (RMES – compare two versions)	Zones IV, V, VI Simple laceration 80–100%	(a) Immediate relative active motion (IRAM) – orthosis: wrist 20–25° extension, MCP 15–20° relative extension. Finger flexion/extension exercises, wrist exercises from 3 weeks Wrist splint weaned after 3 weeks, yoke weaned at 6 weeks; strengthening from 5 to 6 weeks (b) Modified Immediate relative active motion (mIRAM) – zone IV/V yoke only, zone VI or EDM repaired yoke + wrist splint (as for (a)), exercises as per (a); Wrist orthosis weaned after 3 weeks; yoke orthosis weaned 4 weeks; strengthening from 4 weeks	Total = 63 (a) 45(48) (b) 18 (19) Loss to follow-up: 4 weeks: (a) 9 (b) 4 6 weeks: (a) 12 (b) 4 8 weeks: (a) 13 (b) 6	Male: (a) 89% (b) 78% Age: (a) 35(b) 35 Dominant hand injured: (a) 49% (b) 44% Manual work: (a) 58% (b) 33%
Cohort studies: single group					
Altobelli et al.[25]	Retrospective review one cohort: EAM (RMES)	IV and V and thumb zone TII,III, IV; complete injury, simple.	Daytime splint: wrist 20–25° ext, MCP 15–20° relative ext; full time; full active motion in splint; wrist splint weaned 3–5 weeks, start wrist exercises; yoke weaned 5–7 weeks; strengthening from 8 weeks Night-time splint: wrist neutral, all finger joints extended; worn 6 weeks	*n* = 8 (9) Fingers: 5 (6) Loss to follow-up: 0	Age: 31 Male: 88%
Howell et al.[32]	Retrospective review: EAM (RMES)	Zone IV – VII tendon repairs – at least one but not all; simple and complex; complex incl complete laceration with no tenorrhaphy	RMES: Splint: wrist 20–25° extension, separate yoke positions affected MCP in 15–20° relative extension to other digits; exercises: until 3 weeks both splints worn fulltime, full active flexion/extension of fingers to be obtained within splint; scar massage; 3 weeks – 5 weeks: wear yoke fulltime, start wrist extension/flexion exercises, combine wrist flexion + fist, wrist + finger extension if no lag; wean out of wrist splint for light actv once wrist moves freely; from 5 weeks start weaning from yoke, wean fully once full composite wrist + finger motion obtained	*n* = 140 Zone IV: 14 Zone V: 112 pts Zone VI: 9 Zone VII: 5 Loss to follow-up: 27%	Male: 87% Dominant injured: 86% Age: 34 Simple: 89 Complex: 51
Saini et al.[27]	Prospective observational	Zone V – VIII; simple and complex injuries,	Splint: wrist 45° extension, MCP 50° flexion, IP extended; exercises: MCP + IP extension and MCP extension with IP flexion; splint till 4 weeks if extensor lag < 30°, 6 weeks if	Total: 26 Zone V: 4 Zone VI: 11	Male: 73% 20 patients < 30 years

(continued)

Table 2. Continued

Authors	Type of study	Inclusion	Interventions	n = Participants(fingers)	Characteristics
	single cohort: EAM (CAM)	include flexor tendon injuries	lag > 30°; continue splint at night another 2 weeks; from 4 weeks increase composite flexion; strengthening from 6 weeks; scar massage if adherence	Zone VII-VIII: 11 EPL: 31% Loss to follow-up: 0	Dominant injured: 62% Multiple tendon involvement: 85%
Cohort studies: single group					
Sylaidis et al.[30]	Prospective observational study: EAM (CAM)	Zone IV to VII, complete Primary extensor tendon repair; simple and complex	CAM: Splint: wrist 45° extension, MCP 50° flexion, IP extension; exercises: MCP and IP extension; MCP extension with IP flexion; 4 weeks: discontinue splint, wear only at night; start gentle fist formation unless lag, then delay by 2 weeks; 6 weeks: discontinue night splint	$n = 27$ Simple = 23 (26 tendons) Complex = 10 (15 tendons) Loss to follow-up: 4 of 27	Male: 100% Age: 28 years

actv: Activities; CAM: controlled active mobilisation protocol; EAM: early active mobilisation protocol; EPL: extensor pollicus longus; EPM: early passive mobilisation protocol; excl: exclude; IF: index finger; incl: include; IP: interphalangeal joint; LF: little finger; MCP: metacarpophalangeal joint; n: number; RMES: relative motion extension splinting protocol.

Svens et al.[28] employed a validated subjective outcome measure, the 'hand health' section of the Patient Evaluation Measure (PEM),[33] where mean scores at 12 weeks were from 87% to 93% (100% indicates no problems with hand health). Hall et al.[14] used a non-validated visual analogue scale to report on perceived function in a study which included a CAM group. In another study which included a CAM group, Patil and Koul[31] assessed pain subjectively using a numeric analogue scale. Interestingly, none of the included studies recorded participant adherence, although lack of adherence was recognised as a potential issue for patients who undergo extensor tendon repair in zone V and VI.[15,24]

Hand therapy intervention was reported as number of sessions or in total therapy time in five of the included studies.[13,14,26,28,32] Where hand therapy intervention was described, therapy time ranged from 300 min[26] to 409 min[14] in studies including CAM protocols; the number of hand therapy sessions was 9 in a CAM group[13] and 3.6 to 8.1 in two studies of RMES groups.[28,32] One study which included a CAM group[27] reported that no hand therapy input was required, although their rehabilitation plan involved the use of a plaster splint and exercises.

Complications

Tendon rupture is a potential risk of early motion protocols, however eight of the included studies[13,24–28,31,32] reported that there were no ruptures in their populations. Two ruptures occurred in the CAM group in the study by Khandwala et al.[15] Evans[29] reported on three ruptures but did not specify in which group they occurred; all three occurred in participants who removed their splints prior to three weeks. No ruptures were reported in any RMES groups. Two studies[14,30] did not report on whether their participants had any ruptures.

Six of the twelve included studies[13,24,25,27,28,32] reported on infection rate. Infection rates ranged from 3% to 11.5% in two studies that included CAM groups,[13,27] 0% in three studies that included RMES groups[24,25,32] and 4% in another RMES study.[28] One study that included a CAM group[27] and two studies that included an RMES group[25,32] reported on the need for tenolysis; no participants in these three studies required tenolysis. One study[15] reported the development of reflex sympathetic dystrophy in one participant.

Methodological quality of included studies

The SEQES scores for each study are presented in Table 5. Four of the included studies were RCTs;[13,15,26,31] one[31] achieved a score of 'high' and

Table 3. Study outcomes.

Authors	Intervention groups	Range of motion (ROM)	Grip strength	Other assessment	Therapy sessions	Complications
Randomised controlled trials						
Bulstrode et al.[26]	(a) Immobilisation (b) CAM ('Norwich') (c) MCP immobilisation with free IPs	**TAM in degrees** 4 weeks: (a) 79°, (b) 165° (c) 160° *(b) and (c) significantly better than (a) 4 weeks + 6 weeks: Injured hand* *TAM significantly poorer than contralateral hand* **TAM Kleinert and Verdan % excellent/good** 12 weeks: 100	**Kg vs. contralateral hand** 12 weeks: (a) 23 vs. 45 (b) and (c) no difference *(a) significantly lower than contralateral hand ($p < 0.01$)*	–	**Overall mean time** 5 hrs (300 min), no difference between groups	No ruptures; flexion/extension deficits in two patients resolved after 12 weeks
Chester et al.[13]	(a) CAM (b) EPM	**TAM % of other hand** 4 weeks: (a) 77 (b) 87 3 months: (a) 100, (b) 98 *(b) significantly greater TAM at 4 weeks ($p = 0.02$)* **TAM Kleinert and Verdan % excellent/good** 12 weeks: (a)100, (b) 100 **Extension lag in degrees** 4 weeks (a) 15, (b) 10 12 weeks: (a) 0, (b) 0 **Flexion deficit in degrees** 4 weeks (a) 45, (b) 25 12 weeks (a) 0, (b) 0 *(b) significantly better flexion lag 4 weeks*	–	–	**Median therapy sessions** (a) 9, (b) 10	No ruptures One patient in each group developed cellulitis
Khandwala et al.[15]	(a) EPM (b) CAM	**TAM Kleinert & Verdan Percentage of excellent/good** 8 weeks: (a)98, (b)95 **Miller percentage of excellent/good** 8 weeks: (a) 95, (b) 93	–	–	–	3 ruptures: 2 ruptures group (b), 1 while riding motorcycle with splint on; 1 rupture group (a); 1 reflex sympathetic dystrophy, resolved

(continued)

Table 3. Continued

Authors	Intervention groups	Range of motion (ROM)	Grip strength	Other assessment	Therapy sessions	Complications
Patil and Koul[31]	(a) Immobilisation (b) CAM	**TAM in degrees** 4 weeks: (a) 142, (b) 200 6 weeks: (a) 186, (b) 224 8 weeks: (a) 212, (b) 246 12 weeks: (a) 233, (b) 261 6 months: (a) 264, (b)269 *Significant difference between groups at 4 and 6 weeks ($p < 0.0001$), 8 weeks ($p = 0.0001$) and 12 weeks ($p = 0.0003$); but not at 6 months ($p = 0.67$)*	**Kg** 8 weeks: (a) 51, (b) 58 12 weeks:(a) 66, (b) 77 *Significant difference between groups at 8 and 12* weeks *($p < 0.01$)*	**Weeks to return to work** (a) 11 weeks, (b) 10 weeks **Pain** (a) Pain week 1, then 4–12 weeks (b) Pain weeks 1–2	–	No rupture No need for re-exploration **Oedema** (a) Until 10 weeks post-op (b) First 3–4 weeks
Pilot study						
Hall et al.[14]	(a) Immobilisation (b) EPM (c) CAM	**TAM in degrees:** 3wk:(a) 109.8, (b) 133.3, (c) 187.9 6wk: (a) 178.4, (b) 197.7, (c) 248.8 12wk: (a) 239.9, (b) 247.8, (c) 266.2 *All pairwise differences significant except immobilisation vs. EPM* **Extensor lag in degrees:** 12 weeks: (a) 14.6, (b) 14.3, (c) 7.87	**Kg** 12 weeks: (a) 34.9, (b) 35.6, (c) 38.9	**VAS function improvement** (0–10 scale) (a) 2.78, (b) 3.15, (c) 3.45	**Mean total contact time** 409 min, no difference between groups Clinic visits per week 1.75, no difference between groups	–
Cohort studies: more than one group						
Evans[29]	(a) Immobilisation (b) EPM (c) CAM	**TAM in degrees** (Timeframe not stated) (a) 189, (b) 235, (c) 248 *(c) Significantly better than (a)*	–	–	–	Three ruptures in patients who removed splints prior to 3 weeks
Hirth et al.[24]	(a) Immobilisation (b) RMES (yoke only)	**TAM Kleinert an Verdan %excellent/good** 6 weeks (a) 62.5, (b) 78.3 12 weeks: (a) 93.85, (b) 100 *Significant difference at 6 weeks, with 12° difference in mean TAM*	–	**Return to work in weeks** (a) 9.4 (b) 3.3 *Significant difference ($p = 0.0062$)* **Return to work**	–	No infection, no rupture

(continued)

Table 3. Continued

Authors	Intervention groups	Range of motion (ROM)	Grip strength	Other assessment	Therapy sessions	Complications
		($p = 0.0076$); use of RMES and increased time after surgical repair = significant improvement in TAM ($p = 0.014$, $p < 0.0001$)		**in weeks manual workers** (a) 11.7, (b)7.7 *Significant difference ($p = 0.0071$)*		
Cohort studies: more than one group						
Svens et al.[28]	RMES (a) Immediate relative active motion (IRAM) (b) Modified Immediate relative active motion (mIRAM)	**TAM in degrees (mean % of contralateral)** 4 weeks: (a) 205(78), (b) 211(84) 6 weeks: (a) 236(89), (b) 244 (94) 8 weeks: (a) 253(94), (b) 256(99) **Kleinert & Verdan % excellent and good** 4 weeks: (a) 72, (b) 86 6 weeks: (a) 91, (b) 100 8 weeks: (a) 94, (b) 100 **Miller percentage of excellent/ good extension lag** 4 weeks: (a) 25 (b) 64 6 weeks: (a) 48, (b)65 8 weeks: (a) 72, (b) 83 **Miller percentage of excellent/ good flexion lag** 4 weeks: (a) 28, (b) 36 6 weeks:(a) 66, (b) 86 8 weeks: (a) 79, (b) 100 *TAM significantly better at 6 weeks and 8 weeks than 4 wk ($p < 0.0001$), 8 weeks TAM significantly better than 6wk TAM ($p = 0.0005$)* *No significant difference IRAM vs. mIRAM for any outcomes ($p \geq 0.09$)*	**Kg (percentage of contralateral)** 6 weeks: (a) 30 (69), (b) 34 (83) 8 weeks: (a) 36 (80), (b) 39 (94) *Grip strength increased significantly from 6 to 8 weeks ($p < 0.0001$)*	**Modified work** (weeks) (a) 3.9 (b) 3.2 **Full work** (a) 6.7, (b) 3.7 *Return to full work significantly faster mIRAM group* **PEM** Baseline (a) 45%, (b)46% 6 weeks: (a) 75%, (b) 82% 12 weeks: (a) 87%, (b) 93% *PEM 12-week scores significantly better than that of 6 weeks ($p < 0.0001$)*	**Mean nr sessions attended** (a) 5.2 (b) 3.6	No ruptures (a) 4% infection, 13% persistent oedema, 1 patient ongoing stiffness + oedema > 8/52 (b) No complications
Cohort studies: single group						
Altobelli et al.[25]	RMES single cohort (with		–	–	–	No ruptures, no wound infections,

(continued)

Table 3. Continued

Authors	Intervention groups	Range of motion (ROM)	Grip strength	Other assessment	Therapy sessions	Complications
	RIHM repair technique)	**Miller (%) excellent/good** Timeframe not stated 100				no extensor tenolysis surgery required
Howell et al.[32]	RMES single cohort	**Miller extension lag (%) excellent/good** 7 weeks: 96 **Miller flexion loss (%) excellent/good** 7 weeks: 94	**Percentage of contralateral hand:** 7 weeks: 85	**Days to return to work** 18	**Mean number of sessions** 8.1	No ruptures, no infections, no pain syndromes; no need for tenolysis or capsulotomies
Saini et al.[27]	CAM ('Norwich') single cohort	**Dargan criteria % excellent/ good:** 6 weeks: 92 12 months: 92	–	–	No specific hand therapy input	No rupture, no tenolysis surgery needed, no re-repairs Scar adherence: 31%; joint stiffness 8%; superficial infection 11.5%, 4% deep infection
Sylaidis et al.[30]	CAM ('Norwich') single cohort	**Dargan % excellent/ good** 4 weeks: Simple: 69, Complex: 47 6 weeks: Simple: 92, Complex: 85	–	Return to work in weeks Simple: 6.5 Complex: 8.5	–	–

CAM: controlled active motion protocol; EPM: early passive motion protocol; hrs: hours; IPs:interphalangeal joints; kg = kilograms; MCP: metacarpophalangeal joint; min: minutes; PEM: patient evaluation measure; RIHM: running interlocking horizontal mattress technique; RMES: relative motion extension splinting; TAM: total active motion; VAS: visual analogue scale.

Table 4. Range of motion outcomes for included studies.

Range of motion (ROM) in degrees at final follow-up						
	TAM Degrees	TAM Percentage of good & excellent	Miller's extensor lag percentage of good & excellent	Miller's flexor lag percentage of good & excellent	Miller's combined percentage of good & excellent	Dargan percentage of good & excellent
RMES protocols						
Altobelli et al.[25]					100	
Hirth et al.[24]		100				
Howell et al.[32]			96	94		
Svens et al.[28] mIRAM/IRAM	256/253	100/94	83/72	100/79		
CAM protocols						
Bulstrode et al.[26]		100				
Chester et al.[13]		100				
Evans[29]	248					
Hall et al.[14]	266.2					
Khandwala et al.[15]		95			93	
Patil & Koul[31]	269					
Saini et al.[27]						92
Sylaidis et al.[30] Simple/complex						92/85

IRAM: immediate relative active motion; mIRAM: modified immediate relative active motion.

Table 5. Quality assessment of included articles using the Structured Effectiveness Quality Evaluation Scale (SEQES).

Evaluation Guidelines	Question	Study Design							Subjects				Intervention			Outcomes			Analysis					Recommend-ations	Score	Rank
Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total	
Randomised controlled trials																										
Bulstrode et al.[26]	1	1	1	2	2	1	1	2	2	2	0	0	2	1	1	1	2	2	1	0	2	1	1	1	30	Moderate
Chester et al.[13]	2	2	1	2	2	1	1	0	1	1	0	0	2	1	2	2	0	2	1	1	1	0	2	2	29	Moderate
Khandwala et al.[15]	2	2	1	2	1	1	1	0	2	2	0	2	2	1	2	1	0	1	1	1	0	2	2	2	31	Moderate
Patil and Koul[31]	1	1	1	2	1	1	1	2	2	2	0	2	2	1	2	2	2	2	1	1	2	2	2	2	37	High
Pilot study																										
Hall et al.[14]	2	1	1	2	1	1	1	0	1	1	1	0	2	2	2	2	2	2	2	1	2	0	2	2	33	High
Cohort studies: more than one group																										
Evans[29]	2	1	0	1	0	1	1	0	0	1	0	2	2	0	2	2	0	1	0	1	0	1	2	2	22	Moderate
Hirth et al.[24]	2	2	1	0	0	1	1	0	0	2	0	2	2	1	2	2	1	2	2	1	1	2	2	2	30	Moderate
Svens et al.[28]	2	1	1	2	0	1	1	1	0	2	1	1	2	1	2	2	2	1	1	0	2	0	2	1	28	Moderate
Cohort studies: single group																										
Altobelli et al.[25]	1	0	0	0	0	0	0	0	0	2	2	0	2	2	0	0	1	0	1	0	0	0	2	2	2	17	Low
Howell et al.[32]	2	0	0	0	0	0	0	0	0	1	2	0	1	2	0	0	1	1	1	0	1	0	1	2	2	17	Low
Saini et al.[27]	1	0	1	1	0	0	0	0	0	1	0	2	2	0	0	1	0	2	0	0	0	2	1	1	15	Low
Sylaidis et al.[30]	1	0	1	1	0	0	0	0	2	2	0	1	2	0	0	1	1	1	0	0	0	1	1	2	16	Low

three[13,15,26] achieved a score of 'moderate' methodological quality. One[14] of the included studies was a pilot study with a randomised design and was rated as having 'high' methodological quality. Three of the included studies compared two or more cohorts and were rated as being of 'moderate' methodological quality.[24,28,29] Four[25,27,30,32] of the 12 included studies were single cohort studies with no comparison group and were rated as having 'low' methodological quality. Many of the included studies scored poorly with regard to the *'Study design'* and *'Analysis'* sections. In the RCTs, the randomisation process was not always clearly described[15] or was not truly random.[31] Only three[26,28,31] studies reported the use of blinded assessors. Sample size calculation was reported for two of the included studies.[14,28] High loss to follow-up was a significant problem for many of the included studies, with drop-outs reported at 15%,[30] 27%,[32] 30%,[28] 33%[13,14] and 36%.[26] Two of the RCTs reported data without *p*-values[15] and/or without an effect size.[13,15] Statistical analysis was limited in all the single cohort studies and two RCTs[15,26] where results for the primary outcome were only reported categorically as 'excellent, good, fair or poor' results.

When reviewed according to the type of EAM protocol, the CAM studies included all the RCTs[13,15,26,31] and the pilot study with randomised design.[14] None of the RMES studies were randomised. The CAM studies included two[14,31] of 'high'[14,31] and four[13,15,26,29] of 'moderate' methodological quality, while those reporting on RMES protocols included two studies[24,28] of 'moderate' methodological quality.

Level of evidence

As a systematic review which examines the efficacy of treatment protocols, where over half of the included studies are either RCTs or cohort studies, this systematic review represents level 2a evidence.[23]

Discussion

This systematic review was undertaken to investigate the different EAM protocols used after extensor tendon repairs in zone V and VI. The aim was to identify whether any one EAM protocol provided superior outcomes. Only full text, English articles were included which may have led to some bias in the results obtained. From a total of 166 articles identified, 12 studies were selected which met the inclusion and exclusion criteria.

A mix of study designs were represented in 12 included studies: four RCTs, one pilot study, three cohort studies including more than one cohort, and four studies reporting the outcomes of one cohort. With this point in mind, it is potentially a limitation of this current review that a mix of study designs was included. The evidence must be interpreted in the light of the high proportion of non-randomised study designs included.

Following the rating of methodological quality, via the SEQES, two studies achieved a score of 'high', six a score of 'moderate' and four a score of 'low' methodological quality. Common limitations in the 12 included studies were high loss to follow-up, poor statistical analysis and/or reporting, and in many cases, risk of bias due to non-blinding of assessors.

The included studies revealed two main protocol types, CAM and RMES. Studies describing CAM protocols were older and demonstrated a higher level of methodological quality than those describing RMES protocols. No studies compared a CAM to an RMES protocol. RMES protocols had a less restrictive splint design and participants in these studies were advised to return to functional use of the injured hand earlier than those treated with the CAM protocols.

Similar satisfactory ROM and grip strength outcomes were reported for participants treated with CAM and RMES protocols. However, there was a notable difference with regard to reported time to RTW post-operatively: participants treated with an RMES protocol returned to work earlier than those treated with a CAM protocol. This earlier RTW in RMES groups may have been influenced by the less-restrictive splint design and the advice provided to participants regarding functional use of their hand.

The main concern relating to any tendon rehabilitation protocol is the risk of rupture of the repaired tendon. The combination of EAM with less-restrictive splinting and advice to return to functional use of the hand earlier may theoretically have increased the risk of tendon rupture in participants treated with RMES protocols. However, no ruptures were reported in any participants treated with an RMES protocol while small numbers of ruptures were reported in participants treated with a CAM protocol. Factors that may have influenced the difference in rupture rate reported for the CAM and RMES groups are splint design and the strength of the repair.

In the study by Khandwala et al.,[15] one participant ruptured the tendon repair when riding a motorbike, while wearing the CAM splint. The design of the splints used in the RMES groups may have reduced the risk of rupture by splinting the affected MCP joint/s in relative extension to the other digits which may harness the supportive effect of the juncturae tendinae connection.[32] Allowing the wrist to be free, as in some RMES protocols, promotes a tenodesis action which reduces tension on the repaired tendon during active digital extension[11,34] and may further reduce the risk of rupture.

In the study by Evans,[29] rupture occurred when participants removed their splints for activity. It is possible that ruptures did not occur in the RMES studies because participants were able to use their hands easily while wearing RMES splints and were therefore less tempted to remove the splint for activity.

Studies included in this review reporting on RMES protocols were more recent than those reporting on CAM protocols. The ability to allow more tendon excursion and active motion without increased risk of rupture may additionally be due to recent improvements in suture technique and materials for tendon repair.[35]

Heterogeneity of outcome measures used in the included studies meant that it was not possible to perform a meta-analysis. Future studies would be more comparable if they reported ROM in degrees and percentages of TAM and reported on grip strength in kilograms and as a percentage of the contralateral side. There was minimal use of subjective patient-rated outcomes in the studies reviewed. As a number of validated standardised tools now exist to measure subjective outcomes, future studies should employ these tools. Adherence is an important parameter which should be recorded in future studies.

Conclusion

This systematic review has investigated the different EAM protocols used after extensor tendon repair in zones V and VI. Two subcategories of EAM protocols were identified: CAM and RMES. The evidence reviewed suggests that there may be some benefits of RMES protocols over CAM protocols with regard to earlier return to work and decreased incidence of tendon rupture. It is possible that the RMES protocols safely allow easier, earlier functional use of the hand. However, CAM and RMES protocols have not been directly compared. Studies describing RMES protocols are of a lower level of evidence and poorer methodological quality than those describing CAM protocols. The splint used in RMES protocols is low-profile and appears to be minimally restrictive to tendon glide and function of the hand, while providing sufficient protection for the repaired tendon. In light of the possibly superior outcomes of participants treated with the RMES protocols, and the absence of high-level, good quality research comparing RMES and CAM protocols, it may be appropriate to conduct a well-designed prospective trial comparing the two protocols.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Ethical approval

Not applicable

Guarantor

SC

Contributorship

SC and EK reviewed and scored the studies. SC wrote the initial review. RE reviewed and provided input into the manuscript and prepared it for publication. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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