

CENTRAL SLIP EXTENSOR TENDON INJURIES: A SYSTEMATIC REVIEW OF TREATMENT

ABSTRACT

Suboptimal management of injury to the central slip of the extensor tendon may result in the development of a boutonnière deformity, posing the risk of a poor long-term outcome. This systematic review describes and compares outcomes of operative and non-operative management of central slip injury.

A PRISMA-compliant methodology identified 3,785 studies. Of these, 29 underwent full text review. No randomised controlled trials were identified. Nine studies evaluated treatment modalities specific to cohorts with acute central slip injuries in adults. A range of operative and non-operative elements of management were identified although no studies directly compared the two. Where aspects of rehabilitation were studied, this was always after surgery. The evidence base informing treatment of central slip injury is limited and the roles of different treatment strategies for open as well as closed injuries are not well-supported by evidence.

INTRODUCTION

Traumatic extensor tendon injuries are commonly encountered with disproportionate representation of young, otherwise healthy males in the patient demographic (De Jong et al., 2014). Injury mechanisms include hyperflexion, direct blunt trauma, and penetrating trauma. Blunt trauma and hyperflexion trauma often cause a closed injury that is commonly encountered in athletes (Weiland, 2012). Penetrating injuries have a comparatively higher incidence than blunt ones, with zone III extensor tendon injuries accounting for 12.6% of all open tendon injuries presenting to emergency departments (De Jong et al., 2014). Disruption of the extensor mechanism over zone three and detachment of the central slip results in a boutonnière deformity characterised by flexion of the proximal interphalangeal joint (PIPJ) and hyperextension of the distal interphalangeal joint (DIPJ) due to volar subluxation of the lateral bands, if untreated (Massengill, 1992). Disfigurement and impaired hand function is common following central slip injury and thus it represents a potential cause of significant morbidity (El-Sallakh et al., 2012).

Closed central slip injuries without substantial bony involvement can be managed non-operatively, using PIPJ extension splinting. Regimens used include immobilisation, dynamic splinting, and progressive static splinting (also termed serial splinting) (Evans, 1994; McAuliffe, 2011).

Operative management strategies include acute central slip repair, open reduction and internal fixation (ORIF), tendon reconstruction, and arthrodesis (Matzon and Bozentka, 2010). ORIF may be applicable when an amenable fracture pattern is present, and arthrodesis should be reserved for patients with PIPJ contractures and degenerative change associated with chronic injury (Imatami et al., 1997). If the central slip is repaired operatively, post-operative PIPJ extension is advocated.

42 Operative approaches might be considered most appropriate for open injuries, which
43 necessitate exploration, debridement and irrigation (Colzani et al., 2016).
44 Current management strategies appear to be informed by anecdotal evidence,
45 without reference to comparative outcome data between operative and non-
46 operative treatment. The aim of this systematic review is to identify reported
47 management strategies of acute open and closed central slip injury, and appraise
48 their clinical outcomes.

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METHODS

Methods were developed using the PRISMA statement, and the protocol was registered in the prospective register of systematic reviews (PROSPERO).

Eligibility criteria

Randomised controlled trials (RCTs), non-randomised controlled trials, cohort studies, case-control studies, case series and case reports were included, irrespective of sample size. Expert opinion, review articles and narrative descriptions of operative technique without an accompanying report of novel clinical data were excluded.

Participants

All studies examining acute, acquired, open or closed central slip injury of index-little digits in adults (aged 18 or older) presenting within one month of injury were included. Studies that included patients with multiple digital injuries, including fractures and open injuries were included. Extensor pollicis longus (EPL) injuries, iatrogenic central slip injuries, and those presenting late with boutonnière deformity or joint destruction that would require other treatment strategies, were excluded.

Interventions and Comparators

Both operative or non-operative management strategies were eligible to be included. Details of the type and duration of rehabilitation protocols were extracted. Given the potentially broad nature of eligible interventions, multiple comparisons were considered: operative versus non-operative strategies, comparisons between different types of operative repair, comparisons between different types of non-operative strategy, comparisons of outcome measures used following intervention, rehabilitation type and duration following operative and non-operative management strategies.

Outcomes

The outcomes assessed included active finger range of motion (AROM), joint angles, mean grip strength, the incidence of complications, the need for further salvage procedures such as arthrodesis, and patient reported outcome measures (PROMs) used, of which generic, upper limb-specific and hand-specific might be expected.

Search strategy

Search strategies were developed using index and free text terms, in conjunction with a search strategist. Full search strategies are given in appendix 1. They were applied to Medline & In Process (1946-July 2017), EMBASE (1974- July 2017) and CINAHL (1981- July 2017) in July 2017. The reference lists of included articles were hand searched for further relevant publications. The literature search was limited to human studies. A second database search, and in addition the Cochrane Central Register of Controlled Trials (CENTRAL), was conducted on 25th August 2018.

Study selection

After pooling and electronic de-duplication, two authors (LG, JCRW) independently screened all abstracts against pre-specified stepwise inclusion criteria (see Figure 1, PRISMA flow chart). Disagreements were resolved by discussion with a third author.

Data extraction and analysis

Standardised data extraction was performed in duplicate (LG, JCRW). Extracted data was then collated and compared. Methodological quality of studies was assessed. Randomised controlled trials were assessed using the Cochrane Risk of Bias tool (Higgins et al., 2011). Non-randomised comparative studies were assessed using the Cochrane Risk of Bias in non-randomised studies of interventions (ROBINS-I) tool (Sterne et al. 2016). The National Institute of Health (NIH) quality assessment tool for cohort studies was employed to assess the quality of cohort studies (National Institute

98 of Health, 2014). The CARE checklist was used to assess the quality of case reports
99 (Gagnier et al., 2013).

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RESULTS

Search results

3,248 records were identified through database searching; 506 from EMBASE, 2079 from Medline, 128 from CINAHL and 535 from CENTRAL. Although it was anticipated that studies discussing boutonnière deformities would be specific to chronic presentations, to minimise any data loss, a second electronic search and screening for boutonnière deformity specifically was performed. This yielded an additional 537 studies. Overall, 3,785 studies were identified, and 3,279 were screened after de-duplication. The combination of both searches is summarised in Figure 1. 29 remaining full text articles were assessed for study eligibility, with nine studies meeting inclusion criteria. Given the large number of excluded studies, they are not provided here, details are available on request.

Study characteristics

There were no randomised controlled trials, and no non-randomised comparative studies identified (see Table 1). Of the included studies, eight of nine were cohort studies, based on an established definition (Dekkers et al., 2012). One case report met inclusion criteria. Two studies were prospective in study design; data from a subset of patients in a third study reported prospective data.

Quality of included studies

All studies were assessed as fair or poor quality, as outlined in Table 1, with a mean sample size of 27 (SD \pm 33) patients. Included studies provided varying clinical descriptions of the extent of central slip injury, management and rehabilitative strategies. The effect of potential confounding variables was seldom reported and loss to follow up varied from 0 to 34%.

Demographics and injury details

In the nine included studies, there were a total of 225 patients with 244 digits with central slip injuries; 79.5% were male with a mean age of 35.5 (range: 29-70) years. Five out of the nine included studies reported that definitive management was commenced within 72 hours of injury. The remaining four studies did not specify how long after initial injury definitive management was commenced; all injuries were considered to have been managed within one month of injury based on consensus discussion between authors. The mean duration of follow up was 23 (SD \pm 30.7) months. The mechanism of injury resulted in open central slip lacerations in 251 of 259 (96.9%) injuries. Thus, very little data describing the management of closed injuries was identified. Overall, 87 of 259 (37.9%) injuries involved bone and joint capsule and were thus considered complex (Evans, 1994). The majority of injuries included were simple (without bony involvement).

Interventions and rehabilitation

All studies reported operative repair as definitive management of both open and closed central slip injury, with variation in repair technique. One study reported the management of closed injuries, (Hou et al., 2014) and one further study did not specify the nature of injuries (Saldana et al., 1991). The mean length of post-operative rehabilitation was seven weeks. Rehabilitation protocols also varied in terms of the number and type of splints used, the duration of dynamic and static splinting, and the total length of splinting protocols. Generally, protocols which implemented early dynamic splinting appeared to be well tolerated and were associated with favourable functional outcomes, as outlined in Table 2.

Outcome measures

Collectively, nine different outcome measures were used across all studies, the majority of which were physician reported measures of function. A bespoke functional

scale based on flexion and extension was reported in one study, and only one study used a patient-reported outcome measure (PROM), the Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) (Feuvrier et al., 2014). All eight studies reporting functional outcome used combinations of outcome measurements at varying follow up time-points.

Outcomes

Comparison could only be made between postoperative rehabilitation involving active mobilisation versus immobilisation. An active mobilisation rehabilitation after operative repair achieved statistically significantly better results than immobilisation in the only comparative study identified in this review (Evans, 1994). Other single arm studies involved varying lengths of immobilisation, typically around 3 weeks, often followed by mobilisation. However, in those studies, mobilisation involved spring-mounted dynamic splints to support extension, rather than the shortened arc of motion regimen.

DISCUSSION

Suboptimal treatment of central slip injuries is expected to result in impaired finger movement, joint stiffness and progression to boutonnière deformity (Evans and Thompson, 1992; Pratt et al., 2002). We examined the evidence for different management and rehabilitation options following acute open and closed central slip injuries in the literature. Of the nine studies that met inclusion criteria, seven reported management of open injuries, one reported the management of closed injuries and one did not specify. All studies reported operative repair of the central slip in the first instance, with various post-operative rehabilitation protocols employed. There were limited comparative data, and no consensus on outcome measurement.

We did not identify any evidence to examine the role of non-operative management, nor for the management of the closed injury. This may represent a dogmatic acceptance of conventional approaches to managing such injuries, or may represent a lack of academic investment in studying such injuries, perhaps owing to the success of conservative treatment in patients with closed injuries.

Most evidence included considered rehabilitations regimens, in the context of rehabilitation after operative repair. Extrapolating this to non-operative management may not be appropriate. Different rehabilitation protocols were reported, which can be broadly classified into: PIPJ immobilisation followed by an isolated PIPJ flexion-extension exercise, controlled early active short arc motion, and PIPJ immobilisation followed by mobilisation with a dynamic spring coil finger splint (Pratt et al., 2002).

There was limited evidence to define roles for the different regimens. Evans' comparative study investigating outcomes after prolonged immobilisation and early short arc motion (SAM) reported significantly better functional results in the SAM cohort (Evans, 1994). However, Pratt et al. demonstrated a comparable angular

outcome with a mean PIPJ active flexion of 94 degrees (compared to 88 degrees in Evans' SAM cohort) following the implementation of hourly DIPJ flexion exercises throughout the PIPJ immobilisation period and subsequent dynamic splinting initiated after three post-operative weeks, potentially challenging the superiority of SAM. This comparison is limited by discrepancies in cohort size, demographics and operative strategies between the two studies. Furthermore, Maddy et al. used a similar rehabilitation strategy to Pratt et al., implementing dynamic splinting from the fourth post-operative week (after immobilisation), but this yielded less mean total active motion. There was no evidence to support the use of prolonged immobilisation (more than three weeks).

Given the barriers to combining the findings of different studies here, this may be the main conclusion for clinical practice at present.

There is a lack of standardised outcome measurement, but the existing evidence is largely based on angular measurements. Despite the growing use of PROMs in hand surgery research in general, only one study comprising four patients reported PROMs, using the QuickDASH. Functional measures and range of motion, such as the Strickland-Glogovac formula, (Strickland and Glogovac, 1980), were widely reported; whether these endpoints are of relevance to patients is not clear.

Our results must be considered in view of the study limitations. Although a sensitive strategy was used, it is possible that relevant publications may not have been identified. Further, this study considers management strategies reported within the literature and may not reflect current clinical practice.

The current evidence base for the management of central slip injuries is limited; all current studies reported operative repair and the role of non-operative management

214 remains equivocal. Evidence from individual studies tentatively supports the use of
215 early mobilisation and does not support prolonged immobilisation.

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217 **Figure Legends**

218 Figure 1: PRISMA flow chart detailing the results of both searches performed.

REFERENCES

- Colzani G, Tos P, Battiston B, Merolla G, Porcellini G, Artiaco S. Traumatic extensor tendon injuries to the hand: Clinical anatomy, biomechanics, and surgical procedure review. *J Hand Microsurg.* 2016, 8: 2-12.
- Dacombe PJ, Amirfeyz R, Davis T. Patient-reported outcome measures for hand and wrist trauma: is there sufficient evidence of reliability, validity, and responsiveness? *Hand.* 2016, 11:11-21.
- De Jong JP, Nguyen JT, Sonnema AJM, Nguyen EC, Amadio PC, Moran SL. The incidence of acute traumatic tendon injuries in the hand and wrist: A 10-year population-based study. *Clin Orthop Surg.* 2014, 6: 196-202.
- Dekkers OM, Egger M, Altman DG, Vandenbroucke JP. Distinguishing case series from cohort studies. *Ann Intern Med.* 2012, 156: 37-40.
- El-Sallakh S, Aly T, Amin O, Hegazi M. Surgical management of chronic boutonniere deformity. *Hand Surg.* 2012, 17: 359-64.
- Evans RB. Early active short arc motion for the repaired central slip. *J Hand Surg Am.* 1994, 19: 991-7.
- Evans RB, Thompson DE. An analysis of factors that support early active short arc motion of the repaired central slip. *J Hand Ther.* 1992, 5: 187-201.
- Feuvrier D, Loisel F, Pauchot J, Obert L. Emergency repair of extensor tendon central slip defects with oberlin's bypass technique: Feasibility and results in 4 cases with more than 5 years of follow-up. *Chir Main.* 2014, 33: 315-9.
- Fletcher D, Edwards D, Tolchard S, Baker R, Berstock J. Improving theatre turnaround time. *BMJ Qual Improv Rep.* 2017, 6.
- Froehlich JA, Akelman E, Herndon JH. Extensor tendon injuries at the proximal interphalangeal joint. *Hand Clin.* 1988, 4: 25-37.

244 Gagnier JJ, Kienle G, Altman DG, Moher D, Sox H, Riley D. The care guidelines:
 245 Consensus-based clinical case reporting guideline development. *Glob adv health*
 246 *med.* 2013, 2: 38-43.

247 Higgins JP, Altman DG, Gøtzsche PC et al. The Cochrane Collaboration's tool for
 248 assessing risk of bias in randomised trials. *BMJ.* 2011, 343:d5928

249 Hou Z, Zhao L, Yu S, Xiao B, Zhou J. Successful Surgical Repair of Central Slip
 250 Rupture in Finger Extensor Tendon. *In vivo.* 2014, 28: 599-603

251 Imatami J, Hashizume H, Wake H, Morito Y, Inoue H. The central slip attachment
 252 fracture. *J Hand Surg Br.* 1997, 22: 107-9.

253 Maddy LS, Meyerdierks EM. Dynamic extension assist splinting of acute central slip
 254 lacerations. *J Hand Ther.* 1997, 10:206-12.

255 Massengill JB. The boutonniere deformity. *Hand Clin.* 1992, 8: 787-801.

256 Matzon JL, Bozentka DJ. Extensor tendon injuries. *J Hand Surg Am.* 2010, 35: 854-
 257 61.

258 McAuliffe JA. Early active short arc motion following central slip repair. *J Hand Surg*
 259 *Am.* 2011, 36: 143-6.

260 Mehdi SY, Masood Q, Lawlor D, Eadie PA. Repair of the central slip of extensor
 261 tendon and the open mallet using Mitek mini bone anchors. *Eur J Plast Surg.* 2011
 262 Feb 1;34(1):13-7.

263 O'Dwyer FG, Quinton DN. Early mobilisation of acute middle slip injuries. *J Hand*
 264 *Surg Am.* 1990, 15:404-6.

265 Pike J, Mulpuri K, Metzger M, Ng G, Wells N, Goetz T. Blinded, prospective,
 266 randomized clinical trial comparing volar, dorsal, and custom thermoplastic splinting
 267 in treatment of acute mallet finger. *J Hand Surg Am.* 2010, 35:580-8.

268 Pratt AL, Burr N, Grobbelaar AO. A prospective review of open central slip laceration
269 repair and rehabilitation. J Hand Surg Am. 2002, 27: 530-4.

270 Rodrigues J, Zhang W, Scammell B et al. Validity of the disabilities of the arm,
271 shoulder and hand patient-reported outcome measure (DASH) and the quickdash
272 when used in dupuytren's disease. J Hand Surg Eur Vol. 2016, 41: 589-99.

273 Saldana MJ, Chohan S, Westerbeck P, Schacherer TG. Results of acute zone III
274 extensor tendon injuries treated with dynamic extension splinting. J Hand Surg Am.
275 1991, 16:1145-50.

276 Sterne JA, Hernán MA, Reeves BC et al. ROBINS-I: a tool for assessing risk of bias
277 in non-randomised studies of interventions. BMJ. 2016, 355:i4919.

278 Strickland JW, Glogovac SV. Digital function following flexor tendon repair in zone ii:
279 A comparison of immobilization and controlled passive motion techniques. J Hand
280 Surg Am. 1980, 5: 537-43.

281 Weiland AJ. Boutonniere and pulley rupture in elite baseball players. Hand Clin.
282 2012, 28: 447.

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