British Association of Hand Therapists

Effectiveness bulletin on tendon injuries in the hand.

Compiled by members of the British Association of Hand Therapists

Editor
Dr Barbara Steward- BAHT R&D Officer

Network Convenors and Chapter Co-authors
Nikki Burr- Central slips
Linda Currie – Mallet deformities
Jacki Hunt – Extensor tendon injuries
Sheila Harris- Thumb tendon injuries
Caroline Southgate – Flexor tendon injuries

Network Members
Nicole Glassey
Tess Hogg
Sue Kennedy
Anna Pratt

Reviewers
Suzanne Beale
Cath Bucher
Justine Bullock
Fiona Cashin
Fiona Coldham
Anita Cooper
Rachel Delaney
Jo Downey
Jane Dulson
Liz Edge
Joanne Ellis
Niall Fitzpatrick
Adrienne Foster
Sharon Gillespie
Janet Hunter
Victoria Jensen
Charlotte Land
Jane Leathwood
Sarah Mee
Linda McKeith
Katrina Mills
Karen Murray
Nicki Noden
Carole Parsley
Fiona Peck
Alison Reeves
Carol Robertson
Claire Seymour
Jane Vadher
Judith Wood

BAHT wishes to acknowledge the outstanding contributions made by these members to the publication of this Bulletin.

Index

Tables

Figures

1.0 Introduction

The purpose of this bulletin is to respond to current political and fiscal demands to identify quality evidence on which to base best practice. It offers an overview and critical appraisal of the evidence for therapy of tendon injuries. This evidence is designed to underpin decisions regarding the choice of the most appropriate management techniques based on research evidence, expert investigation and consensus opinion.

As a guide to best practice, it may be considered to be flawed by the relative absence of 'hard evidence', which may suggest that therapists cannot take this as a final guide to practice. However, this raises the issue of what does constitute best evidence. It should be noted that in most instances the individuality of the client or the special needs of a group are ignored in the analysis of quasi-experimental research, which treats participants as homogeneous. Can randomised controlled trials (RCTs) and experimental trials provide a full answer to what should inform effective treatment for each client? Clinical governance guidelines stress that expert opinion is also to be valued. Therapists need to look at the complexities of each case to identify and negotiate treatments which incorporate the widest evidence base, service user perspectives and health economics.

The publications reviewed here also reveal schools of thought which are in conflict, and which bias the formulation and analysis of data, although in no situation can any research, of course, be considered value free. The focus on comparing types of splints which appear to be equally effective may indicate competition between different units or schools of thought but offer little understanding of successful treatment. The review suggests that further research might focus on why, with whom and in what situations protocols prove to be effective or ineffective and how this can be resolved.

This bulletin must be read with the full appreciation that it is only one element in determining practice and has to be applied within the complexity and unpredictability of the life of an individual client. A bulletin may only help with limiting the uncertainty of the therapist in making appropriate, effective and cost effective choices based on accumulated and shared past experience. However, a good hand therapist is not one who works from a prescription, nor who assumes treatment can be objective and rational. The art of therapy is to offer skill and knowledge to meet individual need.

Therapists espouse the two key notions of client-centredness and holistic practice. The concerns of a good therapist are to understand the meaning and experience of the injury and treatment from the patient's perspective, within their past, present and future life history and social context. A good therapist debates and adapts interventions with the client and over the course of the recovery period. They negotiate the choice and extent of outcomes with the client.

The literature review carried out here suggests three themes;

- The search for a single or even an effective outcome measure may have sent hand therapy down a blind alley. The values set by surgeons and therapists are poorly synchronised with those of the patient. Some effort to find a method of appraising an excellent or good result from a surgical, therapeutic and a client-centred perspective should be sought.
- A considerable tension sometimes appears to exist between patients and staff. Effective treatment is repeatedly claimed to be enhanced by complete patient compliance with the treatment protocol. Yet people are non-compliant for reasons poorly understood by clinical staff, which suggests an urgent need to identify ways to individually negotiate a balance between minimising of risk while maximising opportunities to undertake necessary or desired activities. Such negotiations cannot

follow any fixed protocol because they rely on communication skill and empathy with complex needs

- There is little 'gold standard' evidence available for hand therapy. This may not be a failure, but a reflection that RCTs are often difficult, if not impractical, to carry out. To locate sufficient numbers for a trial, and the ethical problems associated with allocation to control or experimental groups often precludes therapists from investigating their work in this way. It also has to be asked if such evidence really can advance 'best practice' or if this type of evidence can be relayed to patients and carers to inform their decision making. The different and combined contribution of evidence gained from a number of different methodologies should not be underestimated. The importance of qualitative research appears to have been overlooked in much of the evidence.

There exists an urgent need in therapy to reclaim an appreciation of the whole person; physical, emotional, motivational, social and spiritual and to recognise the importance of the interpersonal relationships in which mutual understanding and shared decision-making take place. Therapists have a special role in bridging the medical and the social world. The role of the therapist is to determine how they can make the accumulated knowledge and uncertainty about tendon injury treatment available for scrutiny by everyone, especially, the patient. A positive and active involvement between people with the injury with those equipped to treat them may serve to reduce dissatisfaction and poor functional outcomes. The team of surgeons, nurses, therapists and technicians all will ideally work collaboratively towards this goal guided by the patients.

1.1 Background to the Bulletin

The British Association of Hand Therapists (BAHT) is an association for occupational therapists and physiotherapists who specialise in the treatment of the hand. BAHT is a Clinical Interest Group of the Chartered Society of Physiotherapists.

In 1998, BAHT surveyed early treatment of the hand following injury or surgery in specialist and non-specialist units across the UK (Stanley et al 1998). The findings suggested that early active treatment appeared to reduce the incidence of oedema, residual stiffness and contracture and had been widely adopted in the specialist units surveyed. However, there were significant differences in the evaluation and use of defined treatment protocols between specialist and non-specialist units and individual therapists. This suggested a need to review the literature and disseminate evidence of best practice.

The BAHT Research and Development Strategy 2001 states that the views of members will be sought every three years to establish research priorities. Two surveys of the membership were carried out in 2001; the first was a pilot project which explored the research needs of delegates at the BAHT Annual Conference (Steward 2001), the results of this informing the development of a full postal membership survey in the same year. In each exercise, participants were required to both identify and justify research questions. Tendon injuries were clearly identified as the priority topic (Steward 2002) with members indicating that these were common injuries requiring hand therapy, but frequently found to have complications affecting outcomes.

Tendon injuries appeared to represent a significant proportion of hand therapists' work. Carlsson's (2003) study indicated that tendon injuries accounted for almost 19% of occupational therapy workload, and 25% of physiotherapist time. A subsequent audit of hand therapy carried out by BAHT showed that 30% of all referrals to hand therapy units were for tendon injuries (Steward 2004a). A rapid appraisal of databases, however, suggested that no current, comprehensive review of the treatment and management of tendon injuries existed (Cochrane Controlled Trials Register; DARE; NHS EED; HTA). Various protocols were required or suggested by surgeons or hand therapy departments, yet evidence to support the effectiveness of one protocol over another was not clear, nor how protocols were adapted by hand therapists. There was a clear need to review the content and appraise the quality of the available evidence of the treatment of tendon injuries to inform debate and guide future research.

1.2 Purpose of the Bulletin

This Bulletin offers an overview of the evidence of hand therapy for flexor and extensor tendon injuries to the whole hand. It does not provide standards for practice nor is it a definitive clinical guideline, but appraises published research, expert opinion and grey evidence using a score for the type of evidence. It is intended that the bulletin will offer hand therapists an evidence-base for their practice.

The Bulletin aims to:-

- Synthesise the evidence on hand therapy for tendon injuries.
- Critically appraise the quality of the evidence.
- Analyse the evidence for clinical effectiveness and explore the extent to which protocols claim to avoid or resolve common complications of tendon injury.
- Offer some practice points
- Suggest areas for further research

1.3 Method

A Network of nine expert hand therapists, identified for their knowledge or skill in treating tendon injuries, were recruited from the BAHT membership to work in collaboration with the BAHT Research and Development Officer (RDO). The content, method and appraisal system for the bulletin were agreed at a preliminary Network meeting. A number of different appraisal methods and scoring systems were examined (Law et al 1998, Morse 2003, CRD 1996). As these were predominantly designed to evaluate medical evidence using quantitative methods, it was decided to adapt a score system produced by the College of Occupational Therapists which allowed the easier incorporation of qualitative evidence (College of Occupational Therapists 2000)

1.3.1 Search methods

A comprehensive search of the literature was carried out using Medline, CINAHL and AMED. Subsequently citation searches were undertaken from the data collected. Members of the Network and the wider reviewing teams were also asked to contribute and canvas for further in-house evidence.

1.3.2 Inclusion and exclusion criteria

Papers were accepted for review if they fulfilled all the inclusion criteria and none of the exclusion criteria. Some latitude, however, was subsequently allowed for topics where there was very little available evidence and where an older key paper was frequently cited or was not published in English. 103 papers were reviewed in total. Background information was sought outside these parameters, including 3 English translations of abstracts of articles in French or German. Where additional key hand therapy papers have been published in 2004, these have been selectively included.

<u>Inclusion criteria</u>

- Any age group including children and the elderly.
- Relevant to any tendon injury to the hand, including the wrist.
- Related to the evaluation of a treatment protocol for managing a tendon injury of the hand.

- The paper must be less than 15 years old (final date for inclusion for peer review- December 2003).
- Papers may be drawn from published or unpublished sources.
- Papers will be in English.

Exclusion criteria.
- Papers more than 15 years old.
- Papers in foreign languages.
- Medical or pathology papers which contain no specific reference to hand therapy

Other papers have been included in the discussion to provide historical and medical context, but were not peer reviewed. Some 2004 papers were included which offer additional contextual information from the British Association of Hand Therapists or provide important new or supportive information. These new papers have not been peer reviewed.

1.3.3 Methods of appraisal

Papers were divided into 5 topic areas. One member of the Network took responsibility for each topic, acting as a convener of the peer reviewers, collating the papers for review and editing drafts of the Bulletin. In addition to the 10 Network members, 30 BAHT members volunteered as expert reviewers, allocated to one or two topic teams. Reviewers were provided with two forms (Appendix 1 & 2). The first required clinical evaluation and a summary of the content; the second a description of the type of research leading to the allocation of an appraisal score.

It was known that few RCTs had been carried out and that evidence was predominantly based on clinical series. The appraisal scores allocated offer a description of the various types of investigations. Sample sizes for research studies are given and brief comments in the tables of any specific methodological problems. Rigorous research evidence was found to be limited. The Bulletin, therefore, includes evidence from expert evaluation, experience and opinion, providing valuable indications of consensus opinion. The scoring system adopted identifies six types of evidence.

Table 1. Appraisal scores

Appraisal score	Type of evidence
1	Randomised controlled trial
2	Quasi-experimental studies
3	Other types of rigorous research evidence, e.g. case studies, cohort studies, qualitative studies
4	Clinical series/practice evaluation
5	Expert opinion
6	Literature review

The scores are not entirely hierarchical. Clearly a good quality literature review involving secondary data analysis is no less valuable than expert opinion. However, a score of 4 does indicate practice evaluations which are considered to lack research rigour, sampling, and adherence to a research method and/or comprehensive statistical analysis of the results. A score of 5 indicates papers with no research or substantial practice evaluation base to the clinical recommendations but are included as contributory evidence of expert opinion or practice consensus.

1.3.4 Evaluation

A first draft of the Bulletin was presented to 50 representatives from BAHT regional groups for critical comment. Their contributions are incorporated into the final edition. BAHT anticipates updating the Bulletin every 5 years.

1.4 Content

The Bulletin has 8 sections. The work has been divided to deal separately with flexor and extensor tendon injuries and injuries within different zones of the hand. It is intended that each section can be used independently for reference although they share the same format for easier access.

The Bulletin considers tendon injuries related to zones, which are illustrated below (Figs 1 & 2). The effective management of the hand is dependent on an appreciation of the range of mobility and different levels of expected function of the hand. Hunter et al (1995) notes the wide range of hand mobility. Some people are normally hyper-mobile at the interphalangeal joints and can spontaneously produce a swan-neck deformity. Some cultures promote finger hyperextension in dancing, or exaggerated ranges of motion develop from prolonged activity, as in potters' hyper extended thumbs, or sport. Therapists will need to assess and discuss concepts of normality with each client.

Successful therapy involves achieving the closest match to the 'normal' hand possible, but only the individual client can determine what that may be. Full negotiation of treatment plans is essential to reaching the optimum result, which might require either the client or the therapist accepting compromises on what aspects of hand function or appearance should be prioritised.

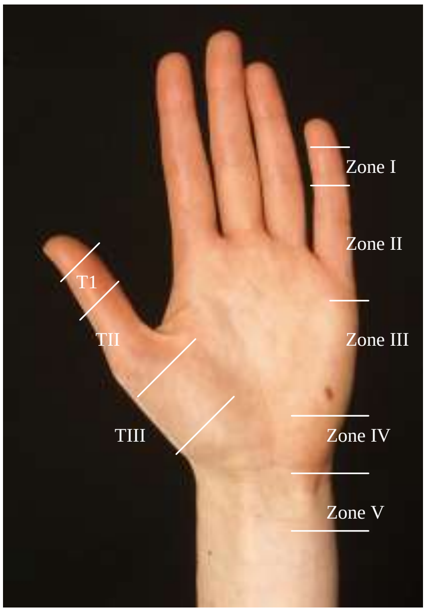

Figure 1. Flexor zones of the hand.

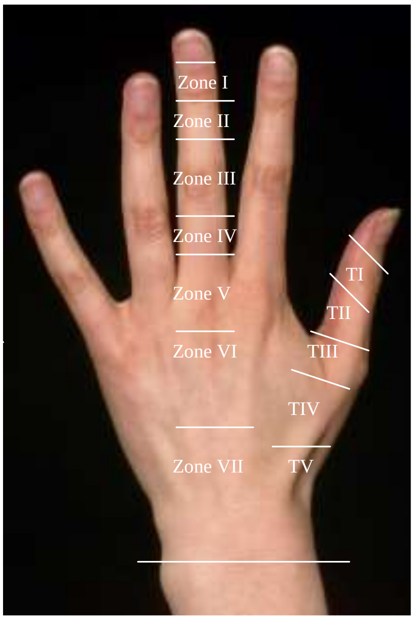

Figure 2. Extensor zones of the hand

1.5 Application of the evidence

The Bulletin acknowledges that while there is a drive to seek evidence for best practice, hand therapy is as much an art as a science. This requires the tailoring of protocols to the needs of the individual, their personality, occupations and culture as much as to their anatomical, physiological and psychosocial make-up. Hand therapists are faced with balancing the demands for evidence-based practice with expectations of providing client-centred care.

2.0 Mallet Finger Injuries

2.1 Definition

Mallet finger deformity occurs when there is a disruption or rupture to the extensor mechanism from its insertion at the base of the distal phalanx to the terminal part of the tendon. A flexion force on the tip of the extended digit causes the extensor tendon to tear or stretch at the distal interphalangeal (DIP) joint. The injury can be open or closed (Garberman et al 1994). Open injuries result usually from sharp objects or crush injuries. Closed injuries often occur when there is forced flexion at an already fully extended DIP joint or extension forces are applied over the joint in any position. These injuries generally heal well with a return of full function, but their management is controversial (Okafor et al 1997).

2.2 Aetiology

The most common causes of mallet deformity are sport (McCue & Meister 1993) or work related injuries (Brzezienski & Schneider 1995). However they may also result from the accidental application of minor forces occurring when making beds, or dressing and undressing (Geyman et al 1998). Foucher et al's study (1996) with 156 patients recorded that 34% injuries were domestic in origin, 33% were caused by sport and 21% were work-related, while Shankar & Goring (1992) classified injuries as resulting from falls (24%), fights (19%) and ball games (17%). The association with ball game injuries explains its various nomenclatures as 'baseball finger' or 'cricket finger'. The cause may also be genetic (Jones & Peterson 1988), associated with other pathologies such as trigger finger, diabetes, rheumatoid arthritis, chronic obstructive pulmonary disease (COPD) or may occur spontaneously (Brzezienski & Schneider 1995). There has been a marked shift away from patterns of causation in Abouna & Brown's (1968) study where 25% injuries were crush related and 73% injuries occurring at work. This probably represents a shift from manufacturing employment and increased safety at work.

Mallet finger injuries occurs twice as more often in men than women (Niechajev 1985), and there is an age difference with female patients being on average 10 years older than males (Geyman et al 1998). The deformity is said to occur most often in the little finger, ring and middle finger, and index finger, in that order and in the non-dominant hand (Auchincloss 1982). Although Niechajev (1985) found no prevalence in the little finger nor in hand dominance, Crawford (1984) found 60% cases occurred in the dominant hand. However, the incidence in patient samples in research projects suggests no clear pattern except that injuries are uncommon in the index finger (Table 2).

Table 2. The incidence of mallet finger injuries in the fingers of the hand

Author/s	Index	Middle	Ring	Little
Auchincloss 1982	7%	29%	29%	34%
Foucher et al 1996	Not stated	42%	Not stated	Not stated
Groth et al 1994	7%	23%	30%	40%
Hovgaard & Klareskov 1988	0%	36%	48%	16%
Niechajev 1985	5%	33%	31%	26%
Richards et al 2004	0%	32%	36%	32%
Okafor et al 1997	6%	20%	42%	32%

The pattern of closed injuries depends on the distal interphalangeal (DIP) joint position and the direction of the force at the time of injury. Direct trauma occurring to the partially flexed (less than 45°) distal phalanx is usually passively correctable. The more extended the DIP at the time of injury, the greater the risk of a large articular fracture at the base of the distal phalanx with instability related to injury of the collateral ligaments (Hunter et al 1995). As a mallet deformity may not occur at the time of injury, patients may not seek immediate treatment and delayed referral for treatment is not uncommon. The untreated finger, however, is often painful and eventually develops the deformity (Hunter et al 1995).

Chronic deformity may present as a single mallet of the DIP joint, or as an imbalance of the whole finger resulting in a swan-neck deformity, developing from compensatory hyperextension at the proximal interphalangeal (PIP) joint (Grundberg & Reagan 1987). Deformity creates a significant therapeutic challenge often requiring both surgical reconstruction of the structures of the joints and splinting. Improvement may take at least a year; the extensor lag may reduce over time as the scar shortens or there is adaptive shortening of the tendon (Hunter et al 1995).

2.3 Diagnosis and clinical features

Presenting symptoms are a mallet deformity and pain at the injury site. X-ray examination is required to identify any fractures and their extent.

2.4 Prevalence

Mallet finger injuries are common. Kings Mill Hospital (2003) calculated 47% of all extensor tendon injuries are zone I injuries and 34% of all tendon injuries referred for outpatient occupational therapy were mallet injuries. Some units treat these problems in accident and emergency (A&E) (Cohn & Froimson 1986) and referrals for complications to hand therapy are very few in number (Semmons 2001). However, the injury can be missed on initial presentation, which is relevant as early intervention can prevent pain, dysfunction and long term complications (Perron et al 2001).

2.5 Aims of treatment

There is general consensus that the distal interphalangeal (DIP) joint should be kept in continuous immobilisation for a period of approximately 6 weeks while healing of the extensor tendon takes place (but allowing full mobility of the unaffected PIP and metacarpophalangeal (MCP) joints). Small fractures can also be treated conservatively in this way (Okafor et al 1997).

Two forms of immobilisation have been tried; a surgical technique using a Kirschner wire or the use of splints. Surgical treatment generally is stated to be the treatment of choice where there is more than approximately 30% fracture of the articular surface. Conners (1995), in a short discussion paper, and Foucher et al (1996) as part of a research study suggested that fractures involving more than 25% of the articular surface should be treated surgically. Yet, there were high morbidity rates associated with surgery. Stern & Kastrup (1988) recorded over 50% of cases with complications when treated surgically. Lester et al (2000) listed these as "infection, nail deformity, joint incongruity and pin or pull-out wire failure" (p202). Surgery has been suggested as only appropriate in the presence of irreducible fracture-dislocations (Okafor et al 1997). Evidence indicates that these and even larger fractures can also be treated conservatively with good effect (Hunter et al 1995). However this approach is not without its own possible complications of tape allergy, dorsal skin breakdown and fingertip maceration (Stern & Kastrup 1988, Rayan & Mullins 1987, Lester et al 2000).

Auchincloss (1982) and Clement & Wray (1986) compared surgical and splint immobilisation. Auchincloss (1982) evaluated surgical intervention using Kirschner wire, versus conservative treatment, using a Stack splint, in a controlled prospective study. Despite considerable methodological weaknesses, the study indicated that both approaches achieved similar results, although good results were related to early commencement of treatment. However, surgical internal fixation of the DIP was associated with a higher incidence of infection. The evidence suggests that surgery is contra-indicated in most cases because of potential complications.

Table 3: Comparisons of surgical versus splint immobilisation of the DIP joint in mallet injuries

Author/s & dates	Method	Sample size	Findings	App. score
Auchincloss 1982	Controlled prospective trial	41 patients	Random patient allocation to surgical or splint protocols. Surgical and conservative treatments achieved comparable results. No statistical analysis.	2
Clement & Wray 1986	Clinical series	41 patients 44 digits	No difference in DIP flexion & extension; DIP TAM; PIP flexion & extension, cold intolerance or pain between surgical and conservative treatment except where fracture exceeds 25% of articular surface. PIP stiffness critical in determining final function.	4
Geyman et al 1998	Literature review	41 articles	No significant difference between surgical and conservative treatment outcomes. Immobilisation required for 6 or 8 weeks.	6
Niechajev 1985	Follow-up clinical series	135 patients	Compared surgical and conservative treatments (splint group) ROM- splint group 42% had minor limitations, but only 18% expressed dissatisfaction. Fracture group- 60% surgically repaired- 58% of fracture group achieved excellent results.	4
Stern & Kastrup 1988	Clinical review of complications	129 digits	Complication rate: splints 45%; surgery 53%. Splint complications- skin related & transient. Surgical complications – infection, joint incongruity & nail deformity 76% surgery complications still present at 38 months	4

Geyman et al's (1998) comprehensive review pooled the results of 26 articles which met their criteria. They reported that 77% of cases were successfully treated using conservative methods compared with 85% using surgical techniques, using an outcome measure of less than 20° extension lag as a measure of success. This may be considered a generous margin. They also applied success criteria as- less than 50° flexion arc, no functional impairment and 90% patient satisfaction. Evaluation of surgical outcomes was based on only three papers, where more complex and severe injury might be expected. There are problems too with pooling of results often based on expert opinion and/or different assessment scales, without clear inclusion and exclusion criteria of the original studies.

Most evidence supported the use of conservative methods, suggesting that the initial treatment of mallet finger injuries should be conservative, with the choice of splint type not having a significant effect on functional outcome. Geyman et al (1998) suggested 3 broad practice recommendations, based as much on expert opinion as analysis of research literature:

1. "The involved finger should be splinted in slight hyperextension of the DIP and moderate flexion of the PIP joints.
2. Patients should be shown how to change the splint carefully, with assistance as necessary, for periodic cleaning without allowing *any* flexion of the DIP joint.
3. Continuous immobilisation should be maintained for at least 6 weeks (some suggest 8 weeks), followed by an additional 2 weeks at night." (p388)

In addition to the debate between surgical and conservative methods, there are controversies regarding the relative effectiveness of various splints; whether the fixation should be internal or external; the DIP joint should be immobilised in neutral or hyperextension; early or delayed treatment optimises outcomes and the duration of the immobilisation period. Evidence on these issues is summarised in Table 4.

Table 4: Evaluation of splinting interventions for mallet injuries

Author/s	**Method**	**Sample size**	**Comparative findings**	**App. score**
Brzezienski & Schneider 1995	Clinical study	N/A	Ideal treatment 6-8weeks immobilisation of DIP in external splint. Surgery may be indicated if rupture to avoid second period of immobilisation. Period of delay before commencing effective treatment is extending.	5
Garberman et al 1994	Retrospective comparative study	40 patients 21 early 19 delayed	Presence or absence of dorsal lip fracture less than third articular surface had no effect. Type of splint used had no effect. Splinting as effective in delayed treatment population as early treatment population	2
Maitra & Dorani 1993	Quasi experimental study.	60 patients	Stack v custom-made splint Both splints equally effective in correcting the deformity Custom-made splint caused fewer skin problems Age affects outcomes. Patients over 40 years old do less well	2
Okafor et al 1997	5 year follow-up (30-74 months) comparative study	31 patients	Delay in splinting not found to be related to extension deficit. Prolonged splinting was significant in reducing ext. lag Arc of flexion reduced in mallet injuries with fractures. 32% reported impairment; 10% dissatisfied.	3
Patel et al 1986	Clinical study	10 patients	Evaluated chronic mallet fingers 4 -18 weeks post injury Treated conservatively for 8 wks 50% excellent, 40% good Splinting predictable and safe for chronic injuries	4

The evidence suggests that splinting is effective in the treatment of mallet injuries, and that while immediate immobilisation is ideal, good results can be achieved even when intervention is delayed. However, Okafor et al's study (1997) highlights an imbalance between surgical evaluation and client satisfaction with final functional outcomes. A recent systematic review (Handoll & Veghela 2004) highlights the poor quality of much of the research and suggests that there is insufficient evidence to establish the effectiveness of any splint or indeed splinting over no treatment at all.

2.6 Treatment

2.6.1 Splint Types

Simple splints were developed by Abouna and Brown (1968) and Stack (1962) to immobilise the DIP joint. Early concerns that movement proximal to the DIP joint might also need to be prevented for good outcomes was shown to be unfounded, confirming the use of splints designed to only immobilise the DIP joint (Katzman et al 1999). There is, however, continuous debate about the most appropriate material for splint construction (types of thermoplastics or plaster of Paris (POP)), and discussion of the value of tailor made splints over off-the-shelf models (Maitra & Dorani 1993).

Splints have been made of POP, dorsal padded or palmar unpadded aluminium (Lester et al 2000), rubber-coated wire (Abouna & Brown 1968) or thermoplastics, either of a solid or mesh format (Foucher et al 1996). While POP has been suggested to reduce skin maceration, thermoplastics are suggested for hygiene and easier cleaning. There is no clear evidence of one being more effective than another, although modifications to avoid skin complications have been developed and proved effective (Table 5).

Table 5: Evidence of splint types and effectiveness for treating mallet injuries.

Author/s & dates	Splint type	Sample size	Method, Findings & claims	App score
Auchincloss 1982	Stack	50 patients 41 patients available for follow-up	Prospective controlled trial. 2 groups randomly allocated to surgical or splint group. Patients initiating treatment in 1st week did better than those in the 2nd week. The latter group may do better with surgical fixation.	2
Crawford 1984	Stack	151 cases 166 digits	14 year follow-up study Claim effective even for complex cases including extensive fracture. Poor results attributed to improper splint wearing or changing by the patient.	4
Evans & Weightman 1988	PIPflex splint	25 patients	Splint in 2 parts which maintain DIP extension and PIP flexion. Treatment period reduced in some cases to 3 weeks. Average 5.8 weeks. Claim method superior to other splints but time in splint altered during study.	5
Foucher et al 1996	Dorsal X-lite (perforated plastic)	156 (over 5 years)	At 6 months mean ext. lag = 7° At 5 years ext. lag = 5° Active flexion unchanged through study Claim that long term follow-up of splinted mallet injuries treated by this method is not necessary.	4
Hovgaard & Klareskov 1988	Elastic double-finger bandage	29 patients	Prospective trial Claims-no disadvantage over other splints Protocol more agreeable to patients - hygienic & reduces skin irritation	5

Kinninmonth & Holburn 1986	Perforated Stack type	54 patients	Controlled trial; perforated v conventional splint materials. Perforated splint does not have to be removed for hygiene. Claims especially effective for patients unable to manage removal and replacement of splint.	4
Lester et al 2000	Foam padded aluminium	37 patients -closed mallet injuries	Splinted in 0° extension Splint simple, easily reproducible and easy to use. 95% excellent results Compares favourably with other splints	5
O'Connor 1997	Tape splint	Not stated	Teaches the client or a carer to use 1cm tape wrapped across the joints to hold the DIP in slight hyperextension & PIP in 'mild flexion'. Cheap and easy to apply Tape can be regularly changed.	5
Richards et al 2004	Prospective clinical series	34 patients	Evaluation of custom made Stack splint 88% 'improved' with custom-made splint No difference in recovery between dominant and non-dominant hands, or tendon and bony mallet injuries 26% attrition rate from initial cohort.	4
Stack 1986	Prefabricated thermoplastic splint	1 patient	Created 2 large windows in a Stack splint. Reduces sweating and allows sensation on finger pulp.	5
Warren at al 1988	Comparison of Stack & Abouna Splints 1 year study	116 cases	Both splints equally effective Stack splint preferred by patients as more robust, comfortable and easier to clean.	4
Wilson & Khoo 2001	Mexican hat splint	Not stated	Designed to avoid skin necrosis Claimed to be effective	5

As can be seen, some claims are made for some splint designs in terms of special efficacy in reducing treatment time, skin irritation, hygiene or patient compliance. There is limited research evidence at present to indicate any guidelines for best practice in splint design or materials used. It is of note that while success rates in general with splinting are high, that patients with a small lag at the commencement of treatment do better than those with a greater extensor lag prior to splintage.

2.6.2 Joint position

Several authors favour splinting the DIP joint in slight hyperextension (Crawford 1984, Garberman et al 1994, O'Connor 1997, Green & Rowland 1984, Webhe & Schneider 1984, Foucher et al 1996, Geyman et al 1998). Others retain the DIP in neutral extension (Lester et al 2000, Maitra & Dorani 1993). Rayan and Mullins (1987) warn about 'overzealous' hyperextension of the DIP joint and advise therapists to ensure there is no sign of blanching on the splinted finger. Only two studies (Evans & Weightman 1988, Geyman et al 1998) recommend including the PIP joint in flexion. There is again, no strong evidence to support splinting in slight hyperextension over the neutral position.

2.6.3 Period of immobilisation

There are some differences in reported protocols for the period of immobilisation and subsequent night resting splintage. The differences are summarised below (Table 6).

Table 6: Evidence for recommended time periods for immobilisation in splints for mallet fingers

Author/s & dates	Period of splinting
Lester et al 2000	4-5 weeks in splint
Auchincloss 1982	6 week in splint/2 weeks night resting splint
Conners 1995	
Geyman et al 1998	
Groth et al 1994	
Kinninmonth & Holborn 1986	
Maitra & Dorani 1993	
Warren et al 1988	
Crawford et al 1984	8 weeks in splint
Foucher et al 1996	
Stern & Kastrup 1988	
Hovgaard & Klareskov 1988	6-8 week in splint
Moss & Steingold 1983	
Shankar & Goring 1992	
Garberman et al 1994	6-10 weeks, (average 7 weeks) in splint/4 weeks night resting splint

Justifications for these clinical decisions regarding time are not always available. An implicit avoidance of risk of tendon rupture in early splint removal may underpin the possibly extended periods of immobilisation. As assessment of tendon healing is impossible without taking a risk, therapists may be erring on the safe side (Lester et al 2000).

2.7 Assessment

There are a range of scales being used to evaluate treatment effectiveness of injuries to the extensor tendons, but these are often 'home-brewed' (Hunter et al 1995) and not standardised, often developed or adapted by authors for their own studies. They apply different criteria to assess excellent, good, fair or poor results (Table 7).

Table 7: Outcome measures and assessment tests for mallet finger injuries

Author/s and dates	Success	Improved	Failed
Abouna & Brown 1968 Warren & Norris 1988	0-5° DIP joint extension	6-15°	16°+

	Excellent	Good	Fair	Poor
Crawford 1984	Full DIP joint extension	1-10°	10(11)-25°	26° plus

Apart from reliability, the scores present some problems of validity. Burke (1988) suggested that "it is arguable whether a patient with 15° extensor lag and no stiffness or loss of flexion has any discernable disability, yet such a patient in this (Abouna & Brown 1968) classification would not be regarded as a success and would lie on the brink of the failure category. It seems likely that many patients in the failure category were in fact improved by splintage, yet insufficiently to register in such a stringent classification, which could be said to obscure rather than expose the effect of treatment" (p116). Conversely, many patients may express dissatisfaction with results medically considered to be excellent or good because of a limitation to some specific function or for cosmetic reasons.

~~3.8~~2.8 Prognosis

Formatted: Bullets and Numbering

The main complications of splinting a mallet finger were identified as skin maceration, itching, and the patient removing the splint without due care (Rayan & Mullins 1987). The first two problems have been found to be transient and more easily remedied than the complications of infection associated with surgery (Stern & Kastrup 1988). Patient education is considered essential by most authors to avoid problems arising from inappropriate splint removal.

Cold intolerance has also been reported as a problem in 25% patients being treated surgically and 50% being treated conservatively (Moss & Steingold 1983, Clement & Wray 1986, Shankar & Goring 1992). Warren et al (1988) reported a third of their subjects complained of cold intolerance even 6 months after treatment. Moss & Steingold (1983) suggested that this complication is more annoying to patients than pain, poor grip or 'catching' from an extensor lag. They also suggested that extensor lag and flexion limitations may not be experienced as disabling and so assessments which employ these as evaluation tools may not be sensitive to wider functional and sensory problems experienced by clients.

Okafor et al (1997) found 32% patients reported impairment, but only 10% were dissatisfied. In a long-term follow-up, Shankar & Goring (1992) in a clinical series of 100 cases identified dissatisfaction with treatment outcomes in 15% of their sample. 50% of this group had cold intolerance, 44% had occasional aches while 31% had pain when the finger was knocked. Within the satisfied group, 10% had a marked extension lag. Final physiological outcome measures appeared to poorly predict levels of patient satisfaction. Nakamura & Nanjyo (1994) suggested that the complications of stiffness and extension lag following splinting might be particularly problematic for clients needing fine manual dexterity, for which surgery might offer a better outcome.

2.9 Health economics

Some simple splint adaptations or construction techniques have been proposed as a means of limiting material or manpower costs. In a letter to the Editor, Gooding (1984) suggests using a plastic spoon to construct a splint which provides DIP joint hyperextension at minimal cost. However, as Stack splints and splints tailored from off-cuts of thermoplastic are cheap, this splint may have provided a solution to a problem that did not exist! Richards et al (2004) calculated an off-the-shelf Stack splint cost seven times as much as their custom-made splint, priced at 22p. Lester et al (2000) also claimed to have produced a cost effective splint, although no comparative cost analysis is offered. It is accepted, although not calculated, that conservative treatment is cheaper than surgery.

Mallet finger deformities appear to be considered simple to treat and yet patients are often required to regularly attend out-patient clinics during the period of immobilisation. The cost for attendance and therapy out-patient time are not included in the calculations.

2.10 Practice points

- While the DIP joint may be splinted in slight hyperextension or neutral extension with equal effectiveness, special care is needed to avoid skin blanching in hyperextension, which may lead to skin necrosis.
- There is no convincing evidence that any splint design is more effective than another.
- The evidence generally supports the continuous wearing of most splints for approximately 6 weeks.
- Choice of splinting material is important to the management of skin problems. A choice of alternative splinting material or lining may be required for sensitive skin and to limit maceration.

- Patients must be taught how to remove the splint for cleaning and avoid risky occupations and movements.
- There is no evidence about how the life style of the patient influences the selection or design of splints, but implicit data suggests that it affects treatment adherence and patient satisfaction.
- Effective treatment is anticipated to be dependent on patient adherence.
- Cold intolerance, skin problems and recurrence of ruptures are common problems requiring special management and education.
- The presence of extensor lag and flexion limitations appears to be poor predictors of patient satisfaction.

2.11 Research recommendations

There appears to be consensus agreement for the conservative treatment of all but the most severe fractures of the articular surface, based especially on expert opinion and clinical series. The following are suggested areas for research and audit:-

- The optimum period for immobilisation based on a calculation of risk.
- The most appropriate patient education or negotiation needed to avoid tendon rupture and recurrence of the lag.
- Explore the possibility for developing a valid and reliable standardised assessment.
- Investigate what degree of extensor lag represents disability and how that might be evaluated for different occupational groups or individual clients. The extent to which a complete absence of lag is a cosmetic ideal, employment imperative or therapy goal needs to be explored.
- The comparative functional implications of injury to the dominant or non-dominant hand.
- Crawford (1984) records 21% of his closed injury cases and 18% of patients with a fracture achieving fair to poor results, attributing these to "improper splint wearing or splint changing by the patient" (p234) An ethnography of the life of patients during the splint period might offer valuable insights into patients' beliefs and behaviours regarding their injury and the compatibility of treatment with life style.

3.0 Central Slip Injuries

3.1 Definition

When an open or closed injury occurs to the extensor tendon mechanism in zones III to IV over the dorsum of the PIP joint it is called a central slip injury. The extensor mechanism essentially consists of three relatively incompliant bands; the central slip, which arise from the extensor communis tendon and two lateral bands, which arise from the extensor digitorum communis (EDC) and the intrinsic muscles. If damage to the extensor mechanism in these zones is undetected or incorrectly managed after injury, a boutonnière (or occasionally referred to as a buttonhole) deformity may occur. Therefore early and effective diagnosis and treatment by surgeons and therapists is imperative for patients to regain good movement and function after this injury.

3.2 Aetiology

The extensor mechanism is particularly prone to injury, being located superficially on the dorsum of the digit and lacking soft tissue protection (Froehlich et al, 1988). There are 4 types of injury to zones III and IV which if left untreated or badly managed can lead to a boutonnière deformity (Coons & Green 1995, Massengill 1992, Imatami et al 1997): -

1. Open injuries associated with lacerations or burns.
2. Closed injuries resulting from forced flexion of a fully extended PIP, crush injuries or volar dislocations of the PIP joint with or without fractures.
3. Infected wounds resulting from subcutaneous and intra-articular infections.
4. Chronic inflammatory conditions occurring due to poor management of rheumatoid or arthritic conditions, including gout.

The most common causes of this injury seen within clinical practice are lacerations to the dorsum of the PIP joint and injuries involving forced flexion of the PIP joint especially within sport requiring early therapeutic intervention (Froelich et al 1988).

As stated earlier the most common complication associated with untreated or badly managed acute central slip injuries is a boutonnière deformity. Damage to the central slip, which lies on the dorsum of the joint, causes the lateral bands to drop volar, below the axis of the PIP joint. The new position of these bands results in them acting as flexors at the PIP, but accentuates their extensor pull at the DIP leading to hyperextension at this joint (Froehlich et al 1988). Therefore the term 'boutonnière' refers to the process whereby the head of the proximal phalanx herniates or 'buttonholes' through the defect at the central slip, stretching or tearing the triangular ligament (Coons and Green 1995). Once these triangular ligaments tear, the PIP joint becomes destabilised and the oblique retinacular ligaments quickly become shortened which adds further DIP hyperextension (Boscheinen-Morin & Conolly 1997). Therapists also receive referrals for the treatment of developing boutonnière deformities to either help correct the deformity or improve range of motion prior to surgical intervention. The boutonnière deformity can have different pathological stages, which are shown below. Therapy will make little difference to the later stages (Newport et al 1990).

Table 8: Stages of development of a boutonnière deformity

Stage 1	Weak extension of the PIP caused by the loss of the central slip. The joint may rest in flexion with disruption of the central slip: extension still exists via the lateral bands.
Stage 2	With stretching of the triangular ligament and contracture of the transverse retinacular ligament, the lateral bands migrate and are fixed volar to the axis of PIP joint rotation. With the volar position of the lateral bands, there is now a loss of active PIP extension.

Stage 3	With the lateral bands in the volar position, the extensor force of the intrinsic muscles is directed exclusively to the distal joint, which progressively hyper extends. The MP joint also may hyperextend because the central slip no longer activates PIP extension.
Stage 4	Fixed flexion at the PIP joint secondary to volar plate or ORL contracture.
Stage 5	Boutonnière deformity with joint destruction.

Taken from Coons & Green (1995: 389-390)

3.3 Diagnosis and clinical features

The extensor tendon mechanism is exceptionally delicate and unforgiving and has far less tolerance to changes in tendon length than the flexor system (Froelich et al 1988). However, while flexor tendon injuries have been widely investigated and surgical and rehabilitation protocols established, extensor tendon injuries are often treated by less experienced staff or go unrecognised (Evans 1995). Less research may have been carried out because extensor tendon injuries have been considered to be unproblematic in the past.

A clear history including the mechanism of injury must be taken from all patients presenting with injury to this region. All patients with lacerations to this region should undergo a thorough examination by experienced staff (Newport 1997). This should establish the extent of injury (even if it initially appears superficial) and assess whether the central slip or lateral bands have been disrupted or require repair. The extent of the central slip damage in zones III and IV may not be apparent immediately post injury, especially with closed injuries (Elson, 1986). Presentation of a swollen painful joint in A&E with no pathology detectable on X-ray may result in discharge. These patients often present with a boutonnière deformity having developed slowly over a period of 2-3 weeks (Froehlich et al 1988). These deformities can also slowly occur in patients diagnosed with arthritic complaints due to the disruption of the central slip.

There are different opinions in the literature on the correct method to use for diagnosis. Boyes' test (1970) for assessing rupture of the central slip is widely reported. However, as it depends on the retraction of the proximal end of the ruptured central slip and its adhesions to surrounding tissues, it will not provide a positive result until, the adhesions form, making its efficacy poor in the early stages (Elson 1986). Elson (1986) suggests an alternative test for the integrity of the central slip in which the affected digit is flexed at right angles at the PIP joint over the edge of a table and held there by the tester. The patient is then asked to extend the PIP joint. Any pressure felt by the tester through extension of the middle phalanx can only have been produced by the central slip and indicates that it is not ruptured. Proof of non-injury is confirmed if the DIP remains flail in the test position, indicating that the functioning central slip is preventing the lateral bands from acting distally.

Smith and Ross (1994) suggest a different method of diagnosis. The tester places a finger on the dorsum of the proximal phalanx of the injured finger and by exerting gentle pressure, causes flexion of the MCP joint. If the central slip is intact, passive extension of the PIP will occur as a tenodesis effect. If the central slip is ruptured, an extension lag will occur. A range of other tests have also been published (Carducci, 1981, Lovett and McCalla, 1983) but there is little research evidence to identify the most reliable procedure. In a study using human cadavers, included here because of the limited evidence for assessment, Rubin et al (1996) compared the effectiveness of the five medical tests developed by Boyes (1970), Carducci (1981), Lovett and McCalla (1983), Smith and Ross (1994) and Elson (1986).They concluded that the Elson (1986) test described earlier was the most reliable.

3.4 Prevalence

The incidence of zone III and IV injuries for each digit was reported in several studies and shows no consensus on the most commonly injured digit as seen below in Table 9. Most studies within the literature use small sample sizes and a range of mechanism of injuries. Results are also included for simple acute injuries and more complicated injuries including bone and joint injury.

Table 9: Occurrence of central slip injuries in the fingers

Author/s & date	Total digits	Index	Middle	Ring	Little
Caroli et al 1990	20	15%	25%	20%	40%
LeBellec et al 2001	47	15%	30%	30%	25%
Maddy and Meyerdierks 1997	7	43%	43%	0%	14%
Pratt et al 2002	31	39%	35%	16%	10%
Salana et al 1991	22	18%	27%	27%	27%
Thomes & Thomes 1995	29	41%	24%	14%	21%

3.5 Aims of treatment

The aim of therapy is to protect and treat early repaired or early-diagnosed conservatively managed central slip problems (Crosby and Wehbé 1996) to prevent an acute injury becoming chronic and intractable. Most of the literature found discusses the rehabilitation of acute injuries. As central slip injuries can be easily missed or misdiagnosed, the therapist should be alert to their possible presence and subsequent development of the boutonnière deformity.

Pratt et al (2002) suggest treatment aims are to:

1. Protect the central slip while recovery occurs (once diagnosed and repaired if necessary).
2. Promote tendon gliding.
3. Prevent deformity and extension lag.
4. Regain strength and function.

As with all tendon injuries a major role of the therapists is to educate the patient on the anatomy of the region, possible complications and the importance of rehabilitation on the overall prognosis.

The most common unwanted side effects of the disorder are insufficient tendon excursion resulting in reduced flexion, extension deficits, joint stiffness and resultant loss of finger flexion (Evans and Thompson 1992). Newport et al (1990) reported that the loss of flexion was a significant complication for extensor tendon injuries and was most apparent in zones III and IV. Oedema is also a major concern after injuries to the PIP joint and if not effectively treated early can persist for many months. Constructing or fitting splints in the early stages is often difficult because of both swelling and pain, so patients may need more intensive monitoring in the early stages. Measuring the joint position may be difficult or inaccurate for the same reasons.

If the injury has already developed into a boutonnière deformity by the time of referral therapy aims would be to improve range of motion especially PIP joint extension and DIP joint flexion before surgical options can be considered or performed. Subsequent post-surgical therapy generally follows the same pattern as for early closed or open injuries (Massengill 1992). Caroli et al (1990) does report on the operative success of established post traumatic boutonnière deformities. All 20 patients discussed in the paper had achieved full passive range of motion prior to surgery and they reported 72% of patients gained excellent outcomes after this delayed surgery.

3.6 Treatment

3.6.1 Splinting

A review of the literature offers no clear evidence that one splinting regime is significantly more effective than another for acute injuries within zones III and IV and there are few comparative research papers. Pratt et al (2002) suggest that there are 4 main treatment options being utilised in practice.

- 6 weeks immobilisation of the PIP joint, followed by an exercise regime.
- Dynamic extensor splint (DES) regime initiating movement within the splint a few days post-operatively or diagnosis.
- Controlled early active short arc motion (SAM) protocol using volar based finger splintage and commencing mobilisation within a few days post-operatively or diagnosis.
- Immobilisation of the PIP joint for 2-4 weeks and then mobilisation within a dynamic spring coil finger splint (sometimes referred to as Capener splints).

Despite different regimes for the treatment of the PIP joint being offered, Pratt suggests that the general consensus from the literature is that, unless lateral band damage is also found, the DIP joint should be free of the splint to mobilise immediately (Pratt et al, 2002). This prevents the development of tightness in structures like the oblique retinacular ligament (Crosby and Wehbe, 1996, Massengill, 1992). Most protocols also recommend a further period of night splinting after the initial period of continuous splinting ends, especially if an extension lag occurs.

The traditional method for treatment of acute central slip injuries has been a period of immobilisation of the PIP in a splint, usually for six weeks, followed by a programme of exercise for the PIP joint (Crosby and Wehbe 1996). This was thought to allow sufficient time for healing to occur before the stress of mobilisation was introduced. However, this method has been associated with problems of limited finger flexion initially and subsequently extension lagging and contractures of uninvolved joints especially the DIP joint and chronic pain (Rolph-Roeming, 1992). He further suggests that tendon to bone adherence in zone IV elevates tension at a zone III repair site when early gliding of the tendon (later than 4 weeks post injury) is not performed. Evidence in the current literature for the effectiveness of this 6 week static splinting for central slip injuries is limited, although it is offered as the regime of choice (Boscheinen-Morrin & Conolly 1997). Walsh et al's (1994) retrospective methodology showed no significant difference between a 4-6 week PIP joint static regime and a dynamic extensor splintage protocol. They stated there was little difference in the outcomes of their range of motion or numbers of outpatient visits. However, the small sample size and the lack of specific information on methods limit its trustworthiness.

As with all tendon surgery improved surgical materials and techniques have offered opportunities to develop early active mobilisation regimes for central slip rehabilitation within different types of splintage. However, it should be noted that evaluations and comparisons of studies reporting outcomes after utilising these early motion techniques cannot be directly compared with traditional static splinting techniques outcomes. Often surgical methods, suture materials and techniques and adaptations to splints are not recorded or discussed. The literature also indicates a lack of consensus about outcome measures appropriate for the rehabilitation of this condition.

The majority of papers report the use of dynamic extensor splints (DES) that allow early active flexion of the digit but then pull the joints back into extension. These can be further divided into hand-based dynamic extensor splints which just support the finger (Walsh et al 1994, Thomes & Thomes, 1995) and forearm-based dynamic extensor splints, which immobilise the wrist joint as well (Saldana et al 1991, Hung et al 1990, Bryon 1997). Hung et al (1990) uses the same dynamic extensor splint for all extensor tendons zones (III –VII) and found that the more distal zones had the poorer outcomes. This suggests that zones III and IV central slip injuries should be treated differently from the other extensor zones due the region's complex anatomy. Evans and Thompson (1992) categorically states that patients with this injury at zone III-IV should not have their wrist joint immobilised within a DES and this is also questioned by Rolph-Roeming (1992). Thomes and Thomes (1995) and Walsh et al (1994) recommend that the DES limits PIP joint motion to 30 degrees initially and this range is gradually increased over the next weeks. It is unclear from the evidence whether the wrist should be immobilised and in what position. Despite the literature reporting successful outcomes with the use of DES for zone III and IV injuries, this splint requires skilled hand therapists to make, apply and monitor it and therefore may be not accessible to all departments treating these injuries.

Evans and Thompson (1992) have proposed the efficacy of a regime they called 'early short arc motion' (SAM) based on sound physiological evidence of the tendon to bone interface within zone IV of a finger. This regime allows early controlled motion of the PIP joint initially to 30° flexion at the PIP joint utilising a small volar hand-based splint instead of the bulky and expensive DES. The aim is to provide early controlled motion and prevent tendon to bone adherence especially in zone IV. The 30° motion at the PIP joint allows 4 mm of extensor tendon excursion, which is stated to successfully reduce adhesions in this region. They also recommend PIP joint exercises with the wrist joint in 30° flexion to reduce flexor resistance, facilitate interossei function and therefore reduce the work of the extensor digitorum. In between exercises the PIP and DIP joints are immobilised in 0° within a volar finger splint. Evans (1994) discussed the positive results obtained with the SAM regime compared with their old regime of 3 weeks immobilisation of the PIP joint regime. But she provided very little information on what occurred after 3 weeks immobilisation of the PIP joint with their old regime, comparisons are difficult to make with other studies.

A regime utilising circumferential Plaster of Paris (POP) or a thermoplastic splint to immobilise the PIP joint initially (3-4 weeks) followed by mobilisation of the PIP joint within a spring coil digit splint (Capener splint) has also been reported with good results (Walsh et al 1994, O'Dwyer & Quinton, 1990, Pratt et al 2002, Caroli et al 1990). Boscheinen-Morrin and Conolly (1997) recommend a POP cast when the digit is swollen as it provides 'gentle even compression and will alleviate joint discomfort'. This regime allows some healing to occur initially but hopefully mobilises the PIP joint before adhesions can occur within zone IV. Table 11 summarises the main literature found on this injury most of which utilise a splintage regime allowing motion of the PIP joint before the traditional 6 weeks post injury or operation. Two other papers were found (Berman and Failla 1995, Bryon 1997), which discuss how splints can be made for zone III and IV injuries but they do not present any outcomes, only descriptions of their splints.

Table.10: Evidence of splint types and exercise regimes for treating central slip injuries.

Author/s & dates	**Splint type**	**Sample size**	**Method, Findings & claims**	**App. score**
Berman & Failla 1995	Adapted Stack mallet finger splint	Not research based	Splint places PIP joint in 'mild' hyperextension. Removal of distal section of Stack splint allows free DIP flexion.	5
Byron 1997	Rotterdam splint Forearm-based	Not research based	Secure PIP in full extension between exercises, mid-phalanx fixation for DIP exercise & avoids lateral forces affecting joint replacements. Claims it offers extra night protection	5

Evans & Beach 1994	Thermoplastic immobilisation splint v immobilisation splint plus SAM exercise splint	55 patients 64 digits	Comparison protocol and simple v complex injuries Group 1- 3-6 wks immobilisation then 'vigorous standard rehab program. (Retrospective review) Group 2 – SAM exercise protocol commenced 2-11 days post op. Gp 1- 42% excellent/good results Gp 2- 65% excellent/good results Claim SAM is safe, simple, effective, comfortable & inexpensive	2
Evans 1994	Quasi experimental comparison of immobilisation v exercise in volar finger splint	55 patients 64 digits	Group 1 3-6 weeks immobilisation of PIP joint regime not clear. Group 2 Hourly exercises for PIP joint (30° flexion then 40° 2 weeks later) and DIP joint within volar finger splints. (20 times /hour) Finger rested in between in extension finger splint IP joints neutral.	2
Evans & Thompson 1992	Literature review		Seeks to identify 'precise parameters for tendon excursion (3.75mm in healing phase), force application (286-291g) & exercise position for SAM protocol (30° wrist flexion, MCP joint 0° extension or slight flexion) & distal joint unrestrained.	6
Hung et al 1990	Forearm-based DES used for all zone II-IV injuries.	38 patients 48 digits	MCP joint flexed 70° and IP joint extended. PIP joint limited 30° flexion. Dynamic splinting commenced at 3 days post-op. 2/3 x week therapy until return to work lesions distal to knuckles (zones II, III, IV) showed worst results. Poorest results in crush injuries Controlled early motion useful for extensor tendon injuries.	4
Maddy & Meyerdierks 1997	Retrospective case study - zone III injuries	5 pts 7 digits	1x week visit 0-3 weeks immobilise PIP joint and exercises for DIP joint 3-6 weeks Capener splint and PIP joint mobilisation (10 exercises/hour) The more rigid the immobilisation of the PIP joint the better the DIP joint flexion achieved. 100% excellent results (Strickland-Glogovac 1980) Methodological weaknesses, Suggest finger-based splinting only, early DIP flexion exercise with PIP in neutral & early referral.	5
O'Dwyer & Quinton 1990	POP & Capener splint.	99 patients	0-2 weeks finger immobilised in POP. 2-6 weeks mobilising PIP joint in Capener splint. DIP joint or exercises schedules not specified. Patients followed up at 2/3 week intervals until 8 weeks post op. 88% excellent/good results at 6 months(TAM Kleinert& Verdan 1983). Poor results linked to complexity of injury & non-compliance. Advocate early mobilisation for middle slip injury	4

Pratt et al 2002	Prospective review Capener coil splint- zone III	27 patients 31 digits	3 weeks static immobilisation of PIP joint with hourly DIP joint exercises. 3-6 weeks mobilise PIP joint in Capener coil splint 10 x hourly with no limitation to range. 100% excellent/good results (Strickland & TAM Kleinert & Verdan 1983) Suggest uncomplicated & complicated injuries can be treated with this regime week	4
Saldana et al 1991	Forearm-based dorsal finger extension assisted splint	19 patients 22 digits	6 week dynamic extension programme plus 4-6 week grip strengthening prog. 3 wks forearm-based splint (controls MCP, allows DIP and immobilises PIP joint motion. Then 3 wks PIP motion & 2 months OT follow-up. 91% excellent/good results (Dargan 1969) Suggest carefully monitored DES is safe. Results better than retrospective results of static regime.	4
Thomes & Thomes 1995	Prospective consecutive study of hand-based DES.	27 patients 29 digits	6 week programme. Splint MCP joint 20º flexion, then graded controlled motion of PIP joint through 30°, 40°, and 50°. Exercise 10/20 times per hour. DIP joint free. Traction removed at 4 weeks allowing unresisted exercises. Splint discontinued at 5 weeks. Only 3 patients with extension lag. 100% excellent results (Strickland-Glogovac 1980) Outcome dependant on resting position. Therapy intensive in early stages	4
Walsh et al 1994	Retrospective & prospective comparison of static extension splinting (SES) v early controlled motion protocol (ECM).	25 patients 31 digits	Group 1 PIP joint immobilised neutral/MCP joint immobilised 70 degrees for 4-6 weeks. 1st seen at 4 wks post op then 2/3 x week Group 2 Hand based DES. MCP and PIP joint neutral. PIP joint flexion to 30 degrees 10 times every 2 hrs. Full DIP, wrist joint motion allowed. Splint discontinued after 4 weeks Seen weekly until 4 weeks, then 2/3 weekly. Multiple evaluations of outcomes. No statistical differences on any variable. Sample too small. Suggest that ECM group require less therapy time overall & recommend DES early motion for uncomplicated injuries.	2

3.6.2 Joint positioning

There is contradictory evidence concerning the most effective position for the hand joints when splinting zones III and IV injuries. As shown earlier, some DES splints include the wrist joint while others are just hand based. A particular, unresolved debate exists concerning whether slight hyperextension of the PIP offers any special gains for tendon healing, but most of the literature discussed above report they placed the PIP joint in neutral or full extension. Thomes and Thomes (1995) and Bergman and Failla (1995) recommend PIP in mild hyperextension but state no specific degree although they do mention that it must concur with the patient's normal hand. This is to improve the approximation of the torn ends of the central tendon, encouraging tendon healing at the proper length

3.6.3 Exercise regimes

Traditionally, zone III –IV central slip injuries have been treated for 6 weeks with immobilisation of the PIP joint in extension with a splint or trans-articular K-wire (Doyle 1993). More recent protocols as discussed above recommend earlier motion of the PIP joint to prevent stiffness and adherence, which can lead to extensor lagging and loss of flexion. The protocols differ in the recommended period of immobilization required before active exercise is started. Saldana et al (1991) uses a DES splint, which initially allows motion of the DIP and MCP joint, but immobilise the PIP joint. Walsh et al (1994) and Thomes and Thomes (1995) initiate PIP joint flexion immediately after surgery (2-7 days post-operation) using dynamic extension splints but limit the degree of flexion. Evans and Beach (1994) started early SAM of the PIP joint within 2-11 days post-operation and again limited the degree to 30 initially. Others delay the start of PIP joint mobilisation by 2 weeks (O'Dwyer and Quinton 1990) or 3 weeks (Maddy and Meyerdierks1997, Pratt et al 2002) or 4 weeks (Caroli et al 1990, Newport et al 1990). Despite this disagreement in time scales only literature by Evans and Thompson (1992) discusses in any detail the physiological reasons around their decisions to mobilise the PIP joint early (2-11 days post operation) and within a limited and controlled range of motion.

The earlier PIP joint mobilisation programmes have the reported advantages of reducing the incidence and severity of complications of prolonged immobilisation in a static splint, including adhesions of the lateral bands (Maddy and Meyerdierks 1997), DIP joint hyperextension and stiffness (Crosby and Wehbe 1996, Massengill 1992). Movement also assists in reducing oedema and earlier active rehabilitation may have positive effects on patient motivation. Unfortunately many papers do not discuss their exercise regime in detail.

Most regimes using hand based splintage indicate patients are encouraged to exercise the MCP and DIP joints during the period of PIP joint immobilisation. Pratt et al (2002) recommend hourly active flexion and extension exercises and passive extension. Where dynamic splints are employed, the PIP joints are actively encouraged to flex and the splint ensures the return to full extension after each exercise. The SAM regime (Evans and Beach 1994) provides two volar exercise splints; the first allows active flexion of the PIP joint to 30° and DIP joint to 25°. The second immobilises the PIP joint in extension and allows free active flexion of the DIP joint. Between exercises a third splint is used to immobilise the DIP and PIP joint in 0°.

Whichever of the regimes above are chosen, the consensus is that forced flexion of the PIP joint should be avoided to ensure no attenuation of the tendon and a return of the deformity. Following a typical period of central slip protection of around 6 weeks passive flexion of the PIP joint may be commenced depending on the patient's active extension (Walsh et al 1994). A programme of strengthening exercises is generally recommended, with special work rehabilitation for identified clients. Identifying and assessing factors associated with return to work is mentioned but not specified within the available literature.

Table 10 also reviews the frequency of therapy sessions required to achieve the outcomes attained. Many authors utilising the dynamic extension splintage regime indicate a frequency of post-operative therapy attendance of 2-3 times weekly (Hung et al 1990, Saldana et al 1991, Walsh et al 1994) which is quite intensive and may not be achievable in many hand units. Maddy and Meyerdierks (1997) and Pratt et al (2002) utilising delayed mobilisation until 3 weeks post-operation achieved their positive outcomes with weekly therapy sessions. Other authors do not discuss this important issue (Evans 1994, Newport et al 1990, Caroli et al 1990). Evans and Thompson (1992) claim SAM reduces the total period of rehabilitation, the incidence of extension lag, deformity and rupture rates but do not discuss the frequency of therapy required.

A comparative analysis of the relative effectiveness of these exercise protocols is difficult as there is no shared assessment procedure to which all have been subjected. The educational programmes given to patients and the specific exercise regimes are not often fully described or clinically reasoned, although they are considered key to excellent results (Thomes and Thomes 1995).

3.7 Assessment

The literature indicated that there is no consensus on which outcome measure /assessment test is the most effective in reviewing results after zone III and IV central slip injuries. The absence of a standardised measure also makes it extremely difficult to review and compare the results from the different regimes in the literature. As Table 11 shows, the largest number of authors have reported the total active motion of the PIP and DIP joints using the Strickland-Glogovac (1980) formula, although this is confusing as the total active motion gained can be put into different categories depending on whether their 1980 or Strickland's 1989 formula are used. Some authors have clearly stated the range of motion achieved and any complications like degrees of extension lag, others have solely used formulae to present their outcomes which can mask poorer results. The range of tools utilised are shown and described below.

Table 11: Assessment tests for zone III and IV central slip injuries

Name Test	**Authors utilising outcomes**	**Description test**
Souter 1967 Assessment of function	O'Dwyer & Quinton 1990	Excellent, good, fair or poor result given. This depends on extension loss at PIP joint, mass flexion deficit to distal palmar crease and percentage of normal flexion at the PIP joint.
Strickland-Glogovac 1980 Formula for total active motion of the IP joints	Maddy & Meyerdierks 1997 Thomes & Thomes 1995 Evans 1984	Sum of active PIP and DIP flexion minus extension lag divided by 175. This is then x100 to receive percentage of the normal TAM (Kleinert & Verdan 1983) The result is then put in a excellent (85-100 % of normal TAM), good (70-84%), fair (50-69%) or poor (0-49%) category
Strickland 1989 Formula for total active motion of the IP joints	Pratt et al 2002	The same method of evaluation as previously but the categories have changed making it easier to achieve better results. Excellent now (75-100 % of normal TAM), good (50-74%), fair (25-49%) or poor (0-24%) category
Total Active Motion (TAM) (Kleinert and Verdan 1983) of involved digits	Hung et al 1990 Saldana et al 1991	Total active flexion range minus total active extension lag. Maximum for the fingers is 270 degrees so formulae include MCP joints and IP joint measurements.
Total Active Motion (TAM) (Kleinert and Verdan 1983)	Pratt et al 2002	Combined active arc of motion of the MCP ,PIP and DIP joints compared with the contra lateral finger provides an excellent, good, fair, poor result. Excellent results are achieved only when the TAM is the same as the other hand.
Miller's classification 1942	Walsh et al 1994 Newport et al 1990	Excellent, good, fair, poor results based on total loss of flexion and total loss of extension.
Dargan formulae 1969	Saldana et al 1991	Excellent, good, fair, poor results based on degree of extension lag and cm deficit of pulp-to-pulp distance.

Caroli formulae 1990	Caroli et al 1990	Criteria provided on how to obtain excellent, good, fair, poor results taking into consideration loss of extension at PIP joint and DIP joint and active flexion at the PIP joint
Report of ROM of patients (mean or individual) Report extension lag separately	Pratt et al 2002 Thomes & Thomes 1995 Saldana et al 1991 Caroli et al 1990	Tables to show each individual patients ROM or a mean of each joints ROM stated**.**

3.8 Prognosis

Hung et al (1990) noted that the outcome of extensor tendon injuries is not always favourable especially with the conventional treatment by immobilisation. With the introduction of techniques borrowed from flexor tendon management, the prognosis for these injuries has improved, as early mobilisation encouraged better tendon gliding and less adhesion. However, the expert design and application of splints and the patients regular involvement in exercise regimes is especially noted (Hung et al 1990, Pratt et al 2002) and the earliest commencement of treatment (Thomes & Thomes 1995). Extension lag remains a frequent problem in complex and complicated symptomatologies (Saldana et al 1991).

3.9 Health economics

Cost effectiveness is addressed briefly within the literature, but while some protocols use cheaper materials or simpler splintage designs, others require fewer follow-up visits. There is some implicit evidence that effective dynamic extension splints require the skills of expert hand therapists, which has human resources implications.

3.10 Practice Points

- Evidence is predominantly drawn from practice observations and clinical series, so no clear single recommendation for best practice can be drawn from the limited and non-research based data currently available.
- Static and dynamic splints appear to be equally effective in the treatment of simple injuries although there may be more complications with static splintage. More complicated injuries may benefit from earlier motion.
- The selection of splint may be determined by the expertise of the hand therapist in splint construction and/or the protocol requested by the surgeon.
- Early DIP joint mobilisation is recommended unless lateral bands are involved.
- Early active motion regimes may decrease the incidence of extension lag and adhesions but robust research is required to confirm this.
- Regular follow-up is required to monitor and manage possible complications.
- The successful outcome of any protocol is dependent on good patient education and their understanding and active involvement in the treatment.

3.11 Research recommendations

It would appear that the success rate for the treatment of central slip injuries is high and that most protocols achieve high levels of excellent and good results. There exist, however a number of research problems which might usefully be explored.

- The development of a standardised assessment for outcomes.

- A comprehensive comparison of static versus early motion protocols including evaluation of cost, ease of splintage construction, patient perceptions and longer term treatment outcomes.
- Investigation of the importance of wrist immobilisation.
- The meaning of compliance, exploring the perceptions and behaviours of clients undergoing treatment for central slip injuries
- A longitudinal study of treatment outcomes to include "non-compliant" clients.
- A comparison of the use of POP and thermoplastic splint materials for skin complications.

4.0 Extensor Tendon Injuries

4.1 Definition

The preceding sections have dealt specifically with mallet injuries occurring in zones I and II, and central slip injuries in zones III and IV. This section deals with injuries to zone V to VIII. Zone V injuries occur to the MCP joints, zone VI across the back of the hand and zone VII and VIII at the wrist and distal forearm respectively.

4.2 Aetiology

As has been noted in discussion of the central slips, the extensor mechanism is prone to injury being located on the dorsum of the hand and lacking soft tissue protection. This area of the back of the hand is comparatively unprotected by muscles compared to the volar surface and the tendons are wide, so parts of the tendons are easily transected in accidents or fights, accounting for their frequent presentation. Khandwala et al (2000) reported that injuries in their sample were caused "mostly by knives or glass while only in 7 (of 146) injuries were due to blunt/crushing trauma" (p140). Newport et al (1990) noted that 50% of their patient sample from Iowa was in heavy manual occupations and 85% of participants were men; results similar to Marin-Braun's (1989) study where 60% of patients were manual workers and 83% were men. Fights and accidents linked to inebriation also accounted for the higher incidence of these injuries in younger men (Walsh et al 1994).

Wolock et al (1987) stated that "specifically, extensor tendon injuries are usually taken lightly. They are widely believed to be easier to treat than flexor tendon injuries and, therefore, are often treated in the emergency room" (p1387). Evidence also suggested that less experienced staff often repaired these tendons and although this had few implications where the injury was simple and juniors medical staff were supervised, poorer results developed in more complex injuries compared to similar conditions treated by experienced staff (Evans et al 1995). Perhaps because treatment initially occurred in A&E, demographic details were not always recorded in the same degree of detail as found for other extensor or flexor tendon injuries. Therefore, limited data exists on which to base retrospective clinical series or research papers of causation. The literature, however, suggested some disagreement regarding the ease of repair of extensor tendon injuries in zones V to VIII and a number of publications by hand surgeons and therapists recorded the difficulties of achieving a good surgical and therapeutic outcome (Zander 1987).

4.3 Diagnosis and Clinical Features

The extensor mechanism comprises 17 muscles and four complicated tendinous tethers to the fingers, the tendons themselves being extra-synovial (Wolock et al 1987). The process of extending the digits occurs through a complex balance of forces between the extrinsic and intrinsic muscles (Littler 1967). In a description of a single case, Zander (1987) noted that injuries to these structure and systems may be complex, infected and prone to scarring and oedema. While Hunt (2000) stated that local adhesions may not be detrimental to the final functional outcome, Hunter et al (1995) suggested that scar formation, especially in complex injuries restrains the extensor tendons and can make these injuries particularly difficult and prolonged to rehabilitate.

The main problem is that tendons may retract a considerable distance following injury. Repair is more difficult as the tendons are thinner, (extensor tendons are more ribbon-like compared to the rope-like structure of the flexor tendons) and hold sutures less well, and being weaker than flexor tendons are more prone to rupture (Newport 1997). The limited amount of surrounding tissue can often result in adhesions to the skin or bone, this tethering further limiting movement in tendons which normally have less excursion than flexor tendons. Lovett and Mc Calla (1983) reported that a 2mm loss of motion in the extensor tendon can result in a 50% loss of motion in the fingers. The extensor system is less able to compensate for changes in tendon length. Injury to the extensor mechanism also causes inflammatory response, an in-growth of capillaries and significant scarring (Walsh et al 1994, Lovett & McCalla 1983).

Hunter et al (1995) described a range of assessment tests for extensor tendon injuries and noted the need to locate the site of blockages caused by adhesions, and to differentiate intrinsic tightness from scarring. Adhesion sites can be localised by comparing active and passive ranges of motion. Skin adherence, local inflexibility and puckering indicate the site of a restraining scar.

Primary loss of extensor tendon function needs to be differentially diagnosed from:-

- Rupture following fractured distal radius and dislocated distal ulna.
- Attrition due to Rheumatoid Arthritis or Kienböcks disease.
- Secretan’s disease which can prevent excursion of the finger extensors and juncturae tendinum.
- Closed soft tissue injuries at the MCP joint level that mimic extensor tendon injury.
- Saddle syndrome, which is a consolidation of the interosseous and lumbrical tendons by adhesions, is characterised by persistent pain with grip.
- Instability of the fully flexed MCP joint to lateral deviation, characteristic of collateral ligament rupture.
- Chronic extensor hood thickening from repeated trauma causing adhesions.

4.4 Prevalence

Injuries to extensor tendons are common, as injuries are associated with fights, work and domestic injuries, but are still only half as common as flexor injuries (Marin-Braun 1989). While Newport (1990) suggests injuries are most common in zone VI, this is not supported by all other researchers’ demographics (Table 12).

Table 12: Incidence of extensor tendon injuries in zones V-VIII

Author/s & date	Zone V	Zone VI	Zone VII	Zone VIII
Evans et al 1995	33%	39%	9%	0%
Hung et al 1990	35%	15%		Not included
Ip & Chow 1997	24%	16%	4%	16%
Khandwala et al 2000	56%	44%	Not included	
Marin-Braun et al 1989	40%	20%	9%	0%
Newport et al 1990	7%	32%	10%	9%

4.5 Aims of Treatment

Zander (1987) suggested that the aim of therapy should be a good balance between strength, mobility and coordination to achieve optimal function. Hunt (2000) listed the aims as the " prevention of rupture and adhesion, promotion of tendon healing and gliding, minimising tendon gapping and extensor lag, restoration of active and passive motion, control of oedema and pain, scar management and maximizing functional abilities" (pp 10-11), aims common to all tendon injuries. Hunter et al (1995), however, prioritised the prevention of scarring and adhesion.

The conventional method of treatment has been immobilisation for 3-4 weeks (Crosby & Wehbe 1996, Browne & Ribik 1989) or 6 weeks (Hunt 2000). Immobilisation achieves good outcomes for tendon healing and limits the incidence of rupture, but reportedly is linked to higher rates of adhesion and joint tightness (Dargan 1969, Evans & Buckhalter 1986). New techniques developed for flexor tendon injuries repair, splinting and EAM techniques have been applied, in an attempt to improve extensor tendon healing and functional outcomes, for example the Norwich regime (Sylaidis et al 1997) which incorporates CAM with static splinting. Unlike flexor tendon splints, the designs of dynamic extensor splints are cumbersome and their effectiveness less convincing, which may explain the continued use of simple immobilisation. Comparisons of static extensor splinting and early controlled motion suggests that while there is no difference in TAM between the two approaches, that treatment time and number of out-patient appointments may be reduced using dynamic splints for uncomplicated injuries (Blair & Steyers 1992). There is no conclusive evidence for the best approach between static or different types of dynamic splinting (Table 13).

Table 13: Comparison studies of static v dynamic splinting for extensor tendon injuries

Author/s & date	Method	Sample size	Findings	App score
Chester et al 2002	Prospective RCT	36 patients	Compared EAM and dynamic splintage regimes At 4 weeks- dynamic spintage regime had better TAM results At 3 months, no significant difference between groups. No ruptures in either group.	1
Chow et al 1989	Comparative 2 site study	86 patients 97 digits	Compared static and dynamic splints Static- 40% excellent 31% good, 29% fair. 6 fingers required tenolysis Dynamic- 100% excellent Dynamic splinting reduced cases of ext. lag	4
Evans 1995	Multi-site comparative study	124 patients 332 tendons	Compared static and early passive motion Combined early passive and short arc motion.	2
Khandwala et al 2000	Prospective RCT	100 patients 162 digits	Dynamic splint (Chow style) v palmar blocking splint - zones V-VI Dynamic outrigger 95% excellent/good results Palmar blocking 93% excellent/good Claim palmar blocking splint is simple, cheap and convenient & requires less therapy time (session number & frequency not specified).	2

4.6 Treatment

4.6.1 Splint types

A number of different splints are described and evaluated (Table 14). Dynamic splints use a number of different mechanisms to return the MCPs to extension using rubber bands, coiled or clock springs with an associated palmar block to limit flexion. An outrigger splint is comprised of a static component to immobilise the wrist with a thermoplastic bar extending over the dorsum of the hand and fingers for attachment of the dynamic components, such as elastic traction.

Table 14: Evidence of splints & effectiveness for treating extensor tendon injuries

Author/s & date	Splint type	Sample size	Findings	App. score
Browne & Ribik 1989	Dorsal dynamic outrigger splint	52 patients 82 tendons	Full extension in 77 digits. All patients regained full flexion and grip strength. Motion commenced after 2-5 days No ruptures or adhesions	4
Crosby & Wehbé 1999	Compares 2 methods of dynamic splinting and EAM	30 hands 50 tendons	90% gained full ROM (mean TAM 262°) 93% regained predicted normal strength. Return to full ADL in 10 weeks.	4
Dovelle et al 1987	EAM dynamic dorsal perforated thermo-plastic splint	1 patient	Full ROM, strength and function at 6 weeks Indicated for zones V to VII. Treatment needs to be individualised for each patient. Reduces length of treatment and return to function.	5
Evans 1989	Early passive motion	112 tendons	Simple repairs achieved 240° TAM; complex in zones V & VI achieved 237°. TAM and no complications; complex in zone VII achieved 242° TAM with 2 ext lags and 2 wrist extension contractures. Indicated for complex injuries Research needed for zone VII	4
Evans & Burkhalter 1986	Dynamic palmar splint	66 tendons	5mm glide is safe and limits adhesions 1 rupture where patient removed splint	5
Frere et al 1984	Levanne splint	80 patients 121 tendons	Study period 5 years. Splinted 30 days post op. 86% good results. No ruptures. Rule of 3 is postulated- In zone VI injuries proximal to the juncturae, adjacent fingers need to be splinted. Free flexion of adjacent fingers can pull on the repair.	4
Hung et al 1990	Dynamic palmar slab with EAM	38 patients 48 tendons	Average final TAM + 229° Lesions distal to knuckles showed worst results; TAM 188°	4
Ip & Chow 1997	Dynamic palmar slab	84 patients 101 tendons	93% excellent results for fingers. 80% pts regained good power grip. Fractures & ragged cuts produced poor results.	4
Kerr & Burczak 1989	Dynamic splint without MCP flexion block	21 patients 46 repairs	Treated with post-op traction without an MCP flexion block. 43% sample reassessed at 14 months - Average TAM= 259° No ruptures, extensor lag or bow-stringing.	4

Marin-Braun et al 1989	Comparative study	41 patients	76% excellent, 16% good, 8% average, 0% poor in simple injuries 31% excellent, 0% good, 13% average, 56% poor in complex injuries. Indicated for simple injuries. No significant benefit for complex injuries.	2
Newport et al 1990	Static splint	62 patients 101 digits	64% excellent/good results. Final mean TAM = 212° Distal zones had poorest results Loss of flexion a significant complication.	4
Sylaidis et al 1997	Norwich regime Static splint with CAM	27 patients	92% excellent/good (simple injuries) 85% excellent/good (complex injuries) Claims it compares favourably with dynamic splinting. This regime does not require outriggers & is easy to follow	4
Thomas et al 1996	Dynamic splint	88 tendons	92% excellent/ 5.7% good results (TAM) 61% patients regained full ROM at 60 days	4

Hunt (2000) reported that static splinting for zone VII injuries was associated with adhesions and limited return of flexion requiring protected wrist motion in dynamic splinting. However, there was some indication that static splinting could be selected in cases of actual or anticipated non-compliance or very late referral for treatment (Evans 1995).

4.6.2 Joint position

Consensus opinion appears to indicate that the wrist should be splinted in some extension to relieve stress at the repair site, but there is less agreement about the precise optimal position within a wide range of different options (20-45°). Patients complain that 45° is very uncomfortable so most authors suggest a narrower range of 20-30°. It is suggested that extensor tendons in zones VI-VII glide from full passive extension to full flexion when the wrist is splinted in more than 21° extension (Hung et al 1990, Ip & Chow 1997) and Marin-Braun (1989) reported that 30° extension will relax the extensor apparatus and offer comfort to the client. Minamikawa et al (1992) suggested from cadaveric studies for optimum wrist position, that if the wrist was extended more than 21°, the extensor tendon glides, with no tension in zone V & VI, throughout fully simulated grip and passive extension. Full grip is permitted post-operatively if the wrist splinted at 45° extension.

The position of the MCP joints is determined by the use of either static or dynamic splints. In the former MCPs are immobilised in 30-45° but may be associated with complications of extensor lag (Chow et al 1987 & 1989) and elongated scar formation (Evans 1989). Positioning the MCPs in 0° is recommended by most authors (see Table 15). Based predominantly on clinical series and expert opinion, this consensus view is challenged by Dovelle et al (1987) who advocated 10° MCP hyperextension. Evans (1989) countered that this may compromise the transverse metacarpal arch or affect collateral ligaments, impacting on joint stability and functional 'cupping' of the hand.

Table 15: Positioning joints for splinting extensor tendon injuries

Author/s & Dates	Wrist Position	MCP Position
Browne and Ribik 1989	Not stated	0°
Chow et al 1987, 1989 Ip and Chow 1997 Marin-Braun et al 1989	30°	0°
Evans 1995 Hung et al 1990	40°	0°
Dovelle et al 1987	45°	-10°
Evans and Burkhalter 1986	45°	0°
Kerr and Burczak 1989	Intrinsic plus position	

Discussion of joint positioning in the literature rarely involved reference to the extent of premorbid joint flexibility, to cultural expectation of normal range of movement (as in Indian dancing) or comparisons with the unaffected hand for a normal range of wrist, MCP and IP hyperextension.

4.6.3 Exercise Regimes

Papers rarely mentioned details of exercise regimes or only offer limited description or justification. Thomas et al (1996) recommended 10 flexions hourly within the limits of a dynamic splint. The philosophy of early controlled motion following extensor tendon repair is largely based on Duran and Houser's work (1975) on flexor repairs which states that 5mm of glide is optimal for tendon healing whilst minimising adhesion, elongation and rupture, and Evans and Burkhalter (1986) who proposed an equation based on joint size and tendon excursion which finds that 28.3º index finger MCP; 27.5º middle finger MCP; 40.9º ring finger MCP; and 38.33º little finger MCP is safe and effective in preventing extension contractures, maintaining collateral ligament integrity, promoting venous and lymphatic return and minimising adhesion. However, these exact positions are very difficult to ensure in practice. The difference in individual safe joint range is related to the differences in joint size and tendon excursion. This work was further refined by Evans in 1989 where an inter-operative study found 30º of MCP joint range correlated with 5 mm of extensor tendon glide. However, the recommendations are based on expert rather than research evidence.

Despite this work and Evans' continued use of 30º MCP joint range as a marker for her modified regimes in the 1990s, the most widely used dynamic splint regimes use a graduated increase in active flexion over 4 to 6 weeks of treatment (Browne & Ribik 1989, Chow et al 1989, Dovelle et al 1989, Hung et al 1990, Ip & Chow 1997). There is little evidence in the literature to justify this regime other than increasing tensile healing strength by early motion whilst protecting the tendon repair through its most vulnerable first 15 days after surgery when tensile strength can reduce (Evans 1995). Increasing the angle of flexion over the first 4 to 6 weeks of regime also maximises joint motion and minimises the need for rehabilitation after removal of the splint. In these regimes the patient is instructed to carry out active flexion exercise ten times per hour to the limits of the splint with the dynamic traction passively returning the MCP joints to extension. A palmar pad usually blocks further flexion.

The most clinically significant change in thinking regarding early controlled motion in the last 6 years is the move towards using a static splint and controlled exercises including the use of active MCP joint extension. This concept was first introduced by Sylaidis et al (1997) advocating a static paddle-type splint with the wrist held at 45º extension, MCP joints at 50º and IP joints at 0º. Here the patient is instructed to perform two active exercises in the splint; combined IP and MCP joint extension and MCP extension with IP joint flexion. The authors justified this regime as simpler and less cumbersome for the patient. Pratt et al (2002) studied this regime, and found that patients preferred EAM rather than static splinting prior to mobilisation, but complained for discomfort at the wrist. They suggest the wrist be positioned at 30° extension.

More recently Khandwala et al (2000) have compared a modification of this static splint regime with a dynamic regime as described by Chow et al (1989). The splint positioned the hand with 30º wrist extension, 45º at MCP joints and IP joints free to move actively at all times. In weeks 1 and 2 the patients actively flex and extend the MCP and IP joints synchronously to 0º extension and back onto the splint at 45º flexion. At 3 weeks the splint is adjusted to 30º wrist extension and 70º MCP joint flexion. During weeks 3 and 4, exercises comprise of synchronous extension between 0º to 70º plus MCP joint active extension to neutral or hyperextension followed by PIP and DIP joint flexion. When compared there was no benefit of this new regime over the more traditional dynamic regime however it is described as easier for both the patient and therapist. Hunt (2000) offered an expert opinion that MCP motion alone is insufficient for zone VII injuries and that protected wrist motion was also required.

4.7 Assessment

As with other tendon injury sites, a number of non-standardised assessment scales have been developed and applied to clinical and research studies (Table 16). Comparing outcomes of protocols is problematic for this reason.

Table 16: Outcome measures and assessment tests for extensor tendon injuries

Author/s & date	Excellent	Good	Fair	Poor
Buck – Gramcko et al 1976	14 to 15 points 50° to 70° flexion 0° to 10° ext lag > 40° TAM	11 to 13 points 30° to 49° flexion 11° to 20° ext lag 30° to 39° TAM	7 to 10 points 10° to 29° flexion 21° to 30° ext lag 20° to 29° TAM	0 to 6 points < 10° flexion > 30° ext lag < 20° TAM
Dargan 1969	0° extensor lag Full pulp to mid-palm flexion	<15° extensor lag Full pulp to mid-palm flexion	16-45° extensor lag <2cm gap pulp-mid-palm	>45° extensor lag >2cm gap pulp-mid-palm
Kleinert & Verdun 1983	TAM = TAM of contra-lateral finger	TAM > 75% of contra-lateral finger	TAM 50-75% of contra-lateral finger	TAM < 50% of contra-lateral finger
Lister criteria 1977	Less than 15° lag	Less than 30° lag	Less than 50° lag	More than 50° lag
Miller 1942	0° extensor lag 0° loss of flexion	<10° extensor lag <20° loss of flexion	11-45° extensor lag. 21-45° loss of flexion	>45° extensor lag >45° loss of flexion

The zero tolerance of any extensor lag in some scores for an excellent outcome skews the outcomes making results appear poor in comparison with scores employing greater latitude for extensor lag. Problems with inter and intra-rater reliability for goniometry are rarely discussed. Newport et al (1990) noted that these goniometric scales poorly reflect wider functional abilities or levels of patient satisfaction. They found that TAM (Kleinert & Verdan 1983) in uncomplicated injuries returned to 89% normal, and 82% in complex injuries, while grip strength averaged 95% in uncomplicated and 91% in complicated injuries, although they question the value of TAM and grip strength for evaluating the effectiveness of treatment for extensor injuries, compared to the importance of a sustained grip.

4.8 Prognosis

The presence of extensor lag is often noted as the principle sequel of extensor tendon lesions, but the loss of flexion is more disabling (Newport 1997). Newport et al (1990) found that more proximal injuries in these zones were reported to have a 63% to 83% excellent or good outcome, compared to 50% for the distal zones. The outcomes for patients with complications at the time of injury were less good.

Controlled active motion regimes have been designed to minimise rupture, adhesion and stiffness following extensor tendon repair particularly with associated complications such as multiple lacerations or MCP joint involvement. When compared to more traditional static treatment regimes, prognosis for complex injuries has been much improved. Evans (1989) found 2 patients required tenolysis and prolonged treatment after a static regime. Results however for simple repairs are largely similar whether treatment is by a static or dynamic regime.

Tendon rupture is a risk associated with dynamic tendon regimes due to tension at the repair site. Evans and Burkhalter (1986), Evans (1995) and Khandwala et al (2000) describe small incidences of tendon rupture but attribute this to non-compliance and premature removal of the splint by the patient. In common with other hand injuries, cold intolerance is reported as a complication (Evans 1994, Campbell & Kay 1998, Irwin et al 1997, Rosen 1999) along with persistent pain. However these are not widely reported as having a substantial disabling effect.

In common with other hand injuries, cold intolerance is reported as a complication (Evans 1994, Campbell & Kay 1998, Irwin et al 1997, Rosen 1999) along with persistent pain. However, the evidence does not indicate that this is viewed as having a substantial disabling effect.

Patient compliance is cited as key to the success following early controlled motion techniques (Browne and Ribik 1987, Dovelle et al 1989, Evans and Burkhalter 1986, Evans 1995, Sylaidis et al 1997, Zander 1987) and to this end patient participants may be selected, based on their special adherence to treatment. This potential bias may influence the reliability of evidence for excellent outcomes when generalised to whole patient populations.

4.9 Health economics

There are several dimensions hinted at in the literature concerning costs. Some splints are clearly easier to construct and so save expert therapist time. It is widely accepted in the literature that early active motion regimes are more costly due to materials and therapy time with 2 to 3 appointments per week recommended to allow close therapist supervision (Browne and Ribik 1989, Flowers et al 1996, Hung et al 1990, Ip and Chow 1997, Marin-Braun et al 1989, Pratt et al 2002). Such therapy intervention is more intensive but is often required for shorter period of time and also minimises the need for further surgical interventions. Thus, patients treated with these regimes return to personal, work and leisure activities more speedily than those treated with a static regime. However, Marin-Braun et al (1989) state that this increase in therapy investment has no added benefit for the treatment of simple injuries. The employment implications of patients taking sickness absence of 6-8 weeks and attending out-patient clinics should be included in cost calculations.

4.10 Practice Points

While dynamic splinting may be more effective, static splinting may be preferred by patients over cumbersome splints.

- Joint positioning is important for good outcomes, especially of the wrist.
- The use of restricted controlled flexion is indicated for poor quality repairs and less compliant patients but the literature suggests that protected active flexion in an outrigger splint is appropriate in most cases with close therapist supervision, but individualisation of the regime as required.
- The most recent literature suggests that EAM is indicated for excellent and good outcomes.
- Prolonged splinting delays return to work and may influence treatment choices.
- Loss of flexion can be a significant complication in extensor tendon injuries.

4.11 Research recommendations

Hunt (2000) suggested a number of research topics, which are supported here;

- The influence of surgical technique for repairing extensor tendons on final functional outcomes.
- Randomised controlled trial (RCT) comparing static and dynamic protocols.
- Investigation of patient compliance.
- Therapist and patient selection criteria for static or dynamic splints.
- Investigation of the influence of other therapeutic interventions during the splintage regime e.g. passive motion, CAM.

- High quality quantitative studies producing statistically significant results.
- The use of ECM for repairs in zone VII due to the likely development of wrist contractures.

5.0 Flexor Tendon Injuries

5.1 Definition

The flexor tendon system is complex in design. Flexor tendons cope with high unidirectional tensile loads, but are flexible enough to curve around bones and joints (Boscheinen-Morrin & Conolly 1997). The flexor mechanisms are divided into 5 zones, injury to tendons being most common and problematic in zone II.

5.2 Aetiology

Fasika & Stilwell (1992), in a study of flexor tendon injuries in NW England, reported 60% of injuries were caused by glass and 20% by knives. They also calculated that 20% injuries occurred in children under 10 years, 38% in the 11-20s and 22% in 21-30 year olds, making this a young persons injury. An audit of flexor tendons carried out in Trent found 81% of cases were male, average age of 30 years with 60% injuries to the dominant hand (TRASH 2001). The incidence of disability after injury and the ease of repair and rehabilitation differs in each zone.

- Zone 1 involves pulp injuries rarely with complete or partial FDP tendon involvement which is the only flexor for the DIP. However, isolated FDP lesions also affect the PIP as the tendon has the greatest moment arm acting on this joint. Lesions of the FDP in the little finger have particular significance as the FDS has limited action in this digit and may be absent, and cannot compensate in ulnar grasp and grip strength (Evans 1990). The tendon normally has a limited excursion at this level and so any loss of ROM can limit fine finger function and impair rapid movement, this being especially linked to patient dissatisfaction (Moiemen & Elliot 2000). These injuries are also prone to adhesions to the A-4 and A-5 pulleys (Hunter et al 1995).
- Zone II is the most complex site of injury and is commonly known as 'no man's land' as historically treatment had very limited success. The most common cause of injury in Rosberg et al's (2003) study of zone II flexor tendon injuries were knife wounds (46%), cuts from broken glass (26%) and metal objects (19%). They also found that the most common injuries were to FDP (28%), combined FDP and FDS (21%) and FDS and FDP with digital nerve injuries (25%) concurring with previous studies (May et al 1992a). The injuries are most common in young men.
- Zone III contains the origin of the lumbricals. Tendon injuries in this zone are less common as the system is protected by muscles. Also, as the tendons lie outside the flexor sheath, adhesions are less likely and outcomes of surgery and rehabilitation are usually unproblematic (Hunter et al 1995). Some thick palmar scarring may occur.
- Zone IV contains the carpal tunnel and injuries here often involve the median and/or the ulnar nerves. However, tendon injuries are relatively uncommon as they are largely protected by muscles, the transverse carpal ligament and bone (Boscheinen-Morrin & Conolly 1997). Some thick palmar scarring may occur.
- Zone V covers the distal portion of the forearm, including the wrist. It is a common site of injury. Its presentation in hand clinics is somewhat increased by cases of self inflicted injury and self harm. Chin et al's (1998) Chicago study found 61% injuries caused by accidental glass laceration, 24% by knife wounds and 9% by self harm, occurring in people predominantly under 40 years of age. It is possible that the last group are underrepresented in research and clinical studies as they are often excluded. Most injuries occur in the dominant hand. Injuries are variously described

as ‘spaghetti wrist’ or ‘full house syndrome’, where 3 structures are completely transected (Puckett & Meyer 1985) or when 10 of the 15 possible tendon, nerve and blood vessel structures are damaged (Widgerow 1990; Hudson & de Jager 1993). Chin et al (1998) describe the typical patient in this group as “an unemployed young man who was intoxicated, angry or both, when he punched a pane of glass” (p101). ‘Do not attend’ rates are often high.

5.3 Diagnosis and clinical features

Vulnerable structures on the palmar surface of the hand include bones, nerves and blood vessels as well as tendons. In many studies injury to these other structures excludes the patient from research statistics. Deliberate self-harm is also often excluded if the patient is deemed unable to follow a regime of rehabilitation precisely. The cases reviewed in the literature therefore only represent relatively straightforward cases. Open lacerations to the flexor tendons carry a high risk of contamination and infection; it is not possible to see from this review how many patients were excluded for any of these reasons.

5.4 Prevalence

Flexor tendon injuries constitute less than 1% of hand injuries but have particular social and economic consequences especially when full rehabilitation is incomplete or return to work delayed. Looking at 176 tendon injuries in all zones, Gault (1987a & b) found the proportion of injuries to each finger was similar; 24% index, 27% middle, 24% ring and 25% little fingers. The incidence of zone II injuries however, varied between digits although studies have produced somewhat different results for the prevalence of injuries to each finger. Clinical series generally report highest incidence of injuries in the index and little fingers.

Table 17: Incidence of flexor tendon injuries in zone II

Author	Index	Middle	Ring	Little
Edinburg et al 1987	13%	36%	34%	17%
Fasika & Stilwell 1992 (Thumb =12%)	23%	15%	19%	31%
May et al 1992a	25%	8%	16%	51%
Riaz et al 1999	15%	13%	39%	33%
Rosberg et al 2003	26%	Not stated	Not stated	43%
Roy 2003	25%	20%	29%	26%
Small et al 1989	29%	20%	27%	24%

There are also different rates of incidence of injury between the zones, being most frequent in zones I, II and V.

Table 18: Rates of occurrence of tendon injuries in zones I-V

Author	No. cases	Zone 1	Zone II	Zone III	Zone IV	Zone V
Edinburg et al 1987	99 tendons	37%	24%	10%	0	29%
Kitsis et al 1998	208 tendons	10%	42%	2%	23%	23%
Roy 2003	84 tendons	12%	20%	6%	1%	61%
So et al 1990	95 digits	17%	34%	6%	9%	34%
Fasika & Stilwell 1992	65 digits Inc. thumb-12%	12%	31%	11%	3%	31%

Rosberg et al’s (2003) Swedish study found 40% of all flexor tendon injuries occurred at home, 30% of injuries were work related and 27% occurred in leisure time. Small et al’s (1989) Ulster study categorised rather different cultural features reporting 45% injuries being caused by glass, 30% by knife wounds, 15% by other sharp objects and 10% in crush injuries. Harris et al (1999) suggested a higher incidence in lower social classes. Causation might be anticipated to have an effect on compliance and eventual outcome, but most research treats the participants as a homogeneous group, avoiding sub-group analysis based on age, gender, occupation, hand dominance or causation.

5.5 Aims of treatment

Strickland (1989) stressed that "it would be totally inappropriate to employ a 'cookbook recipe' for all flexor tendon repairs" (p76), a view supported by Peck et al (1998) who strongly "support the philosophy that every patient must be managed according to their individual needs and the variable characteristics of injury; surgical findings and lifestyles" (p45). They identified substantial psychological, sociological and biological responses to injury and surgery, which required each patient to be treated as a unique case. Hunter et al (1995) indicated that some patients, for good reasons might be unable or unwilling to participate in early mobilization programmes, and would benefit from immobilization, which will serve to protect the repair until there was sufficient healing to commence an exercise regime. However, the aims of therapy were to limit the occurrence of the common complications of adhesion, stiffness, scarring, joint contracture and rupture (Taras & Lamb 1999) and optimise function.

The treatment of flexor tendon injuries has changed significantly over the period of the last 20 years, moving away from immobilisation for periods of 6 weeks to the use of early controlled motion using a dynamic splint consisting of rubber band traction, as in a modified Kleinert splint and finally to early active motion (EAM is suggested to be far superior to Kleinert). ECM was developed for zone II injuries to limit adhesions and joint stiffness which were the complications of POP splinting. Changes in protocols were possible through refinements to surgical materials and techniques in tendon suturing. This approach was applied to other zones, based on the evidence that controlled stress improves healing and scar remodelling (Hunter et al 1995, Stewart 1991). Subsequently, active exercise elements were introduced, and generated a lively debate comparing these 'passive' v 'active' approaches. Many units have developed their own original or modified treatment protocols, but have reported their results as clinical series, not always undertaking rigorous research of their effectiveness. Without clear descriptions of the protocols or rigorous comparative data a clear recommendation of clinical effectiveness is impossible. The absence of standardisation of assessment further muddies the water, making it impossible to state which regime is producing the best rates of excellent and good results. In-house traditions and consultant and/or therapist preference tend to influence treatment choice more than an evidence base. Both approaches have a risk of tendon rupture, so Schneider (1985) suggests generally the faster the patient's progress and range of motion, the slower the programme should be undertaken for fear of rupturing the repair.

The exploration of therapy protocols will focus on zones I, II and V and on a critical comparison of active, passive and combined early motion regimes.

5.5.1 Zone I

Complication rates can be high and excellent and good results are not reported as often as in zone II injuries. Rupture rates occurred in about 4-5% cases in all the studies. Only 62% patients achieved excellent or good results in Moiemen and Elliot's (2000) study. However, patients expressed dissatisfaction even if excellent results were achieved because of the hand's cosmetic look or if they had limited fine and fast finger dexterity.

Evans (1990) recommended the use of a dorsal static splint and early active motion for 3 weeks with the wrist at 30-40° flexion, all the MCP joints at 30° flexion and the PIPs in a neutral position. The splint has an additional dorsal piece which holds the DIP at 40-45° flexion. It appeared that while there was some latitude concerning the optimum position of the wrist, PIP and DIP joints, there appeared to be consensus that the MCP joints should be splinted in 30° flexion. Results were best in the ring finger and worst in the little finger. Research suggests that the application of protocols developed for zone II injuries to zone I injuries are not without difficulties (Gerbino et al 1991) although complication rates might be reduced by especially gentle technique in passive motion and the avoidance of simultaneous passive stretching of the PIP and DIP. Ruptures rates are increased where the patient fails to understand or follow risk reducing instructions (Harris et al 1999).

Table 19: Zone I flexor tendon clinical evidence

Author & date	Method	Sample size	Findings	App. Score
Evans 1990	Retrospective & prospective studies- zone I	89 patients 99 digits	Comparison Kleinert and limited excursion technique. Complication rates the same for both groups. New protocol more effective for DIP and combined DIP and PIP ROM. Technique suggested to limit gap formation, & tendon elongation. EAM - 55% excellent and 35% good results. Kleinert - 24% excellent, 44% good results.	2
Gerbino et al 1991	2 year retrospective study of end-to-end repairs	20 patients	35% cases had complications. Passive stretching in wks 1-2 contributes to post operative complications	4
Harris et al 1999	Retrospective study of case notes & follow-up	120 patients 129 digits zone I injuries	Questionnaires & interviews with rupture cases. 5% cases ruptured.	4
Moiemen & Elliot 2000	7 year clinical series	89 patients 93 digits	Categorises different types of zone I tendon injuries Use of ROM at DIP provides best assessment. Closed avulsion of FDP have poorest outcomes	4

5.5.2 Zone II

Recent developments in surgery and therapy protocols have improved outcomes, but risks are prevalent in this zone, especially adhesion between the various bony and soft structures in the area. There is unequivocal historical evidence that early controlled motion is more effective than immobilisation (Kleinert et al 1967, Strickland & Glogovac 1980, Chow et al 1987, Wang & Gupta 1996). The splinting and exercise regimes developed promoted passive flexion and active extension (Kleinert protocol); passive extension and passive flexion exercises (Duran & Houser 1975) or early active flexion and extension (May et al 1992a). Rosberg et al (2003) found that although there was a longer in-patient stay for people undergoing controlled motion regimes than with people with an immobilisation splint (p=0.0001), that out-patient visits were higher for the immobilisation regime (p=0.05). They identified better outcomes, measured by ROM, for EAM and Kleinert splints (p=0.05). There were no other statistically significant differences between the 3 regimes. The literature suggests that the comparative effectiveness of each regime is contested and repeat studies of each often fails to produce earlier excellent results (Silfverskiold 1993, Schenck & Lenhart 1996).

Results may be biased by the exclusion of non-compliant patients from the sample or subsequent analysis, attributing poor results to patient non-compliance. Researchers generally agreed that an ability to understand the treatment regime and follow it with precision was vital to a successful outcome, but there exists little evidence of how motivation and involvement might be encouraged or negotiated, nor is it clear how authors define 'compliant' patients or what constitutes their compliance.

Table 20: Management of zone II injuries

Author/s & date	Method	Sample size	Findings	App. Score
Burge & Brown 1990	Single case study - zone II injury	1 subject	Aim- to avoid PIP joint contracture. Forearm laceration produces poor DIP movement compared to dorsal and palmar Not necessary to place MP joints I flexion.	2
Cetin et al 2001	2 year prospective clinical series	37 patients 74 digits	Combined modified Kleinert traction and modified Duran passive exercise 73% excellent results (97% Exc. & good) Extensor ROM deficits most frequent in little finger.	4
Chow et al 1988	5 year prospective study. Total FDP & FDS laceration zone II.	66 patients 78 digits	Used Washington regime Combines active extension and passive flexion and passive flexion and extension protocols 98% excellent and good results Rupture rate – 5%	4
Deniz et al 2000	Prospective clinical series of pts zone II injuries-	25 patients 36 digits	Early controlled passive motion protocol- wrist at 20-30° flexion, MCPs - 70° flexion and IPJs in neutral in Kleinert, Duran or static splint. Immediate post-op. mobilisation reduced adhesions Assessment of grip, pinch, dexterity and ADL function should be included in evaluations. Limited control of variables.	4
Dovelle & Heeter 1989	Clinical series	21 patients	Devised Washington regimen combining Kleinert CAM with rubber band passive flexion, Duran passive techniques & Kleinert splint modified with palmar pulley. Claims effective in controlling pretendinous scarring and joint contractures.	5
Gelberman et al 1991	Quasi-experimental study- zone II	51 patients	Control-traditional early passive motion Experimental - mechanical device to provide greater intervals of motion Early passive motion in both instances reduced adhesions. The more passive motion, the greater the improvement-experimental group gained more ROM. Device subject to power and mechanical failure. Longer intervals of tradition motion could achieve the same results.	2
Karlander et al 1993	Quasi-experimental study- zone II	79 patients 85 digits	Control- bands to only affected finger; Experimental-modified Kleinert attaching bands to all the fingers. Results best attaching bands to all 4 fingers Experimental group-96% excellent results. Control group 51% excellent. No differences detected in treatment of little finger. Rupture rates identical.	2

May & Silfverskiold (1993)	Quasi-experimental study zone II	158 patients 178 digits	Compared single digit; single digit with passive exercise and all digit Kleinert protocols. More frequent treatment in first 3 months does not speed recovery No difference in outcome between regimes. Continued recovery over 1 year period. Suggest delay decisions for tenolysis for 1 year especially for 'poor' results.	2
May et al 1992a	1 year prospective clinical series in zone II	178 consecutive digits	Active extension/passive flexion protocol Wrist 30-45° flexion. MCP-50-70° flexion, IP straight. 10 active extensions per hour. The larger the IP ROM produced during the controlled motion period, the better the results. Protocol safe, reliable & cost effective. Advantages sustained over 1 yr period.	2
May et al 1992b	Prospective clinical series complete FDP laceration zone II	48 patients 51 digits	POP dorsal splint and 10 IP active extensions per hr with pulley system for passive flexion. Strong correlation between exercise and subsequent ROM maintained until 1 year post surgery Suggests similar results would occur with all CAM protocols.	4

These papers appear to suggest that all the digits should be moved through as wide a range of motion, as early as possible and as frequently as possible. There is no unequivocal evidence, however, about the extent to which these more rigorous regimes alter rupture and adhesion rates, nor is there any clear longitudinal evidence of eventual outcomes. Combining these different elements of management into a research study has yet to be undertaken.

5.5.3 Zone III

The aim of treatment is the avoidance of adhesion, this time between tendons, lumbricals and interossei, fascia and skin. Treatment approaches are determined by the number of tendons, nerves and blood vessels damaged. Cannon & Strickland (1985) suggested that 3-4 weeks immobilisation was often recommended, followed by 6 weeks wearing a dorsal splint with the wrist at 30° flexion, the MCPs at 50° flexion and the IP joints in full extension. Active and passive exercises were carried out hourly. There is limited evidence for best practice for this zone.

5.5.4 Zone IV

Adhesions are to be avoided between synovial sheaths and structures lying within the carpal tunnel space. There is also a risk of median nerve tethering and the development of neural symptoms.

5.5.5 Zone V

Evidence regarding zone V is limited compared to zone II. Conventionally, wrist tendon injuries are treated with 3 weeks of immobilisation (Potenza 1970) but treatment strategies are influenced by the presence of nerve injuries. Where these occur, active regimes may not be possible. The prevention of adhesions is the primary aim of treatment in cases of 'spaghetti wrist' (Panchal et al 1997). Different results are reported with the use of the Kleinert splint; Puckett et al (1985) reporting 89% excellent or good results compared to 54% in Hudson and Jager (1993). Cannon & Strickland (1985) also reported high levels of adhesions using a Strickland modification of the Duran regime even with fully compliant patients. The healing process which allows adhesion of the ends of the tendon serves to restrict tendon glide.

Table 21 tabulates the evidence for protocols designed to manage zone V injuries. Panchal et al (1997) employed a splint to immobilise the wrist in neutral, the MCP joints at 90° and the IP joints at full extension. Full passive flexion of the digits was allowed within the splint. After one day post operative, patients commenced an early active flexion regime following Small et al's (1989) protocol involving active flexion and active extension of the digits twice every 4 hours for 6 weeks. A progressive increase of the excursion of the flexor tendons between day 10 and six weeks with both active and passive flexion, especially active flexion appeared to reduce adhesions.

Chin et al (1998) used a clamdigger splint with the wrist in 20-45° flexion, the MCPs in 40-60° flexion and the IP joints fully extended. They reported wrist injuries to be more common on the ulnar side, as it represents the leading contact point in the pronated hand. Common side effects associated with ulnar nerve injuries were clawing, loss of full sensation and poor return of opposition of the little finger (Widgerow 1990; Puckett & Meyer 1985; Rogers et al 1990) even where there were high levels of excellent ROM results.

Stefanich et al (1992) also used a Kleinert splint but do not record the joint positions. An out-patient programme was followed for 4 months with 13% of patients not completing the programme. They recommend that all lacerations are surgically repaired. In therapy, joint contractures have proved to be problematic with the Kleinert splint when digits are not fully extended or patients are non-compliant. In these cases they recommend switching to a modified Duran protocol where no rubber band traction is used. This study uniquely records results using the Baltimore Therapeutic Equipment (BTE) which showed diminished power, endurance and strength in the injured hand in all planes of wrist motion except flexion.

Injuries at the wrist can be complex involving up to 15 major internal vascular and muscular structures. Spaghetti wrist injuries occur between the distal wrist crease and the flexor musculotendinous junction (Puckett & Meyer 1985). Adhesions to the skin and fascia are common but not so functionally limiting.

Table 21: Management of zone V and 'spaghetti wrist' injuries

Author/s& date	**Method**	**Sample size**	**Findings**	**App. Score**
Chin et al 1998	8 year retrospective review of spaghetti wrist	60 patients 19 followed up	ROM in follow-up patients was good or excellent after rehab with clamdigger splint. Ulnar-based injuries were most common. Sensory return poor in 12 participants with nerve injuries. Glass injuries had poorer outcomes than knife injuries.	4
Hudson & Jager 1993	9 year prospective study of spaghetti wrist	60 patients 15 reviewed over 4 years	All patients received sensory re-education Conflict between immobilisation for nerve repair and mobilization for tendon repair. Median nerve recovery better than ulnar nerve recovery. 54% excellent/good results. Jebsen test showed 87% with borderline or significant functional impairments.	4
Panchal et al 1997	Experimental study	2 cadavers 2 patients	Comparison of Belfast and Duran regimes. Increased excursion of repaired tendons following early active flexion mobilisation.	2

Puckett & Mayer 1985	Retrospective review of spaghetti wrists at 1 - 7 years.	38 wrists/37 patients	Immediate repair of all structures followed be early mobilisation with rubber band dynamic splinting (no details given. Young patient group, range 1-45 years. 89% excellent/good results. Study lacks detail of assessment findings. Relate good results to "aggressive occupational therapy".	4
Rogers et al 1990	10 year retrospective review of spaghetti wrist	26 patients 8 follow-up	Retrospective study limited by poor medical and rehab record keeping. Therapy regime not specified. Poor sensory recovery and 64% had cold intolerance, but compensated well. 7 follow-up patients had returned to full time employment.	4
Stefanich et al 1992	Prospective study of zone V injuries, 13-87 months after repair	23 patients (excluding self-inflected injuries)	Evaluations made using BTE. All patients treated with Kleinert protocol but some problems with joint contractures. Poor return of sensation was not associated with good function. Compensation mechanisms were adopted. Modified Duran technique effective for 'non-compliant' and joint contractures.	4
Yii et al 1998	2 year prospective study of zone V injuries	52 wrists	33% cases had spaghetti wrists. EAM had excellent or good results in 90% all cases. Age not a significant factor in recovery.	4

Strickland (1989) suggested that the complexity of wrist injuries makes any recommendation for a single protocol inappropriate.

5.6 Treatment

5.6.1 Splint types and protocols

There is controversy about what design of splints and intervention protocol are most effective.

5.6.2 Early controlled motion regimes

The evidence strongly suggests that early mobilization regimes are more effective than immobilization and widely adopted by hand therapy teams (Crosby & Webhe 1996). Gelberman et al (1983) demonstrated that early controlled mobilisation not only improved blood supply and gliding, but increased tensile strength better than immobilisation. While this may offer a general guide to effective practice, certain groups, i.e. certain employment groups, children or cognitively impaired adults are suggested to be less likely to benefit because of specific aspects of life style or an ability to understand and follow the exercise and splint care instructions. Therapists must balance evidence-based practice and client-led approaches, avoiding inappropriate stereotyping.

Strickland (1989) relates the development of controlled motion protocols for tendon repair which "paradoxically maximize the amount of stress applied to the offending scar while minimizing damage to healing tissues" (pp71-2). A series of in vitro and cadaveric studies showed that repaired tendons could tolerate the application of stress through passive motion. Gelberman et al (1991) showed that while a passive mechanical mobilization led to increased tensile strength, a reduction in adhesions and improved excursion, the same effects could be achieved by undertaking more motion using traditional non-mechanical methods. A combination of an effective suture technique (Tang et al 2001) recommend cruciate sutures with early motion has produced increasingly good results. It is outside the remit of this bulletin to explore the pathology and physiology of tendon injuries and healing or suture techniques.

The Kleinert splint was initially developed to facilitate passive flexion with active extension, but has later undergone a variety of modifications. Comparison of the following studies is problematic as these modifications are not always fully described.

5.6.3 Early passive flexion/active extension and passive flexion/passive extension programmes

The Kleinert splint consists of a dorsal splint with the wrist in flexion. The injured finger (or all the digits) is held in flexion by an elastic band attached to the finger nail. The patient may actively extend the finger, but the band returns the finger to the flexed position. This is in contrast to the Duran and Houser (1975) splint in which the fingers were passively exercised in both flexion and extension, the splint merely providing protection to the injured hand. McGrouther & Ahmed (1981) suggested both techniques are equally effective.

The Kleinert splint has been variously modified by reducing the degree of flexion at the wrist and increasing flexion at the MCP joints and attaching a palmar bar to improve the direction of force from the rubber band. Advocates of the Duran splint point to the greater protection it offers the digit between periods of exercise. Both protocols employ an exercise programme requiring set numbers and timings of finger movements. In both cases the splint is normally worn for 6 weeks and no aggressive use of the hand is usually permitted before 8 week post surgery. These protocols are said to require motivation and a degree of intelligence to comprehend and adhere to the programme and avoid risky hand activities.

Table 22: Evidence for use of controlled passive motion or combined passive flexion and active extension protocols

Author/s & date	Method	Sample size	Findings	App. Score
Burge & Brown 1990	Experimental study on normal (non-injured) subject. Zone II injuries	1 subject	Compares relation of 3 types of elastic band (forearm-Kleinert; palmar pulley-Slattery & McGrouther & Dorsal-Knight) on joint position & flexion force PIP joint. Overall authors 'prefer' the dorsal splint.	2
Cetin et al 2001	2 year prospective clinical series zone II	37 patients 74 digits	Compares Kleinert and modified Duran. Patient assisted passive exercise more safe and cost effective than therapy assisted.	4
Edinburg et al 1987	10 month prospective clinical series zones I-V	36 patients 70 digits	Used dorsal POP splint with palmar bar All digits- 61% excellent & good. 3% rupture rate. Simple split allows patients greater independence.	4
Fasika & Stilwell 1992	1 year retrospective study - zone II	50 patients 65 digits	Used modified Kleinert. Age 8yrs plus. Results unclear. Suggest an ideal method yet to be found and good results only achieved with carefully supervised physiotherapy	5
Gelberman et al 1991	Quasi-experimental zone II	51 patients	Compared traditional early passive motion v use of a mechanical device to provide greater intervals of motion Early passive motion in both instances reduced adhesions. Experimental group gained more ROM. The device was subject to power and mechanical failure. Suggests that the more passive motion, the greater the improvement. Longer intervals of traditional motion could achieve the same results.	2

Karlander et al 1993	Quasi-experimental zone II	79 patients 85 digits	Compared control bands to only affected finger v modified Kleinert attaching bands to all the fingers. Rupture rates identical. Modified technique produced 96% excellent results compared to 51% in control group. No differences detected in treatment of little finger	2
Kitsis et al 1998	9 year prospective study zones I-V	130 patients 208 digits	Used modified Kleinert with more "aggressive regime than standard" (p344) All zones- 68% excellent, 24% good, 7% fair, and 1% poor. Zone II Strickland- 89%excellent & good- 9% fair, 2% poor. Rupture rate zone II= 6% Consultants achieved more excellent results -77% than juniors- 59% Results attributed to suture techniques plus physiotherapy.	4
May et al 1992b	1 year prospective clinical series in zone II	48 patients 51 digits	Active extension/passive flexion protocol.10 active extensions per hour. Wrist 30-45° flexion. MCP-50-70° flexion, IP straight. The larger the IP ROM produced during the controlled motion period, the better the results Advantages sustained over 1 yr period.	2
Silfverskiold & May 1993	Case study zone II	35 patient 36 digits	Explored gap formation usually associated with adhesion in immobilisation using metal markers surgically inserted measures gap formation in tendon. 96% excellent/good results using modified active extension and passive flexion Kleinert protocol. Gaps of 8.5mm compatible with good results using early controlled motion	2
Strickland 1989	Summary of evidence	N/A	Judicious application of motion stress to the tendon in the early stages will increase tensile strength	6

Wang & Gupta (1996) in a review of the evidence for Kleinert and Duran protocols reported excellent and good results in only 50-60% cases, with a rupture rate of 3% in the early stages of their development. This was attributed to surgeons operating with limited experience and the need to have high levels of patient compliance. Early motion was found to increase the excursion of the tendon repair especially at A3 and A4 pulley levels. They identify passive flexion using rubber band traction as an effective component of therapy yielding the best functional and lowest rupture rates if combined with a compliant patient, skilled surgery and strong suturing and the use of a Kleinert splint with a PFT brace (the technique adopted by the unit in which the reviewers work). They are critical of the early active regimes. Wang and Gupta's (1996) review indicates problems of comparing different protocols but state that active flexion and active extension protocols have not achieved higher than 80% excellent and good results and have higher rupture rates 6-10% compared to active extension and passive flexion programmes.

5.6.4 Early Active Motion and Controlled Active Mobilization

Small et al (1989) initially published work on early active motion in 1989, but the protocol is also known as controlled active motion, involving both active flexion and active extension. It draws on a long history of trials to encourage motion within ranges of resistance tolerance to suture strength. While shown to be effective, it is the risk of rupture which is the prime concern of much research investigation.

Reappraisal of research for passive flexion and active extension protocols has not always found the initial results favourable (Taras & Lamb 1999). Schenck & Lenhart (1996) only found 48% patients achieved excellent or good results compared to Chow's (1997) 82%, suggesting in their conclusions that typical primary repairs may not always regain normal function. Early active motion protocols involved the use of a thermoplastic splint in which the patient was required to exercise actively 48 hours after surgery (Bainbridge et al 1994). The wrist was held at 45° extension with maximum MCP flexion to optimally reduce tension on the affected tendon (Savage 1988). This is not generally accepted as there is a risk of rupture rate. Small et al (1989) and Cullen et al (1989) described a 2-hourly exercise regime of 2 passive and 2 active flexions throughout the day. Table 23 summarises the evidence.

Table 23: Evidence for the use of early active flexion and active extension

Author/s& date	**Method**	**Sample size**	**Findings**	**App. score**
Al-Qattan 2000	Prospective clinical series.	15 patients	Treatment of zone II injuries using early active motion. 100% gained excellent or good results. No patient developed triggering or ruptures	4
Cannon & Strickland 1985	Expert opinion zones I-V	N/A	Reviews different approaches (Kleinert and Duran). Overview of therapy.	5
Cullen et al 1989	2 year prospective clinical series of EAM use with zone II injuries	27 patients 31 digits	POP dorsal splint worn for 4 weeks. Full recovery expected by 12 weeks. EAM compared favourably with similar or Kleinert studies. 64% excellent & good results.	4
Elliot et al 1994	3.5 year prospective clinical series of CAM in ZI & II-all digits	233 patients 347 complete flexion lesions	Used Billericay Regime. 79% excellent & good results. 6% digit rupture rate (FPL zone II = 19%). Most effective if suture moves freely. CAM safe and as effective as Kleinert and Duran but unsuitable for FPL mobilization.	4
Glassey 2000	3 year retrospective audit	105 patients 210 tendons	Zones I-III - rupture rate 3.5% Zones IV-V – rupture rate 0% Proposes change to more active regime with 10 exercises per day (2x passive flexions & extensions & 2x active flexions and extensions	5
Klein 2003	2 year retrospective study DASH questionnaire to 35 subjects	35 patients 40 digits DASH-n=13	Dorsal splint with wrist in neutral; MCPs 50-70° and IPs allowed full extension. Traction to all 4 fingers. 95% excellent/good results in zone II (72% for zone I). DASH results indicated minimal disability.	4
Riaz et al 1999	10 year mean follow up of patients from previous study.	34 patients 39 digits	Utilised sample from Small 1989 study. 88% injuries to dominant hand. 2 active & 2 passive exercises every 2 hrs ROM 75% excellent & good for both gps. Grip strength - mean 95.5% of uninjured hand.	4
Savage & Risitano 1989	Clinical series zone II	17 digits	70% excellent & good results at minimum 3 month follow-up	4
Small et al 1989	Prospective clinical series-clinical pilot study with military personnel	98 patients 117 digits zone II	Early active mobilization was commenced 48 hours post-operatively. 77% excellent/good results at 6 mths. Results compared favourably to Kleinert. 9% rupture rate. Very high levels of compliance.	4

Small et al (1989) produced 77% excellent or good results using EAM in a pilot study.
In an even smaller study, Al-Qattan (2000) also supported early mobilization for partial lacerations of the tendon, producing 93% excellent results, although there were reported complications of rupture or triggering. These conservative methods avoided patients undergoing surgery and the associated problems of scarring and adhesions.

Wang & Gupta (1996) suggested that while there has been considerable research and clinical evaluation of dynamic splints, the same depth of study has yet to be rigorously applied to EAM protocols. Their review suggested results for EAM were worse than for dynamic splinting, however as their work was supported by the Kleinert Institute, some bias might be anticipated. The absence of reliable and standardised measures makes any simple comparative evaluation difficult.

A specific claim for using EAM and CAM is a reduction in the risk of rupture. Elliot et al (1994) studied the safety of the regimen and reported rupture rates of 4.8% which are better than those reported by Small et al (1989) and Cullen et al (1989) Results compare favourably with dynamic splints, although a statistical analysis has not been carried out. Strickland (1989) stated that "the exact protocol for commencing early motion of an injured digit following a tendon interruption is a highly inexact science" (p76).

5.6.5 Comparative research between types of early controlled motion protocols

There has been a lively debate about the relative merits and clinical effectiveness of the various regimes. Table 24 summarises the research evidence.

Table 24: Evidence of comparisons of EAM protocols

Author/s & date	Method	Sample size	Findings	App. Score
Bainbridge et al 1994	3 year consecutive comparative study ZI & II	52 patients 68 digits	Compared Kleinert –passive flexion/active extension v controlled active motion (CAM) regime. Zone 1-90% good/excellent CAM v 89%% good/excellent passive/active. Zone II -95% good/excellent CAM v 50% good/excellent passive/active: Lack of palmer protective bar blamed for this.	2
Baktir et al 1996	2 year small scale comparative investigation	71 patients 88 digits	Compared Kleinert & Cullen method (2 active & 2 passive flexion and extension movements) Same splint but with wrist in neutral but with active motion exercises 4 hourly Kleinert- 78% excellent & Good Combined Kleinert-Cullen- 85% excellent & good. Rupture rate the same	2
Chambon et al 2001	2 year retrospective study in A&E	47 patients 54 digits	Compares Kleinert, Duran & Strickland. Combined results gave 65% satisfactory results, 22% fair results and 13% ruptures. Side effects less frequent with Strickland.	2
Deniz et al 2000	Kleinert or static splint	25 patients 36 digits	No exclusions from study, included bone, nerve injuries and secondary repairs. Unclear results.	5
Esther & Silfverskiold 1993	40 month quasi experimental study- consecutive sampling	158 patients 145 digits	Compares 3 groups- i. Kleinert ii. Kleinert + passive extension exercises. iii. 4 finger traction No significant difference in rates of recovery; dom/non-dom hand injuries or manual or non-manual workers.	2
Gelberman et al 1991	CPM EAM	51 patients 60 digits	Investigated passive motion regimes- increasing repetitions/use of CPM device v conventional regime (control group). More motion improves results.	2

Karlander et al 1993	Quasi-experimental study	79 patients 85 digits	Comparison conventional & modified Kleinert splint. 96%:51% good/excellent modified: conventional Kleinert. New splint aids detection of flexor contracture. 6% rupture both groups	2
May, Silfverskiold & Sollerman 1992	Prospective quasi experimental study zone II	158 pts 178 digits	Compared conventional Kleinert and modified Kleinert (all fingers involved in short splint) Results suggest modified regime is safe, reliable and cost effective.	2
May, Silfverskiold 1993	Quasi experimental study	140 patients 159 digits	Compares Kleinert, combined Kleinert and passive exercises & authors own 4-digit short splint. Shows no significant difference between groups except 4 finger protocol lowered incidence of flexion contractures	2
Peck et al 1998	2 year prospective consecutive study- matched subjects zone II	52 patients 52 digits 92 tendons	Compares modified Kleinert (Knight) and CAM (Belfast). Rupture rate – Kleinert 8%, CAM 46% Excellent & good results- Kleinert 87% CAM 69% Not statistically significant. Flexion contracture – Kleinert 31% CAM 42%	2

Four publications have been located which compare EAM and dynamic splinting. Gelberman et al (1991) studied 52 patients who were randomly allocated to one of two groups, either fitted with a CPM splint or treated with EAM. They suggested that EAM prevented adhesions and may accelerate healing through limiting inflammation, and that the more frequent the exercises the better the functional outcome for ROM at 6 months. May and Silfverskiolds' study (1993) offered less information about the comparative effectiveness of each regime than that improvement may continue over a long period at the IP joint and so any tenolysis might be delayed for a year while therapy was continued. However, both this study and a previous investigation (May et al 1992a) did not fully explore with a control group the effects of continuous but unspecified hand therapy. While Deniz et al's (2000) study involved two subject groups; no comparison of results was made. In the final paper, published in French (Chambon et al 2001) compared passive mobilisation versus two forms of active mobilisation in a small scale study. They suggested that immediate early mobilisation as described by Strickland was most effective as side effects were reduced.

5.6.6 Dynamic splints

Karlander et al (1993) compared the Kleinert and a modified Kleinert regime, the latter applying rubber bands to all the fingers. A palmar splint piece was applied to keep the IP joints straight between exercise sessions and for night resting. It was also designed to prevent inadvertent gripping. Their protocol was suggested to shorten the treatment time and the produce higher rates of excellent results. They claimed to show improved results for the treatment of the little finger and reduce PIP joint contractures. There was no further evidence to support this approach. Klein (2003) also used this splint, placing the wrist in neutral, MCPs in 50-70° flexion and the IP joints full extension, with an exercise regime of 10 full IP extensions hourly. She achieved 53% excellent results and 42% good results (Strickland-Glogovac scale 1980) and with high functional scores on DASH (Hudak et al 1996, Gummesson et al 2003, Beaton et al 2002).

A less rigorous study by Bunker et al (1989) suggested the use of a battery powered continuous passive motion (CPM) machine applied and tested at the time of surgery and used for the first 4-5 weeks to passively flex and extend the fingers. There was no supportive evidence from elsewhere for this protocol. Silfverskiold & May (1993) attempted to bring an objective measure to the analysis of splint technique, inserting metal markers to the tendons during initial surgical repair. The study showed that controlled motion using a modified Kleinert splint with bands to all fingers appeared to be effective in restricting adhesions associated with gap formation during postoperative immobilisation.

McGrouther and Ahmed (1989) found that a Kleinert splint poorly mobilised the DIP joint and required complementing with early motion regimes for full digital flexion and extension. Kleinert splints in conventional and modified forms are reported to produce excellent and good results (Chow et al 1987, Chow et al 1988, Saldana et al 1991) although results in other studies have been less convincing (Britton et al 1993).

Table 25: Evidence for the use of splinting protocols in flexor tendon injuries

Author/s & date	Splint type & method	Sample size	Findings	App. score
Bunker et al 1989	Toronto Mobilimb continuous passive motion machine 18 month prospective study clean ZII injuries (incl. 3 ZI & ZIII injuries)	20 patients 35 tendons	Machine used for 1st 4-5 wks 70% excellent and good results 30% developed cold intolerance Elastoplast attachment of device to digit stretched and required frequent replacement DIP joint movement was limited.	4
Edinburg et al 1987	Dorsal POP splint with palmar bar 10 month prospective clinical series	36 patients 70 digits	All digits- 61% excellent/good. 3% rupture rate Simple split allows patients greater independence	4
May et al 1992a	POP splint with palmar pulley – wrist 30-45° flexion; MCPs 50-70° flex; IP straight.	48patients 51 digits	Significant correlation made between IPJ ROM at intervals of 3, 6 weeks and 1 year. Recommends maximising controlled IP ROM in the early stages.	2
May et al 1992b	Modified Kleinert splint. Comparison with original Kleinert	44 patients 46 digits	Mean TAM of IP joints was increased at 6/52 and 1 year in modified group. Ext deficit was less in modified group.	4
Klein 2003	Modified Kleinert splint – wrist neutral; MCPs 50-70° flexion, IPs full extension. 2 year retrospective review of zones I,II & III	35 patients 40 digits	Extended protective splint period to 12 weeks. DASH used to assess 37% response. Zones assessed separately – ZII 95% excellent/good. No ruptures.	4

It would appear therefore that both regimes have their strengths and weaknesses, but from the available evidence both seem more effective in the treatment of zone II injuries than a programme of immobilization. Elliot et al (1994) stated that the similarity of the results in different studies showed that an adequately trained, but not necessarily experienced, surgeon, using a routine repair of divided tendon, and with good therapists, would achieve approximately 70% to 80% good and excellent results and suffer a rupture rate of about 5%, whatever the method of mobilization was used post-operatively" (p 611). This evidence might suggest the use of specialist units and experienced staff is the more important factor in increasing excellent outcomes than the choice of protocol.

There is little evidence to indicate how frequently exercises should be repeated. The risk is also that those compliant patients progressing well may be encouraged to use their hands more and risk rupture.

Evidence concerning joint positioning is not always clear. In a flexor tendon audit in Trent (TRASH 2001) there were clear unit differences in protocols with close adherence to a protocol, but comparing therapists in close geographical and professional contact; 47% positioned the wrist in neutral, 22% at 10° and 19% at 30°. The range of wrist flexion ranged from neutral to 60° with one splint placing the wrist in extension (although there is no expert evidence for placing the wrist in extension). Similar differences existed for MCP position, with

40% therapists placing the joint at 40°, 19% at 70° and 17% at 90°. This may suggest poor consensus of opinion, or a range of individual patient factors which determine joint positions. As excellent or good results were achieved in 72% cases it may suggest that a standardised treatment is not appropriate. Further examination of optimal joint positions or clinical decision trails used to determine the choice of joint position would be beneficial. The Cochrane review by Thien et al (in preparation) may clarify many issues.

5.6.7 Treatment modifications

There is a debate about the length of time the patient should be in a splint and the period before full activity is allowed (Table 26). A conservative approach is generally adopted because of the fear of rupture, and unrestricted use of the hand is delayed until 8-12 weeks post surgery. Adolfsson et al (1996) experimental study compared the relative grip strength, range of movement and return to work rates after using protocols which either allowed full hand use at 8 weeks and 10 weeks. They concluded that the post operative mobilisation programme for tendon repairs in zone II could be safely reduced to 8 weeks. Collins and Schwarze (1991) recommended an early progressive resistance protocol for patients with dense adhesions which responded poorly to other programmes.

Table 26: Evidence of treatment modifications to flexor tendon splints

Author/s & date	Method	Sample size	Findings	App. score
Adolfsson et al 1996	Prospective randomised study	82 patients 91 digits	Compared passive flexion-active extension protocol after Karlander – bands to all 4 digits. Compared 8 or 10 week point of allowing unrestricted activity. ROM, hand function and return to work same in both groups.	1
Ashall & Foster 1989	Clinical description	N/A	Cage splint to limit uncontrolled movement and discourage gripping objects.	5
Chow et al 1990	Experimental mechanical testing of range of traction systems	28 tendons	From experimental work developed modification of Kleinert using spring-wire /elastic band system to lower tension. At 4 weeks 53% experimental group had flexion contractures compared to 76% with Kleinert. At 8 weeks 3° experimental group had flexion contractures compared to 11° with Kleinert	3
Citron & Forster 1987)	Experimental electromyographic study zone II	4 subjects plus 1 patient	Used Kleinert splint. No advantage found in giving extra resistance to extensor muscles. Rubber band traction only needs to be strong enough to flex finger passively back to resting position.	2
Collins & Schwarze 1991	Prospective clinical series- final measures 18 months post surgery zones I-III	20 patients 25 digits	Selected patients with more than 50° difference between active and passive flexion= dense adhesion. Used early progressive resistance programme - hourly exercises out of the splint to gain max. tendon excursion. Grip strength (return to normal) dominant hand 72%: non-dominant 80%. Active ROM – (TAM) excellent & good- 76%. No ruptures	4
Dymarczyk 2001	Clinical description zone II	N/A	Uses tenodesis splint with locking device for use when not exercising Patient selection critical- i.e. 4 strand surgical repair & no nerve repair and can follow extremely strict exercise & splinting regimen.	5
Knight 1987	Clinical description	N/A	Modified Kleinert splint where rubber band is looped around the hand rather than attached to volar aspect of wrist or forearm.	5

5.7 Assessment

The plethora of assessment procedures and a lack of standardisation plague the assessment of flexor tendon injuries and limits comparison of research results (Table 27). Harris & Elliot (2003) note that nearly 20 methods of assessment for flexor tendon injuries have been devised in the last 50 years and yet none have been established as the most effective and adopted universally. Most are restricted to ROM measured using a goniometer or measurement of pulp to finger crease distance. Both procedures are subject to poor levels of inter and intra-rater reliability (So et al 1990). This research applied 5 different assessment methods and found that the Buck-Gramcko et al (1976) method was comprehensive and had the most advantages in measuring tendon glide and function. It was easy and quick to administer, although So et al (1990) continued to have reservations about its reliability.

Table 27: Outcome measures and assessment tests for flexor tendon injuries

Author/s & dates	Form/s of assessment	Excellent	Good	Fair	Poor
Lister & Tonkin 1986	TAM (Kleinert & Verdan 1983) compared to contra-lateral digit	100% correspondence	75-99%	50-74%	Less than 50%
Buck-Gramcko et al 1996	Finger nail to distal palm crease Total extension deficit TAM (Kleinert & Verdan 1983)	Combined score of crease, lag and TAM (Kleinert & Verdan 1983) 16-17 points	Very good 14-15 points Good- 11-13 points	7-10 points	0-6 points
Kleinert 1983	Pulp to crease (Flexion) Extension deficit	Less than 1 cm 1-15°	1-1.5 cm 16-30°	1.6-3 cm 31-50°	More than 3 cm More than 50°
Lister et al 1977	Pulp to Palm distance	Flexion within 1 cm of distal palmar crease (DPC)	1.5 cm DPC	3cm DPC	> 3cm DPC
Moiemen & Elliot 2000	TAM (DIP only) expressed as % of a normal finger for which ROM (DIP) =74%	85-100% >62°	70-84% 52-62°	50-69% 37-51°	<50% <37°
Strickland & Glogovac 1980	TAM of DIP and PIP joints expressed as % of a hypothetical normal finger for which ROM (PIP & DIP) =175°	85-100% >150°	70-84% 125-149°	50-69% 90-124°	<50% <90°
Strickland 1985	As for Strickland & Glogovac 1980	75-100% >132°	50-74% 88-131°	25-49% 45-87°	<25% <44°

Elliot & Harris (2003) reviewed assessment methods to categorise the outcome of treatment in each zone and suggested that a classification of excellence reflected medical rather than patient perceptions of function. An excellent score did not equate to a full return to a patient's view of normal function. More sensitive therapeutic measures were required to better capture a range of physiological and occupational outcomes.

Deniz et al (2000) questioned the dependence on goniometry. They stated that "as the aim of the rehabilitation process is to decrease disability and maximise hand functions, pinch grip, finger dexterity and hand disability should also be taken into consideration during follow up of these patients for evaluation of functional outcome after hand injuries" (p 66). Only one paper in the review of flexor tendon injuries referred to DASH or any other functional assessment (Klein 2003).

5.8 Prognosis

Gault (1987a) in a study of 176 flexor tendons found that the mean return of grip strength and finger pinch pressure was only approximately 75% of the contralateral digit even where mobility had been fully restored. Regrettably he did not record the proportion of dominant and non-dominant hand injuries.

5.9 Health economics

A detailed cost analysis by Rosberg et al (2003) of zone II injuries found that EAM and Kleinert protocols were more expensive in terms of diagnostic procedures, operations and rehabilitation than immobilisation regimes, but improved ROM at discharge by 5-7%. Costs were unsurprisingly higher for people with injuries to more than one digit, had ruptured during the course of rehabilitation and those over the age of 35. More unexpectedly, total health costs were lower for people with injuries to the dominant hand and for people over the age of 63; even though healing is slower in the older client and they have a greater risk of adhesions (Grobbelaar & Hudson 1995).

Panchal et al (1997) suggested that early active flexion regimes for zone V injuries reduce the need for out-patient physiotherapy and allow earlier return to work making this approach medically and socially cost effective.

A review by Meikle and Price (2003) indicated that while Chow's passive Washington Regime (1990) offered the best results from their appraisal of the literature, there were cost implications of daily supervised exercise for patients travelling to the hand therapy unit which made it inappropriate for use in their department with a geographically dispersed population.

5.10 Practice Points

- Evidence clearly indicates the effectiveness of early active motion and dynamic splint regimes for the treatment of flexor tendon injuries over immobilisation regimes.
- Recovery occurs over a long period and further surgical intervention might be delayed for 6-12 months with continued hand therapy.
- EAM and dynamic splinting appear to be equally effective in improving ROM and have a similar, but not statistically calculated risk of tendon rupture.
- Patient education and full co-operation with the treatment is essential to a good outcome and to reduce DNA rates.
- Outcome measures should be extended beyond those focussed on ROM to include fuller functional measures.
- The therapist needs to appreciate the risks of rupture and provide clear management guidelines or agree to the fitting of restraining splints to help the patient avoid ruptures during unavoidable risky activities.
- Therapists should estimate the cost implications for the service and the patient in terms of materials, time and travel of intensive hand rehabilitation programmes.

5.11 Research recommendations

The paucity of comparative papers might suggest the following areas for research development:-

- More substantial RCTs are required to determine the effectiveness of EAM and dynamic splint approaches.
- Determine how treatment choices might better match client need.
- Investigate the type and delivery of patient education.
- Explore the frequency and form of out-patient follow-up which contributes to effective treatment.

6.0 The Thumb

6.1 Definition

A fully opposable thumb differentiates humans from all other non-primate species (Emerson et al 1996). Colditz (1995) calculates that 50% of hand function is contained within the movement of the thumb; Doegge & Houston (1993) estimated 40%. Yet while much has been written about the treatment of finger tendon injuries comparatively little is available on the management of the thumb. Most evidence relates to flexor tendon injuries. These papers also predominantly offer an overview of surgical procedures for tendon repairs in this digit rather than the post-operative aspects of care. The central importance of the thumb to hand use may create particular frustration with treatment and may contribute to poor treatment compliance with long periods of immobility. It may be both the complexity of many injuries and the difficulty in establishing reliable and valid outcomes which explains the limited literature.

The thumb presents a conundrum, in that the full range of motion considered both ideal as an outcome of surgery and therapy is in considerable excess of that required for everyday hand function (Khandwala et al 2004). Flexion and opposition of the thumb across the palm to the little and ring fingers is not necessary to achieve adequate function in most activities of daily living which require only pinch and tripod grip with the index and middle fingers. What should be considered a satisfactory functional outcome should also be based on individual need and life style.

The thumb's wide range of motion and its key role in most forms of grip mean that injuries result in complex and often unpredictable disability.

6.2 Aetiology

Flexors
There is limited data available about the aetiology of thumb injuries, especially flexor tendon injuries. An unpublished review of cases over a period of 6 years showed that these are commonly caused by domestic accidents such as crockery breaking, separating frozen foods or by grasping sharp objects such as knives. Injuries often involve neurovascular complications, only 15% being simple tendon injuries (Nunley et al 1992).

Extensors
The literature agrees that most extensor tendon injuries occur in men as a result of work, DIY, road traffic accidents or violent incidents and are frequently caused by band/circular saw or craft knife damage across the proximal phalanx or metacarpal. In a study of 100 patients in zones I to IV, 90 had injuries caused by knives or glass and seven by blunt or crush injuries, and the remainder by road traffic accidents (Khandwala et al 2004). Mallet type injuries to the thumb in zone I are rare (Niechajev 1985), although as with mallet injuries in the fingers, evidence of prevalence is equivocal. Extensor tendon injuries can also occur through fraying of the tendon in RA or as delayed sequelae of fracture although this only occurs in only 0.3% cases (Hove 1994). In this study only 18 such cases were treated in five years.

The extensor pollicis longus (EPL) is subject to continuous stress and tenosynovitis is an occupational risk for certain professions, such as musician (Crabbe 1980). Ruptures usually occur at the level of the distal radius beneath the extensor retinaculum (Hunter et al 1995).

6.3 Diagnosis and clinical features

Flexors
The inability to flex the interphalangeal joint of the thumb is the most obvious diagnostic feature in flexor pollicis longus (FPL) injuries, although it is usually still possible to flex the MCP and the carpometacarpal (CMC) joints due to the action of the intrinsic thenar muscles. If the FPL is severed, it frequently retracts to such an extent that, unless surgery is undertaken in the first few hours, it would be impossible to perform a primary repair and obtain a good outcome. Murphy (1963) indicated that while it was possible to improve the outcome by using step lengthening procedures, delay often resulted in the need for grafts. As with other complete tendon lacerations, primary repair is reported to be generally carried out in the first 48 hours after injury using a modified Kessler and an overlocking suture (Marin-Braun et al 1991). Rupture rates are higher for the thumb than other digits (Sirotakova 1999, Percival & Sykes 1989).

Extensors
The EPL is the most mobile of the digital extensor tendons (Rosenthal 1995). The most disabling feature of rupture to EPL is loss of extension at the interphalangeal (IP) joint (Hunter et al 1995). The ability to extend the MCP joint to 0º is due to the action of extensor pollicis brevis (EPB). However, the abductor pollicis brevis (APB) inserting into the extensor expansion is often retained after an EPB lesion. The one sure test of an EPL lesion is whether the patient can lift the thumb up dorsally from the table. Closed rupture of the EPL "mimics the mallet tendon injury of the finger. Loss of full active extension of the IP joint with localized dorsal swelling occurs" (Hunter et al 1995 p552). The consensus is that the repair is made with either a modified Kessler plus overlocking suture where the tendon is of sufficient size, or alternatively with a simple mattress suture.

6.4 Prevalence

Thumb injuries are common in all age groups, with damage to the flexor pollicis longus accounting for 10% tendon injuries in children. Within research projects involving all the digits, thumbs appear to represent a small proportion of their sample, but it is uncertain whether thumb injuries were excluded from most studies. The prevalence of thumb injuries and the specific types of injury are therefore unclear (Table 28)

Table 28: Percentage of tendon injuries in the hand occurring in the thumb
Flexors

Author/s & dates	Sample size	% incidence	Comments
Glassey 2002	85 patients with flexor tendon injuries	8%	Incidence of FPL lesions in all referrals – in-house audit
Purcell et al 2000	88 patients 116 digits	9%	Flexor tendon injuries Only 38% sample attended review
Roy 2003	84 digits	12%	Referral audit in hand therapy unit

Extensors

Author/s & dates	Sample size	% incidence	EPL injury	EPB injury	Comments
Ranelli & Henk 1998	27 patients 38 digits	26%	86%	14%	Patients considered inappropriate for active mobilisation excluded.
Glassey 2002	100 patients with extensor tendon injuries	21%	9%	n/a	Incidence of EPL lesions only in all referrals – in-house audit

6.5 Aims of treatment

Flexors and Extensors.
The aim is to optimally restore all the essential functions of the thumb in fine and gross grip while protecting the repaired tendon from rupture. While the loss of flexion at the MCP joint appears to have limited functional importance, loss of flexion at the interphalangeal joint does have major implications, particularly for those whose work entails fine movements and precision grip. (Khandwala et al 2004)

6.6 Treatment

6.6.1 Splint types

Flexors
Splints for flexor tendon injuries usually involves a dorsal hood similar to that for finger flexors with the MCP joint in approximately 20º flexion and the IP joint in neutral. Some evidence suggests that splinting the wrist in slight extension and ulnar deviation may reduce the risk of rupture (Sirotakova 1999) and that including the fingers in a protective hood may help reduce the risk. Duration of splinting is normally the same as for finger flexors

Extensors

Splints for extensor tendon injuries of the thumb can be either static, usually a volar forearm based gutter, or dynamic in design. As with flexors the duration is the same as for finger extensors.

6.6.2 Evidence for the use of static and dynamic splinting

There is controversy about the comparative benefits of dynamic splinting over static splinting for both flexor and extensor tendon injuries. The evidence suggests that dynamic splinting gains extra range of motion at no increase in the rupture rate (Table 29). There is limited evidence to suggest that early active motion may have the same benefits but be more cost effective.

6.6.3 Flexor tendon injuries of the thumb

Evidence for the treatment of flexor tendon injuries is scarce (Table 29). While zone I and II injuries of the fingers are well documented, research and clinical studies of these injuries on the thumb are not differentiated. The focus has rather been on the comparative value of dynamic or static splinting; the results of which are inconclusive

Table 29: Evidence comparing dynamic and static splinting and different types of dynamic splinting

Author/s & date	Method	Sample size	Findings	App. score
Percival & Sykes 1989	Comparative study- matched groups- Kleinert and Static protocols. Flexor tendon injuries	51 patients	Compared Kleinert and static splints Rupture rate same for both protocols ROM poorer in static splint. Static 44% Good and excellent, rupture 8% Kleinert good and excellent 60% , rupture 8% (White's assessment)	2
Sirotakova 1999	Comparative study Flexor tendon injuries	148 patients	EAM produced similar results to dynamic regimes EAM more "user friendly" and cost effective	2

6.6.4 Extensor tendon injuries of the thumb

Evidence for therapy for extensor injuries in the thumb is slightly greater (Table 30) although often evidence appears as part of all digit investigations of extensor tendon injuries in the hand, of which thumb injuries form a small part (Ip & Chow 1997, Hung at al 1990, Browne & Ribik 1989). Hunter et al (1995) stated that the treatment for rupture of EPL was continuous dorsal splinting with the IP joint in slight hyperextension for six weeks with a recommendation of 2-4 weeks additional night splinting. Evans and Burkhalter (1986) suggested that special attention is needed when treating EPL in the third dorsal compartment, because of the likelihood of adhesions. These injuries are usually treated statically with the MCP in 20 degrees of flexion and IP joint in a neutral position. However, Khandwala et al (2004) stated that dynamic extension of the thumb for injuries to the EPL was safe and effective and that early active motion may be possible. Evans (1988) recommended alternating web spacing with dynamic splinting to stretch contracted tissues, but all the movements of the thumb must be incorporated.

Table 30: Evidence of effectiveness of splinting methods for thumb Extensor tendon injuries

Author/s & date	Splint & Method	Sample	Findings	App score
Barinka 1988	Volar POP with all joints immobilised in slight hyperextension	N/A	Only POP strong enough to maintain correction position. Can be combined with rubber band technique if MCP joint limited by scarring.	5
Browne & Ribik 1989	DES- Motion from 3-5 days; 5 wks in splint	12 thumb tendons- zones III-VII	75% regained normal pinch No specific thumb results	4
Hung et al 1990	DES Motion from 3 days:5 wks in splint	10 thumb tendons – zones I-V	80% excellent/good results (TAM)	4
Ip & Chow 1997	DES- motion from day 2; 5 wks in splint	37 thumb tendons- zones I-VI	97% excellent/good results (Dargan)	4
Khandwala et al 2004	Clinical series – 76% pts followed up to 12 weeks Palmar POP followed by DES for injuries in zones II, III & IV	100 patients 100 EPL divisions	Assessment using White, Buck-Gramcko & TAM. 21% sample did not complete 8 week programme. 2% rupture. Improvements shown when therapy extended from 8 to 12 weeks (81% to 90% excellent)	4

Newport et al 1990	Static splint	10 thumb tendons	60% excellent/good results (Miller)	4
Purcell et al 2000	Static splint	10 digits – zones I-V	80% excellent or good(but includes 1 pt in constant pain) 20% fair. Zone II particularly problematic. Static splinting as effective as dynamic.	4

6.6.5 Joint positioning

There is no clear agreement about the most effective positioning of the joints for splinting tendon injuries to the thumb (Table 31).

Table 31: Joint positioning for thumb splinting

Flexor tendon injuries

Author/s & date	Wrist joint	Radio-carpal joint	MCP joint of thumb	PIP joints
Percival & Sykes 1989	Not stated	Not stated	20° flexion	0° flexion
Sirotakova 1999	10° extension	Ulnar deviated	Not stated	Not stated

Extensor tendon injuries

Author/s & date	Wrist joint	Radio-carpal joint	MCP joint of thumb	PIP joints
Khandwala et al 2000	30° extension	Not stated	20° flexion	0° flexion

6.7 Assessment

Assessment of the thumb is difficult because of the complex movements it performs. Khandwala et al (2004) in a study of extensor tendon injuries noted that total capacity of thumb movement exceeds that necessary for normal hand function, measurement of excellent function is problematic.

Table 32: Outcome measures and assessment tests for flexor tendon injuries in the thumb

Author/s & date	Measurements	Excellent	Good	Fair	Poor
White 1956	TAM (IP only) Expressed as a % of the opposite thumb	70-100%	60-69%	40-59%	<40%
Buck-Gramcko et al 1976	Designed for FPL and EPL. Flexion IP joint Extension lag TAM- thumb	14-15 points (Maximum points 15)	11-13 points	7-10 points	0-6 points

Other assessments mentioned in the literature include designs for EPL, but were found to be unreliable (Khandwala et al 2004), Millers 1942 test, which when applied to the thumb tends to downgrade most results to fair or poor. None are proven to be reliable and specific enough to highlight the problems of the thumb

6.8 Prognosis

The protocols listed above are generally found to be effective in restoring a functional level for activities of daily living in most cases. However, there is likely to be a loss compared to the contra-lateral thumb. Nunley (1992) reported key pinch strength of 81% for end to end repair of FPL, although the range of the follow up period is from 3 –120 months (mean 26 weeks) which confuses the results.

6.9 Health economics

In the absence of any convincing evidence on thumb splinting, no cost evaluation can be made.

6.10 Practice points

Flexors

- EAM is suggested within 24 - 48 hours of surgery for flexor tendon injuries.
- Splints should position the wrist, radio-carpal, MCP and IP joints carefully to reduce risks of rupture.
- Mobilisation of the thumb either actively in both extension and flexion; or actively in extension and passively in flexion. Either protocol is generally preferable to immobilisation.
- Active flexion regimes, given adequate suturing are comparable to passive flexion regimes. Treatment choice should be made in collaboration with the surgeon.
- All treatments should be tailored to the individual patient’s needs.

Extensors

- Splints should position the wrist, radio-carpal, MCP and IP joints carefully to reduce risks of rupture.
- Mobilisation, either in dynamic splintage or even actively is preferable to immobilisation

6.11 Research Recommendations

Research data for the thumb is limited both in relation to surgical and post-surgical procedures and for conservative interventions. There is a clear case for more detailed investigations.

- Any research on the thumb.
- Comparisons involving more rigorous, prospective research methods of data collection and data analysis between dynamic splinting and EAM protocols.
- The paucity of evidence in this area of the hand is particularly surprising considering the frequency of injuries occurring in the thumb. It may, however, be due to the number of complications present with these injuries.
- Evaluation of patients’ perspectives of thumb function for full return to activities of daily living and employment.

7.0 Common Disensions of Hand Therapy for Tendon Injuries

This Bulletin presents the evidence for the treatment of specific locations of tendon injuries in the hand. However, in the course of carrying out the review, certain themes emerged of importance to the treatment of tendon injuries which need to be identified and managed. The themes identified were oedema, assessment, adherence and costs. These are discussed but do not offer comprehensive or complete peer reviewed evaluation of the evidence for these themes.

7.1 Oedema

Stanley et al (1998) surveyed hand therapists in the UK and found that oedema was often or sometimes encountered in hand injuries in 89% of cases in specialist units and 75% cases in non-specialist units. In the former, 89% therapists used a protocol designed to reduce oedema compared to only 41% of therapists in the non-specialist units. This suggested that the importance of, or facilities to manage oedema may not be fully appreciated by non-specialists. From a review of the literature, Stanley et al (1998) stated that oedema was inevitable after injury, and would cause fibrosis and contractures, limiting range of movement in the hand. Stiffness can become irreversible and inflammation causes pain. For these reasons elevation is recommended (Brand & Hollister1992) and active movement in the proximal joints of the arm as well as the hand will reduce both stiffness and oedema. Massage, particularly if used in elevation and performed from distal to proximal, can aid venous return, increase lymphatic drainage and mobilise oedema. However, it is important that following massage the dispersal of oedema is maintained by patient compliance with elevation, pressure garments and exercise (Palmada et al 1999, Sorenson 1989).

7.2 Assessment protocols

The valid and reliable measurement of the hand is problematic. In the early stages of treatment the presence of swelling and pain and practical difficulties due to working within a splint, limit the accuracy of joint measurement using goniometry or dynamometry. There is also clear evidence of poor inter- and intra-rater reliability in using these tools (Jones 1989).

In addition, a number of scales have been developed for assessing surgical effectiveness. Although similar in format, either identifying excellent, good, fair or poor results (Crawford, Dargan, Miller and Kleinert scales) or successful, improved or failed outcomes (Abouna & Brown and Warren & Norris scales) they do not share common assessment criteria. For example, in the case of mallet injuries, Crawford's scale only accepts the complete absence of extension lag as an excellent result, while Abouna and Brown and Warren and Norris' scale tolerates 5° degrees of lag. The extent to which each of these scale has been standardised is unknown. Evans (1990) notes the often liberal allowances for excellent and good results when using these scales and the conflation of these two scores when reporting findings. This makes comparison of research or clinical series results very difficult. It is also apparent that some projects have excluded patients with fair or poor results, because they are deemed to have been non-compliant (Caroli et al 1990), while the compliance of the whole cohort has not been established.

It is of note that although demographic details of gender, age and dominance are often included in results, these variables are rarely addressed in the analysis of the findings. Where client groups are characterised as older women with domestic injuries and young men with sports injuries, outcomes might be expected to differ. Yet results frequently treat patient samples as homogeneous based on their diagnosis alone. Similarly little account is taken of whether the injury occurred in the dominant or non-dominant hand or in a specific digit (Caroli et al 1990).

Surgical papers often provide minimal information about the patient's involvement in hand therapy. Many papers fail to record the type, frequency or duration of occupational therapy and/or physiotherapy involvement. Therapy papers too, often omit descriptions of the surgical procedures previously carried out. Therefore it is not easy to differentiate the effectiveness of combined or sequential treatments.

So et al (1990) carried out a comparative evaluation of 5 assessment procedures on 95 digits (135 tendon injuries). These included linear measurement, Buck-Gramcko, Grossman, ASSH and Strickland. They found the Buck-Gramcko gave the best results and took the average therapist only 10 minutes to administer but suggest the TAM score it offers is too lenient. They called for a universal system which meets four requirements; integration of tendon gliding and function, the inclusion of MP joint measurements, angular measurement and representations of joint positions. Without these valid measurements, they claim all the assessment systems have significant flaws.

These assessment tests respond to a medical need to evaluate outcomes of surgery, and do not include function criteria linked more closely to activities of daily living. Therapists may choose to use DASH (Solway et al 2002; Gummesson et al 2003) or the Smith Hand Function Evaluation (Smith 1973) or add an assessment such as Patient Evaluation Measure (PEM) (Dias et al 2001, Burke & Macey 1995) or the Canadian Occupational Performance Measure (COPM) (Law et al 1995) to capture client-led objectives. In view of the link with self harm in a small percentage of tendon lacerations, depression and anxiety scales might also be employed to evaluate mental state.

The comparison of hand therapy protocols is limited by the absence of standardised assessments tests, or agreed batteries of tests with proven validity and reliability. The assessment criteria employed by surgeons for treatment outcomes may also not be those which accurately reflect outcomes of therapy or functional limitations from the patients' perspectives.

7.3 Management of tendon injuries in children

Ljungberg (2003) reviewed the epidemiology of general hand injuries in children in Sweden. It was found that boys were more commonly injured (61%) with a higher incidence of injuries between May and September. Injuries to tendons in children however are quick to heal as the tendons have a better blood supply than in adults (Verdan 1972), adhesions are more pliable (Arons 1974) and tissue healing in general is more rapid (Hendon 1976). The majority of studies reviewed the effects of flexor tendon injuries in children (Table 33). It is generally agreed that children under 10 years old, are unable to follow the instructions for a mobilisation programme and should be treated with immobilisation (Rosberg et al, 2003). Kato et al (2002) recommended a younger age (under 6 year olds), advocating immobilisation in an above elbow cast for 3 – 4 weeks with the repaired finger held in flexion at all joints whilst the uninjured fingers were maintained in extension of the PIP & DIP joints. Following this post-operative management they reported that out of 12 subjects, only one required tenolysis. Fitoussi et al (1999) examined factors that may influence the prognosis for children with flexor tendon injuries and found that ruptures occurred in children less than 5 years old who had below elbow splintage. Therefore they recommended that very young children should be immobilised in above elbow cast.

A number of studies compared immobilisation with early passive motion (Kleinert regime) and found no significant difference in outcome (O'Connell et al, 1994; Berndtsson & Ekeskar 1995; Fitoussi et al, 1999). However, the reliability of these researches is uncertain, as in

Berndtsson & Ejeskar's paper, where injuries involving nerve injury are combined with those which do not. Fitoussi et al (2000) also reviewed FPL repairs in children and found that although assessment methods were lacking, below elbow splintage led to rupture or loss of motion but neither the zone of injury nor early mobilisation had any significant effect on the outcome. However, other studies noted that early mobilisation was essential for an adequate outcome following flexor tendon injury (Hendon 1976, Hollwarth & Haberlik 1985, Grobbelaar & Hudson 1995).

Stahl et al (1997) compared primary repair of partial flexor tendon (less than 75% of cross section) injuries followed by early motion to conservative management. It was found that the outcome of the 2 groups were similar and recommended that early motion should be used for those children who were found clinically to have partial injuries but those for whom there was doubt should be explored to exclude complete division. Tuncay et al (2002) recommended excision of the FDS tendon and repair of FDP tendon in children as this simplified the operative procedure and reduced the number of sutures inside the sheath. Hazarika (1988) describes an electrical gadget which lights a lamp when the child achieves the movement of the fingers into extension against the dorsal splint where an electrical contact is completed. This gadget provides motivation for exercise suitable for children from 11 months old. Further development of systems linked to play are also suggested, including using sound as monitor and incentive and micro technology to record number of exercises completed.

Valenti & Gilbert (2000) stated the importance of patient and parent co-operation following hand surgery. They found that the results of two stage reconstructive procedures following flexor tendon injuries were better with older children (10 – 15 years old). Most evidence suggests that outcomes are better with older children up to the age of 19 (Rosberg et al 2003), and with girls more than boys, possibly related to their ability and willingness to follow instructions (Berndtsson & Ejeskar 1995).

Valenti & Gilbert (2000) also noted the problem of growth of the child following any procedure and Gaisford & Fleegler (1973) reported retardation of growth of digits if flexor tendon injuries were not repaired. Graham & Berger (2003) reported a case of a child who following an oblique retinacular ligament reconstruction for swan-neck deformity, developed a boutonnière deformity due to tightening of the tendon transfer as the patient grew.

Table 33: Evidence for treatment following FPL injury in children

Author/s & date	**Method**	**Sample**	**Findings**	**App. score**
Fitoussi et al 1999	3year follow-up study	44 patients 58 digits	Participants aged 1-13 yrs TAM (Strickland) 84% excellent, 5% good, 2% fair, 9% poor. 9% rupture rate especially in young children EAM, post-operative immobilisation and digital nerve involvement had no significant effect on final results	4
Grobbelaar & Hudson 1995	Retrospective study	9 patients	Participants aged 7 months -11 yrs	4

Clearly the treatment options selected must be related to age, stage of cognitive development, in discussion with parents/carers and in relation to the play or school activities undertaken by the child. There appears to be a need for further research in this area probably dealing separately with interventions and instructions to children in different age groups.

7.4 Adherence and compliance

The literature reveals two key issues related to compliance:
1. That a significant proportion of patients are reported to be non-compliant with treatments considered by the treatment team to be effective.
2. That compliance is a significant factor in the exclusion of people from the data collection or analysis stage of research on tendon injury.

These present problems for identifying effective treatment and defining the nature of what constitutes non-compliance. There are some implicit indications that groups of clients are viewed as problematic because of their inability or unwillingness to follow the selected protocol. The terms used to identify these people suggests some negative stereotyping; Kleinert (1967) described them as unreliable and indigent and Harris et al (1999) suggested that these incidents were described by staff as 'acts of stupidity'. Throughout much of the literature non-compliant patients are either excluded from the studies or fair or poor results are attributed to their failure to comply. In the absence of a clear and proven measure of compliance, it is unclear how this interpretation has been reached.

Kitsis et al (1998) stated that "apart from patients who clearly were not going to co-operate with any form of post-operative physiotherapy, there were few problems with compliance" (p346). Kirwan et al (2002) highlighted the problems of defining and identifying features of non-compliance which were viewed as a patient problem by staff and not one caused or sustained by health professionals or the hospital environment. More importantly they show that staff and patients viewed compliance differently. Patients described lacking time, discomfort and pain as reasons for not following treatment programmes and dissatisfaction with the quality and duration of interactions and care, as reasons for not attending appointments. They were unsure of the importance of daily living restrictions suggested by staff. In contrast, staff viewed non-compliance in terms of forgetfulness or low motivation, suggesting the client was ignorant, blasé or forgetful (Meikle 2002, Ray 1999).

Compliance is clearly identified in the literature as a complication for the therapist's management of tendon injuries. The need to follow instructions on wearing splints, their care and removal and the accurate completion of exercise regimes are considered key to the success of most early motion protocols (Groth et al 1994). Yet less is discussed about how patients can be best educated and trained in these programmes, or how people are selected or can negotiate which type of approach would best suit their work and domestic life styles (Meikle 2002). Efforts to encourage mutual understanding of expectations might reduce the waste of resources, dissatisfaction and possible limitations to full recovery (Steward 2004b). An understanding of patients' experiences of hand injury and its treatment may facilitate their full involvement in treatment (McIver 1991, Meredith & Wood 1995). Psychosocial problems of hand disfigurement are not necessarily linked to the degree of injury Rumsey et al (2003). Dissatisfaction with the physical and social environments in hand clinics may also contribute to low levels of adherence to and satisfaction with treatment. Work is clearly required to identify and debate general and individual reasons for poor adherence to recommended treatment. While non-compliance is generally viewed as the principle problem, over-adherence also creates risks (Stewart & van Strien 1995).

7.5 Costs

There is little evidence in the articles reviewed about cost effectiveness of rehabilitation intervention in hand therapy. Therapists are often left to draw their own conclusions. The empirical fact remains that the cost of materials i.e. thermoplastic, is the least of the resource expenditure, if the same splint can be used for the protective period of rehabilitation, and splintage minimised for the post-acute phase of after the 6th post-operative week.

It behoves the therapist to choose the optimum therapy to ensure prevention of tendon dehiscence, promote healing and tendon glide and prevent joint stiffness and contracture. The majority of expenditure is on therapists' time and therefore therapy protocols / guidelines that minimise the number of treatments and ensures a favourable outcome equates to cost effectiveness. For most tendon injuries this equates to optimum care within the first 6 weeks of post-operative therapy. A model of follow-up in practitioner-led hand clinics can optimise care and can provide the most cost effective care for all but the most complex injuries, which require medical supervision.

There are wider issues of cost analysis which the therapist needs to consider when planning treatment. The first is the human resource costs of making more complicated splints where simpler ones might be equally effective. Therapists must be sure that there is clear proof that a specific type of splint is significantly more effective must be established, and then ensure that adequately trained staff provide it. This has human resource implications. The second involves calculating the costs to the patient of frequent visits for out-patient appointments in travel costs and time lost at work. A cost benefit analysis of any intervention, carried out with the client may prove valuable and avoid later non-attendance. The extent to which out-patient appointments have unequivocal benefit to the patient presents a financial and an ethical calculation.

8.0 Summary

The literature review summarised in this Bulletin indicates the breadth and depth of the available evidence on the treatment of tendon injuries. There is evidence of considerable areas of broad consensus on the importance of early intervention, early referral for therapy, early mobilisation and patient education. There are also live debates about the fine details of many elements of therapeutic intervention which require further investigation. Much new evidence is already in press and this review, in such a topical area will require review in five years time.

Glossary of Terms

Term	Definition
ADL	Activities of daily living
Baseball finger	Mallet finger deformity
Billericay CAM regime	Splint wrist & MCP at 30° flexion for 5 weeks Movements 10pd. Full ROM at end 3rd week. Passive extension after 8wks.
Boutonnière deformity	PIPJ flexion & DIPJ hyperextension deformity due to disruption of extensor digitorum central slip
BTE	Baltimore Therapeutic Equipment
Button hole deformity	As for Boutonnière deformity
Capener splint	Dynamic splint that holds PIPJ in extension at rest but permits active flexion
Central slip injuries	Injuries to the extensor digitorum tendon in zone III over the dorsum of the PIP joint
Clamdigger splint	Dorsal splint for flexor tendon rehabilitation, positions: • Wrist 20-45 degrees flexion • MCP joints in 40 – 60 degrees flexion • IP joints allowed to fully extend
Cold intolerance	Sensitivity of the injured hand to cold
Controlled active motion (CAM)	A regime of exercise for repaired flexor tendon injuries which requires the patient to actively exercise the digits into flexion followed by extension to a dorsal blocking splint
COPD	Chronic obstructive pulmonary disease
COPM	Canadian Occupation Performance Measure
Cricket finger	Mallet finger deformity
DASH	Disablement Arm Shoulder and Hand Questionnaire
DES	Dynamic extension splint
Drop finger	Mallet finger deformity
Early active motion (EAM)	Synonymous with CAM
Early passive motion	A regime of exercise for repaired flexor tendon injuries which maintains passive flexion and requires active extension to a dorsal blocking splint
EPB	Extensor pollicis brevis
EPL	Extensor pollicis longus
Extensor lag	Loss of active extension at a joint
Full house syndrome	See spaghetti wrist
Glassona splint	Very early polythene splint developed by Smith & Nephew and adapted by Stack
Jammed finger	Closed subcutaneous rupture following forced digital flexion
Kirschner wire	Internal wire fixation of a fracture / tendon repair
Kessler suture	Locking suture for repair of flexor tendons
Louisville system	An assessment procedure based on flexion and extension
Mallet finger deformity	Following a mallet injury the unopposed pull of the FDP tendon causes the DIPJ to be held in flexion
Mallet injuries	Injuries to the extensor digitorum tendon in zone I over the dorsum of the DIP joint
No man's land	Zone II for flexor tendon injuries: extends from distal palmar crease to DIP joint
Norwich regime	Controlled active motion regime for extensor tendon repairs
OT	Occupational therapy/ist
Overlocking suture	Circumferential epitendinous suture that aims to smooth the surface of the repaired tendon and facilitate glide
PEM	Patient Evaluation Measure
PFT	Palmar flexion ?

PT	Physiotherapy/ist
Rotterdam splint	Forearm-based dynamic extension splint with the affected digit slung in leather loop attached to dorsal outrigger.
Rugby shirt injury	Zone I flexor tendon avulsion injury
SAM	Short Arc Motion
Spaghetti wrist	Injuries occurring between the distal wrist crease and the flexor musculocutaneous junctions involving at least 3 completely transected structures including at least one nerve and often one blood vessel (Chin et al 1998)
Stack splint	Off the shelf splint for mallet finger deformity available in various sizes
Total active motion (TAM)	Total sum of active flexion at each joint of one digit minus total sum of active range of extension at each digit joint – gives a global picture of digit active motion
Total passive motion (TPM)	Total sum of passive flexion at each joint of one digit minus total sum of passive range of extension at each digit joint – gives a global picture of digit passive motion
Trigger finger	Locking of a digit in flexion followed by a sudden resumption of extension often associated with an audible click. Due to a swelling on the tendon within the region of the MCP joint which prevents smooth gliding of the tendon beneath the A1 pulley
Washington Regime	Dorsal blocking splint devi sed by Chow et al–wrist at 30° flexion and MCPs at 35-40°.

References

Abouna JM & Brown H (1968) The Treatment of Mallet finger *British Journal of Surgery 55(9): 653-667*

Abouna JM (1966) Another splint for mallet finger. *Nursing Mirror & Midwives Journal vii*

Adolfsson L, Soderberg G, Larsson M & Karlander LE (1996) The effects of a shortened postoperative mobilization programme after flexor tendon repair in zone 2 *Journal of Hand Surgery 21B(1): 67-71*

Al Qattan MM (2000) Conservative management of zone II partial flexor tendon lacerations greater than half the width of the tendon *Journal of Hand Surgery 25A(6): 1118-1121*

Arons MS (1974) Purposeful Delay of the Primary Repair of cut flexor tendons in 'some-man's-land in children. *Plastic Reconstruct. Surgery 53: 638-642*

Ashall G & Foster A (1989) The "cage" splint: an added protection for flexor tendon repair *Journal of Hand Surgery 14B(1): 128*

Auchincloss JM (1982) Mallet finger injuries: a prospective, controlled trial of internal ad external splintage. *Hand 14: 168-173*

Bainbridge LC, Robertson C, Gillies D & Elliot D (1994) A comparison of post-operative mobilization of flexor tendon repairs with "passive flexion-active extension" and "controlled active motion" techniques *Journal of Hand Surgery 19(4):517-521*

Baktir A, Turk CY, Kabak S, Sahin V & Kardas Y (1996) Flexor tendon repair in zone 2 followed by early active mobilization *Journal of Hand Surgery 21B(5): 624-628*

Barinka L (1988) Rehabilitation in plastic surgery, simple splinting of extensor tendons of the hand. *Acta Chirurgiae Plasticae 30(1): 44-57*

Beaton D E et al (2002) The DASH (Disabilities of the Arm, Shoulder & Hand) Outcome measure: what do we know about it now? *The British Journal of Hand Therapy* ***6*** *(4) pp 109 - 118*

Berman K & Failla JM (1995) A method of converting a mallet splint into a Boutonnière splint. *Journal of Hand Therapy 8: 214*

Berndtsson L, Ejeskar A (1995) Zone 2 flexor tendon repair in children. A retrospective long term study. *Scandinavian Journal of Plastic & Reconstructive Surgery & Hand Surgery, 29(1):59-64*

Blair WF & Steyers CM (1992) Extensor tendon injuries. *Orthop Clin North America 23: 141-148*

Boscheinen-Morrin J & Conolly WB (1997) *The fundamentals of hand therapy.* Oxford, Butterworth-Heinemann

Boyes JH (1970) *Bunnell's surgery of the hand*. Philadelphia, Lippincott

Brand PW & Hollister A (1992) *Clinical mechanics of the hand, 2nd edition*. St Louis, Mosby

Britton E, Chesher SP & Kleinert JM (1993) *A prospective evaluation of zone II flexor tendon injuries after early post-operative mobilization*. Paper given at the meeting of the ASSH, Sept 1993.

Brown CP & McGrouther DA (1984) The excursion of the tendon of flexor pollicis longus and its relation to dynamic splintage. *Journal of Hand surgery 9A(6): 787-791*

Browne EZ & Ribik CA (1989) Early dynamic splinting for extensor tendon injuries. *Journal of Hand Surgery 14A: 72-76*

Brzezienski MA & Schneider LH (1995) Extensor tendon injuries at the distal interphalangeal joint. *Hand Clinics 11: 373-386*

Buck Gramcko D, Dietrich FE & Gogges S (1976) Bewertungkriterien bel nauchuntsuchungen von beugesehnenwiederherstellungen. *Hand Chirugie 8: 65-69*

Bunker TD, Potter B & Barton NJ (1989) Continuous passive motion following flexor tendon repair. *Journal of Hand Surgery 14B(4): 406-411*

Burge PD & Brown M (1990) Elastic band mobilisation after flexor tendon repair; splint design and risk of flexion contracture. *Journal of Hand Surgery 15B(4): 143-148*

Burke F (1988) Mallet finger. *Journal of Hand Surgery 13: 115-117*

Burke FD & Macey AC (1995) Outcomes of hand surgery. *Journal of Hand Surgery 20B(6): 841-855*

Byron P (1997) The Rotterdam splint. *Journal of Hand Therapy 10: 240-241*

Campbell DA & Kay SP (1998) What is cold intolerance? *Journal of Hand Surgery, 23B(1): 3-5*

Cannon NM & Strickland JW (1985) Therapy following flexor tendon surgery. *Hand Clinic 1:147-165*

Carducci AT (1981) Potential boutonnière deformity; its recognition and treatment. *Orthopaedic Review 10:121*

Carlsson I (2003) Hand Rehabilitation in Sweden: an occupational analysis with the focus on specialisation and educational objectives. *British Journal of Hand Therapy 8(2): 62-69*

Caroli A, Zanasi S, Squarzina PB, Guerre M & Pancaldi G (1990) Operative treatment of the post-traumatic boutonnière deformity. *Journal of Hand Surgery 15B(4): 410-415*

Cetin A, Dincer F, KecikA & Cetin M (2001) Rehabilitation of flexor tendon injuries by use of a combined regimen of modified Kleinert and modified Duran techniques. *American Journal of Physical Medicine and Rehabilitation 80(10): 721-728*

Chambon X, Paysant J, Gavillot C, Petry D, Andre J-M, Dap F, Dautel G & Merle M (2001) Rehabilitation protocols after flexor tendon of the hand repaired in zone II: presentation and indications. *Chirurgie de al Main 20(5): 368-377*

Chester DL, Beale S, Beveridge L, Nancarrow JD & Titley OG (2002) A prospective, controlled, randomized trial comparing early active extension with passive extension using a dynamic splint in the rehabilitation of repaired extensor tendons. *Journal of Hand Surgery 27B: 283-288*

Chin G, Weinzweig N, Mead M & Gonzalez M (1998) “Spaghetti Wrist”: Management and Results. *Plastics and Reconstructive Surgery 102(1):96-102*

Chow IP (1997) Results of dynamic splintage following extensor repair. *Journal of Hand Surgery 22B: 283-287*

Chow JA, Dovelle S, Thomes LJ, Ho PK & Saldana J (1989) A comparison of results of extensor tendon repair followed by early controlled mobilisation versus static immobilisation. *Journal of Hand Surgery 14B: 18-20*

Chow JA, Thames JL, Dovelle S, Milnor WH , Seyfer AB & Smith AC (1987) A Combined regime of controlled motion following flexor tendon repair in “no man’s land”. *Plastics and Reconstructive Surgery 79:447-453*

Chow JA, Thomes LJ, Dovelle S, Monsivais J, Milnor WH & Jackson JP (1988) Controlled motion rehabilitation after flexor tendon repair and grafting. A multi-centre study. *Journal of Bone and Joint Surgery 70B(4): 591-595*

Chow SP, Stephens MM, Ngai WK, So YC, Pun WK, Chu M & Crosby C (1990) A splint for controlled active motion after flexor tendon repair. Design, mechanical testing, and preliminary clinical results. *Journal of Hand Surgery 14B(1): 18-20*

Citron ND & Forster A (1987) Dynamic splinting following flexor tendon repair *Journal of Hand Surgery 12B(1): 96-100*

Clement R & Wray RC Jr (1986) Operative and non-operative treatment of mallet finger. *Annals of Plastic Surgery 16: 136-141*

Cohn BT & Froimson AI (1986) Case report of a rare mallet injury. Orthopaedics 9: 529-531

Colditz JC (1995) Anatomical considerations of splinting the thumb. In JM Hunter, EJ Mackin & AD Callahan (eds.) (1995*) Rehabilitation of the Hand: Surgery and Therapy.* 4th Edition. St Louis, Mosby.

Colditz JC (2002) Plaster of Paris: The forgotten hand splinting material. *Journal of Hand Therapy 15(2): 144-157*

College of Occupational Therapists (2000) Producing clinical guidelines for occupational therapy practice. *London College of Occupational Therapists*.

Collins & Schwarze (1991) Early progressive resistance following immobilization of flexor tendon repairs. *Journal of Hand Therapy 4:111-116*

Conners GP (1995) Index of suspicion. Case 1. Diagnosis: Mallet finger. *Pediatrics Review 16:37-8*

Coons MS & Green SM (1995) Boutonnière deformity. *Hand Clinic 11: 387-402*

Cozen L (2000) A simple splinting technique for the mallet finger. *American Journal of Orthopedics 29: 657*

Crabbe DJ (1980) Hand injuries in professional musicians. A report of six cases. *Hand 12: 200*

Crawford GP (1984) The molded polythene split for mallet finger deformities. *Journal of Hand Surgery 9A: 231-237*

Crosby CA & Wehbé MA (1996) Early motion after extensor tendon surgery. *Hand Clinics 12:57-64*

Crosby CA & Wehbé MA (1999) Early protected motion after extensor tendon repair. *Journal of Hand Surgery 24A: 1061-1070*

Cullen KW, Tolhurst P, Lang D & Page RE (1989) Flexor tendon repair in zone 2 followed by controlled active mobilization. *Journal of Hand Surgery 14B(4): 392-395*

Dargan EL (1969) Management of Extensor Tendon Injuries of the Hand. *Surgery, Gynaecology and Obstetrics 128: 269-273*

Deniz E, Ayes K, Shim K, Mahomet D, Alyson S & Surreys E (2000) Post-operative management of flexor tendon repairs in zone II. *Journal of Physical Therapy Science 12(1): 63-66*

Dias JJ, Bhowal B, Wildin CJ & Thompson JR (2001) Assessing the outcomes of disorders of the hand: Is the Patient Evaluation Measure reliable, valid and responsive and without bias? *Journal of Bone and Joint Surgery 83B(2): 235-240*

Din KM & Maggitt BF (1983) Mallet Thumb. *Journal of Bone and Joint Surgery 66B: 606*

Doegge TC & Houston TP (eds) (1993) *Guides to the evaluation of permanent impairment 3rd edition.* Chicago, American Medical Association pp 15-65

Dovelle S & Heeter PK (1989) The Washington Regimen: rehabilitation of the hand following flexor tendon injuries. *Physical Therapy 69(12): 1034-1040*

Dovelle S, Heeter PK, Fischer R & Chow JA (1987) Rehabilitation of extensor tendon injury of the hand by means of early controlled motion. *American Journal of Occupational Therapy 43(2): 115-119*

Doyle JR (1993) Extensor tendons: acute injuries in Green DP (ed) *Operative Hand Surgery 3rd Edition.* New York, Churchill Livingstone.

Duran RJ & Houser RG (1975) Controlled passive motion following flexor tendon repair in zone II and III. in *American Academy of Orthopaedic surgeons: Symposium on tendon surgery of the hand.* St Louis, Mosby. Chapter 2 pp 102-114

Dymarczyk M (2001) A new device for flexor tendon injuries. *Journal of Hand Therapy 14(3): 216-218*

Edinburg M, Widgerow AD & Biddulph SL (1987) Early postoperative mobilization of flexor tendon injuries using a modification of the Kleinert technique. *Journal of Hand Surgery 12A(1): 34-38*

Elliot D & Harris SB (2003) The Assessment of flexor tendon function after primary repair. *Hand Clinics 19:495-503*

Elliot D, Moiemen NS, Fleming AF, Harris SB & Foster AJ (1994) The rupture rate of acute flexor tendon repairs mobilized by the controlled active motion regimen *Journal of Hand Surgery 19B(5): 607-612*

Elson RA (1986) Rupture of the central slip of the extensor hood of the finger. A test for early diagnosis. *Journal of Bone and Joint Surgery 68B: 229-231*

Emerson ET, Krizek TJ & Greenwald DP (1996) Anatomy, physiology and functional restoration of the thumb. *Annals of Plastic Surgery 36(2): 180-191*

Esther J, Silfverskiold M & Silfverskiold KL (1993) Rate of recovery after tendon repair in zone II: A prospective longitudinal study of 145 digits. *Scandinavian Journal of Plastic and Reconstructive Hand Surgery 27: 89-94*

Evans JD, Wignakumar V, Davis TRC & Dove A (1995) Results of extensor tendon repair performed by junior accident and emergency staff. *Injury 26(2): 107-109*

Evans RB (1986) Therapeutic management of extensor tendon injuries. *Hand Rehabilitation 2(1): 157-169*

Evans RB (1989) Clinical application of controlled stress to the healing extensor tendon: a review of 112 cases. *Physical Therapy 69: 1041-1049*

Evans RB (1990) A study of the zone I flexor tendon injury and implications for treatment. *Journal of Hand Therapy July-Sept: 133-148*

Evans RB (1995) Immediate active short arc motion following extensor tendon repair. *Hand Clinics 11(3): 483-512*

Evans RB & Beach V (1994) Early Active shprt arc motion for the repaired central slip. *Journal of Hand Surgery 19A: 991-997*

Evans RB & Burkhalter WE (1986) A study of dynamic anatomy of extensor tendons and implications for treatment. *Journal of Hand Surgery 11: 774-779*

Evans RB & Thompson DE (1992) An analysis of factors that support early active short arc motion of the central repaired slip. *Journal of Hand Therapy 5: 187-201*

Fasika OM & Stilwell JH (1992) Flexor tendon injuries: the result of primary management: a retrospective review of 50 cases treated at Whiston Hospital, England. *Central African Journal of Medicine 38(2): 74-77*

Fitoussi F, Lebellec Y, Frajman J & Pennecot G (1999) Flexor tendon injuries in children: factors influencing prognosis. *Journal of Paediatric Orthopaedics, 19(6): 818-821*

Fitoussi F, Mazda K, Frajman J, Jehanno P, Pennecot G (2000) Repair of the flexor pollicis longus tendon in children. *The Journal of Bone & Joint Surgery (Br) 82(8): 1177-1180*

Flowers KR, McClure B & McFadden L (1996) Management of a patient with lacerations of the tendons of the extensor digitorum and extensor indicis muscle to the index finger. *Physical Therapy 76(1): 61-66*

Foucher G, Binhamer P, Cange S & Lenoble E (1996) Long-term results of splintage for mallet finger. *International Orthopaedics 20: 129-131*

Foucher G, Tilquin B & Lenoble E (1992) (Treatment of post-traumatic swan-neck deformities of the fingers; apropos of a series of 43 patients) French Language. Review of English abstract *Chir Orthop Reparatrice Appar. Mot. 78: 505-511*

Frere G, Moutet F, Sarorius C & Vila A (1984) Controlled post-operative mobilization of sutured extension tendons of the long fingers. *Ann Chir.Main 3:139-144*

Froehlich JA, Akelman EA & Herndon JH (1988) Extensor tendon Injuries at the Proximal Interphalangeal. *Joint Hand Clinics 4(1): 25-37*

Gaisford JC & Fleegler EJ (1973) Alterations in finger growth following flexor tendon injuries. A clinical and laboratory study. *Plastic Reconstructive Surgery, 51: 164-8*

Garberman SF, Diao E & Peimer CA (1994) Mallet finger: results of early versus delayed closed treatment. *Journal of Hand Surgery 19A:850-852*

Gault DT (1987a) Reduction of grip strength, finger flexion pressure, finger pinch pressure and key pinch following flexor tendon repair. *Journal of Hand Surgery 12B(2): 182-184*

Gault DT (1987b) A review of repaired flexor tendons. *British Journal of Hand Surgery 12B(3): 321-325*

Gelberman RH, Nunley JA, Osterman AL, Breen TF, Dimick MP & Woo SL (1991) Influences of the protected passive mobilization interval on flexor tendon healing. A prospective andomised clinical study. *Clinical Orthopedics 264: 189-196*

Gelberman RH, Van de Berg JS & Lundborg GN (1983) Flexor tendon healing and restoration of gliding surface. *Journal of Bone and Joint Surgery 2: 441-451*

Gerbino PG, Saldana MJ, Westerbeck P & Schacherer TG (1991) Complications experienced in the rehabilitation of zone I flexor tendon injuries with dynamic traction splinting. *Journal of Hand Surgery 16A(4): 680-686*

Geyman JP, Fink K & Sullivan SD (1998) Conservative versus surgical treatment of mallet finger: a pooled quantitative literature evaluation. *Journal of the American Board of Family Practitioners 11: 382-390*

Glassey N (2000) *Flexor tendon* *audit.* Physiotherapy Department, Nottingham City Hospital

Glassey N (2002) *Audit of referrals to the hand therapy unit; in-house report.* Physiotherapy Department, Nottingham City Hospital

Gooding CA (1984) Spoon splint for mallet finger. *American Family Physician 29: 23*

Graham AJ & Berger AC (2003) Boutonnière deformity after correction of childhood swan-neck deformity: a case report. *Hand Surgery 8(1): 119-20*

Green DP & Rowland SA (1984) Fractures and dislocations in the hand, in CA Rockwood & DP Green (eds.) *Fractures in Adults*. 2nd edition. Philadelphia, Lippincott

Griffin JM & Lissner G (1972) Tape splinting for mallet finger *Mo Med 69: 813*

Grobbelaar AO & Hudson DA (1995) Flexor pollicis longus tendon injuries in children. *Annals of the Royal College of Surgeons of England 77(2):135-7*

Groth GN, Wilder DM & Young VL (1994) The impact of compliance on the rehabilitation of patients with mallet finger injuries. *Journal of Hand Therapy 7: 21-24*

Grundberg AB & Reagan DS (1987) Central slip tenotomy for chronic mallet finger deformity. *Journal of Hand Surgery 12A:545-547*

Gummesson C, Atroshi I & Ekdahl C (2003) The Disabilities of the arm, shoulder and Hand (DASH) outcome questionnaire: longitudinal construct validity and measuring self-rated health change after surgery. BIOmedical Central Musculoskeletal Disorders 4 (11): http://www.biomedcemtral.com/1471-2474/4/11

Handoll HHG & Veghela MV (2004) Interventions for treating mallet finger injuries. *Cochrane Library, Issue 3.*

Harris SB, Harris D, Foster AJ & Elliot D (1999) The aetiology of acute rupture of flexor tendon repairs in zones I and II of the fingers during early mobilization. *Journal of Hand Surgery 24B(3): 275-280*

Hawkins S & Sheldon T (2000) Report of a single complex case of one-stage reconstruction of extensor tendons. *British Journal of Hand Therapy 7(1): 25-27*

Hazarika EZ (1988) An Inducement to exercise after flexor tendon repair. British *Journal of Plastic Surgery 41: 187-189*

Hendon JH (1976) Treatment of Tendon Injuries in Children. *Orthopaedic Clinics of North America 7: 717-731*

Hollwarth M & Haberlik A (1985) Flexor tendon injuries in childhood. *Zeitschrift fur Kindrchirurgie, 40(5): 294-8*

Hove LM (1994) Delayed rupture of the thumb extensor tendon. A 5 year study of 18 consecutive cases. *Acta Opthopedic Scandinavia 65: 199-203*

Hovgaard C & Klareskov B (1988) Alternative conservative treatment of mallet finger injuries by double-finger bandage. *Journal of Hand Surgery 13B: 154-155*

Hudak PC, Amadio PC & Bombardier C (1996) Development of an upper extremity outcome measure: the DASH (Disabilities of the Arm, Shoulder and Hand). *American Journal of Industrial Medicine 29: 260-265*

Hudson DA & de Jager LT (1993) The Spaghetti Wrist: Simultaneous laceration of median and ulnar nerves with flexor tendons at the wrist. *Journal Hand Surgery 18B: 171*

Hung LK, Chan A, Chang J, Tsang A & Leung PC (1990) Early controlled active mobilization with dynamic splintage for treatment of extensor tendon injuries. *Journal of Hand Surgery 15A: 251-257*

Hunt J (2000) Early controlled motion following extensor tendon repair: a critical review. *British Journal of Hand Therapy 5(1): 10-15*

Hunter JM, Mackin EJ & Callahan AD (1995) *Rehabilitation of the Hand: Surgery and Therapy 4th Edition.* St Louis, Mosby

Imatami J, Hashizume H, Wake H, Morito Y & Inoue H (1997) The central slip attachment fracture. *Journal of Hand Surgery 22B: 107-109*

Ip WY & Chow SP (1997) Results of dynamic splintage following extensor tendon repair. *Journal of Hand Surgery 22B: 283-287*

Irwin MS, Gilbert SEA, Terenghi G, Smith RW & Green CJ (1997) Cold intolerance following a peripheral nerve injury. *Journal of Hand Surgery, 22B(3): 308-316*

Jones LA (1989) The assessment of hand function: A critical review of techniques. *Journal of Hand Surgery 14A: 221-228*

Karlander LE, Berggren M, Larsson M, Soderberg G & Nylander G (1993) Improved results in zone II flexor tendon injuries with a modified technique of immediate controlled mobilization. *Journal of Hand Surgery 18B(1): 26-30*

Kato H, Minami A, Suenaga N, Iwasaki N & Kimura T (2002) Long term results after primary repairs of zone II flexor tendon lacerations in children younger than age 6 years. *Journal of Pediatric Orthopedics, 22(6): 732-735*

Katzman BM, Klein DM, Mesa J, Geller J & Caligiuri DA (1999) Immobilisation of the Mallet Finger: Effects on the extensor tendon. *Journal of Hand Surgery 24B(1): 80-84*

Kerr CD & Burczak JR (1989) Dynamic traction after extensor tendon repair in zones 6, 7 and 8: a retrospective study. *Journal of Hand Surgery 14B: 21-22*

Kessler I & Nissim F (1969) Primary repair without immobilisation of flexor tendon division within digital sheath. *Acta Orthopaedic Scandinav 40: 587-601*

Khandwala AR, Blair J, Harris SB, Foster AJ & Elliot D (2004) *Immediate repair and early mobilisation of the extensor pollicis longus tendon in zones I-IV.* Hand Surgery Department, St. Andrews Centre for Plastic Surgery. Chelmsford.

Khandwala AR, Webb J, Harris SB, Foster AJ & Elliot D (2000) A comparison of dynamic extension splinting and controlled active mobilization of complete division of extensor tendons in zones V and VI. *Journal of Hand Surgery 25B: 140-146*

Kings Mill Hospital (2003) *Tendon injury audit*. In-house document Mansfield, Kings Mill Hospital

Kinninmonth AW & Holborn F (1986) A comparative controlled trial of a new perforated splint and a traditional splint in the treatment of the mallet finger. *Journal of Hand Surgery 11B: 261-262*

Kirwan T, Tooth L & Harkin C (2002) Compliance with hand therapy programs: therapists' and patients' perceptions. *Journal of Hand Therapy 15(1): 31-40*

Kitsis CK, Wade PJ, Krikler SJ, Parsons NK & Nicholls LK (1998) Controlled active motion following primary flexor tendon repair: a prospective study over 9 years. *Journal of Hand Surgery 23B: 344-349*

Klein L (2003) Early Active Motion Flexor Tendon Protocol Using On Splint. *Journal of Hand Therapy Jul-Sept 199-206*

Kleinert HE & Verdan C (1983) Report of the Committee on Tendon Injuries. (International Federation of Societies for Surgery of the Hand). *Journal of Hand Surgery 8A(5 Part 2):794-798*

Kleinert HE, Kutz JER & Ashbell JS (1967) Primary repair of lacerated flexor tendons in "no man's land". *Journal of Bone Joint Surgery 49A: 577*

Knight SL (1987) A modification of the Kleinert splint for mobilisation of digital flexor tendons. *Journal of Hand Surgery 2: 441-451*

Law M, Stewart D, Pollock N, Letts L, Bosch J & Westmorland M (1998) *Guidelines for Critical review Form- Quantitative Studies.* McMaster University Occupational Therapy Evidence-based Practice Research Group. McMaster University Publication.

Law M, Baptiste S, McColl MA, Opzoomer A, Polataijko H & Pollock N (1995) The Canadian Occupational Performance Measure: an outcome measure for occupational therapy. *Canadian Journal of Occupational Therapy 57: 82-87*

LeBellec Y, Loy S, Touam C, Alnot JY & Masmejean E (2001) (Surgical treatment of boutonnière deformity of the fingers. Retrospective study of 47 patients) *Chir. Main 20: 362-367* (English translation of French abstract).

Lengsfeld M & Koebke J (1990) Controlled and supporting apparatus of the deep finger flexor tendon and the long extensor tendon of the thumb. Clinico-anatomical analysis. *Handchir. Microchir. Plast.Chir. 22(5): 250-254* (English translation of German abstract)

Lester B, Jeong GK, Perry D & Spero L (2000) A simple effective splinting technique for the mallet finger. *American Journal of Orthopedics 29(3): 202-206*

Levanne JH & Durafourg MP (1987) *Reeducation des traumatises de la main*. Paris, Maloine pp 109-114 (English translation of French abstract).

Lister GD & Tonkin M (1986) The results of primary flexor tendon repair \\/ closure of the tendon sheath. *Journal of Hand Surgery 11A: 76*

Lister GD, Kleinert HE, Kutz JE & Atasoy E (1977) Primary flexor tendon repair followed by immediate controlled mobilization *Journal of Hand Surgery 2A(6): 441-451*

Littler JW (1967) The finger extensor mechanism. *Surg Clin North America 47: 415-432*

Ljungberg E, Rosberg HE & Dahlin LB (2003) Hand injuries in young children. *Journal of Hand Surgery 28B(4): 376-80*

Lovett WL & McCalla MA (1983) Management and rehabilitation of extensor tendon injuries. *Orthopaedic Clinics of North America 14: 811-826*

Maddy LS & Meyerdierks EM (1997) Dynamic extension-assist splinting of acute central slip lacerations. *Journal of Hand Therapy 10: 206-212*

Maitra A & Dorani B (1993) The conservative treatment of mallet finger with a simple splint: a case report. *Archive of Emergency Medicine 10: 244-248*

Marin-Braun F, Foucher G, Buch JN & Sammut D (1991) Repair of the flexor digitorum profundus and the flexor pollicis longus by the “rope-down” technique. Results in a series of 77 cases. *Annals Chir. Main Memb.Super 10: 13-21* (from English translation of abstract)

Marin-Braun F, Merle M, Sanz F, Foucher G, Viory MH & Petry B (1989) Primary report of extensor tendons with assisted post-operative mobilisation: a series of 48 cases. *Annales de Chirurgie de la Main 8(1): 7-21*

Massengill JB (1992) The boutonnière deformity. *Hand Clinics 8: 787-801*

May EJ & Silfverskiold KL (1993) Rate of recovery after flexor tendon repair in zone II. *Scandinavian Journal of Plastic Reconstructive Hand Surgery 27: 89-94*

May EJ Silfverskiold KL & Sollerman CJ (1992a) Controlled mobilization after flexor tendon repair in zone II: A prospective comparison of three methods. *Journal of Hand Surgery 17A:942-952*

May EJ Silfverskiold KL & Sollerman CJ (1992b) The correlation between controlled range of motion with dynamic traction and results after flexor tendon repair in zone II. *Journal of Hand Surgery 17A: 1133-1139*

McCue FC III & Meister K (1993) Common sports hand injuries: An overview of aetiology, management and prevention. *Sports Medicine 15: 281-289*

McFarlane RM & Hampole MK (1973) Treatment of extensor tendon injuries of the hand. *Canadian Journal of Surgery 16: 366-375*

McGrouther DA & Ahmed MR (1981) Flexor tendon excursions in "no-man's land". *The Hand 13:129-141*

McIver S (1991) *An introduction to obtaining the views of users of health services.* London, Kings Fund

Meikle CF (2002) *Patients' views of their outcomes and the information provided to them during treatment for flexor tendon injuries.* MSc dissertation. Unpublished.

Meikle CF & Price G (2003) "Navigating no-man's land": The Cornwall Flexor tendon guideline. Royal Cornwall Hospitals NHS Trust.

Meredith P & Wood C (1995) Identifying the roots of patient dissatisfaction with care. *Health Care Risk Report Sept: 22-24*

Miller H (1942) Repair of severed tendons of the hand and wrist. *Surgery, Gynaecology and Obstetrics 75: 693-698*

Minamikawa Y, Peimer CA, Yamaguchi T, Banasiak NA, Kambe K & Sherwin FS (1992) Wrist position and extensor tendon amplitude following repair. *Journal of Hand Surgery 17A: 268-271*

Miura T, Ryogo N & Shuhei T (1986) Conservative treatment for a ruptured extensor tendon on the dorsum of the proximal phalanges of the thumb (mallet thumb) *Journal of Hand Surgery 11A: 229*

Moiemen NS & Elliot D (2000) Primary flexor tendon repair in zone I. *Journal of Hand Surgery 25B(1): 78-84*

Morse JM (2003) A review committee's guide for evaluating qualitative proposals. *Qualitative Health Research 13(6): 833-851*

Moss JG & Steingold RF (1983) The long term results of mallet finger injury. A retrospective study of one hundred cases. *Hand 15: 151-154*

Nakamura K & Nanjyo B (1994) Reassessment of surgery for mallet finger. *Plastic Reconstructive Surgery 93: 141-149*

Newport ML (1997) Extensor tendon injuries of the hand. *Journal of the American Academy of Orthopedic Surgery 5(2): 59-66*

Newport ML, Blair WF & Steyers CM Jr (1990) Long-term results of extensor tendon repair. *Journal of Hand Surgery 15A: 961-966*

Niechajev IA (1985) Conservative and operative treatment of mallet finger *Plastic Reconstructive Surgery 76: 580-585*

Nunley JA, Levin LS, Devito D, Goldner RD & Urbaniak JR (1992) Direct end-to-end repair of flexor pollicis longus tendon lacerations. *Journal of Hand Surgery 17A(1): 118-121*

O'Connell SJ, Moore MM, Strickland JW, Frazier GT & Dell PC (1994) Results of zone I and zone II flexor tendon repairs in children**.** *Journal of Hand Surgery – American, 19(1): 48-52*

O'Connor JF (1997) Mallet finger. *Canadian Family Physician 43: 1725-1726*

O'Dwyer FG & Quinton DN (1990) Early mobilisation of acute middle slip injuries. *Journal of Hand Surgery 15B: 404-406*

Okafor B, Mbubaegbu C, Munshi I & Williams DJ (1997) Mallet finger deformity of the finger.: A five year follow-up of conservative treatment. *Journal of Bone and Joint Surgery 79B: 544-547*

Palmada M, Shah S & O'Hare K (1999) Hand Oedema: pathophysiology and treatment. *British Journal of Hand Therapy 4(1): 26-32*

Panchal J, Mehdi S, Donoghue JO, O'Sullivan ST, O'Shaughnessy M & O'Connor TP (1997) The range of excursion of flexor tendons in zone V: a comparison of active vs passive flexion obilization regimes *British Journal of Plastic Surgery 50(7): 517-522*

Patel MR, Desai SS & Bassini-Lipson (1986) Conservative management of chronic mallet finger. ***Journal of Hand Surgery 11A: 570-573***

Peck FH, Bucher CA, Watson JS & Roe A (1998) A comparative study of two methods of controlled mobilization of flexor tendon repairs in zone 2. *Journal of Hand Surgery 23B(1): 41-45*

Peck FH, Kennedy SM, Watson JS & Lees VC (2004) An evaluation of the influence of practitioner-led hand clinics on the rupture rates following primary tendon repair in the hand. *British Association of Plastic Surgeons (2004) 57, 45-49*

Percival NJ & Sykes PJ (1989) Flexor pollicis longus tendon repair: a comparison between dynamic and static splintage. *Journal of Hand Surgery 14B(1): 412-415*

Perron AD, Brady WJ, Keats TE & Hersh RE (2001) Orthopedic pitfalls in the emergency department: closed tendon injuries of the hand. *American Journal of Emergency Medicine 19: 76-80*

Potenza AD (1970) Flexor tendon injuries. *Orthop Clin North Am 1:355-373*

Pratt AL, Burr N & Grobbelaar AO (2002) A prospective review of open central slip laceration repair and rehabilitation. *Journal of Hand Surgery 6B: 530-534*

Prosser R (1996) Splinting in the management of proximal interphalangeal joint flexion contracture *Journal of Hand Therapy 9(4): 378-386*

Puckett CL & Meyer VH (1985) Results of treatment of extensive volar wrist lacerations: The Spaghetti wrist. *Plastics and Reconstructive Surgery 75: 714*

Purcell T, Eadie S, Murugan M, O'Donnell M & Lawless M (2000) Static splinting of extensor tendon repairs*. Journal of Hand Surgery 25B (2): 180-182*

Ranelli S & Henk G (1998) *Early active extension exercise programme for extensor tendon repairs zones II-VII.* Conference presentation. BAHT Annual Conference, Oxford.

Ray L (1999) Evidence and outcomes: agendas, presuppositions and power. *Journal of Advanced Nursing 30(5): 1017-1026*

Rayan GM & Mullins PT (1987) Skin necrosis complicating mallet finger splinting and vascularity of the distal interphalangeal joint overlying skin. *Journal of Hand Surgery 12A:548-552*

Riaz M, Hill C, Khan K & Small JO (1999) Long term outcome of early active mobilization following flexor tendon repair in zone II *Journal of Hand Surgery 24B(2): 157-160*

Richards SD, Kumar G, Booth S, Naqui SZ & Murali SR (2004) A model for the conservative management of mallet finger. *Journal of Hand Surgery 29B(1): 61-63*

Rogers GD, Henshall AL, Sach RP & Wallis KA (1990) A simultaneous laceration of median and ulnar nerves with flexor tendons at the wrist *Journal of Hand Surgery 15A: 990*

Rolph-Roeming K (1992) Early mobilisation of extensor tendon lacerations in zones III-IV**.** *Journal of Hand Therapy 45:*

Rosberg HE, Carlsson KS, Hojgard S, Lindgren B, Lundborg G & Dahlin LB (2003) What determines the costs of repair and rehabilitation of flexor tendon injuries in zone II? A multiple regression analysis of data from Southern Sweden. *Journal of Hand Surgery 28(2: 106-112*

Rosen B (1999) Cold intolerance in the hand – an unsolved problem. *British Journal of Hand Therapy, 4(1): 23-25*

Rosenthal EA (1995) The extensor tendons: anatomy and management. In JM Hunter, EJ Mackin & AD Callahan (eds.) *Rehabilitation of the Hand: Surgery and Therapy 4th Edition.* St Louis, Mosby

Roy C (2003) *Audit of flexor tendon repairs April 2001-March 2002*. In-house report of Radcliffe Infimary, Oxford

Rubin J, Bozentka DJ & Bora FW (1996) Diagnosis of closed central slip injuries. A cadaveric analysis of non- invasive tests *Journal of Hand Surgery 21B(5): 614-616*

Rumsey N, Clarke A, White P & Hooper E (2003) Investigating the appearance–related concerns of people with hand injuries. *British Journal of Hand Therapy 8(2): 57-61*

Saldana MJ, Choban S & Westerbeck P (1991) Results of acute zone III extensor tendon injuries treated with dynamic extension splinting. *Journal of Hand Surgery 16: 1145-1150*

Savage R (1988) The influence of the wrist position on the minimum force required for active movement of the interphalangeal joints. *Journal of Hand Surgery 13B:262-268*

Savage R & Risitano G (1989) Flexor tendon repair using a "six strand" method of repair and early active mobilization *Journal of Hand Surgery 14(4): 396-399*

Schenck R & Lenhart D (1996) Results of zone II flexor tendon lacerations treated by the Washington Regime. *Journal of Hand Surgery 21A:984-987*

Semmons J (2001) *Extensor tendon audit.* In-house document.

Shankar NS & Goring CC (1992) Mallet finger: long-term review of 100 cases. *JR Coll Surg Edinb 37: 196-198*

Silfverskiold KL & May EJ (1993) Gap formation after flexor tendon repair in zone II. Results with a new controlled motion programme. *Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery 22(4): 263-268*

Silfverskiold KL (1993) Tendon excursion after flexor tendon repair in zone II: results with a new controlled motion program. *Journal of Hand Surgery 18A:403-410*

Sirotakova M & Elliot D (1999) Early active mobilisation of primary repairs of the flexor pollicis longus tendon. *Journal of Hand Surgery 24B(6): 647-653*

Small JO, Brennen MD & Colville J (1989) Early active obilization following flexor tendon repair in zone II. *Journal of Hand Surgery 14B(4): 383-391*

Smith HB (1973) *American Journal of Occupational Therapy 27(5): 244-251*

Smith PJ & Ross DA (1994) The central slip tenodesis test for early diagnosis of potential boutonnière deformities. *Journal of Hand Surgery 19B: 88-90*

So YC, Chow SP, Pun WK, Luk KD, Crosby C & Ng C (1990) Evaluation of results in flexor tendon repair: A critical analysis of five methods in 95 digits. *Journal of Hand Surgery 15A: 258-264*

Solway S, Beaton DE, McConnell S & Bombardier C (2002) *The DASH Outcome Measure User's Manual 2nd Edition*. Toronto, Ontario: Institute for Work & Health

Sorenson MK (1989) The edematous hand. *Physical Therapy, 69(12): 1059-1064*

Souter WA (1967) The boutonniere deformity: A review of 101 patients with division of the central slip of the extensor expansion of the fingers. *Bone and Joint Surgery 4: 710-721*

Stack HG (1962) *The Mechanism of Mallet Finger.* In Proceedings of the Second Hand Club, HG Stack & H Bolton (eds.) London, British Society for Surgery of the Hand 1975 154-155.

Stack HG (1986) A modified splint for mallet finger *Journal of Hand Surgery 11B(1): 263*

Stahl S, Kaufman T & Bialik V (1997) Partial lacerations of flexor tendons in children. Primary versus conservative treatment. *Journal of Hand Surgery 22B(3): 377-80*

Stanley JK, Birch A & Gwilliam L (1998) *Clinical guidelines for the treatment of the hand following injury or surgery.* BAHT Unpublished

Stefanich RJ, Putman MD, Peimer CA & Sherwin FS (1992) Flexor tendon lacerations in zone V. *Journal of Hand Surgery 17A: 284-291*

Stern PJ & Kastrup JJ (1988) Complications and prognosis of treatment of mallet finger. *Journal of Hand Surgery 13A:329-334*

Steward B (2001) Live Research: A Preliminary Investigation of Research Interest and Activity in Hand Therapy *British Journal of Hand Therapy 6(4): 119-125*

Steward B (2002) Priorities in Hand Therapy Research *British Journal of Hand Therapy 7(1): 28-33*

Steward B (2004a) *Audit of return to work following hand injury*. Conference paper. College of Occupational Therapy Annual Conference, Harrogate.

Steward B (2004b) Compliance, Adherence and Concordance. *British Journal of Hand Therapy 9(3): 88-95*

Stewart KM & van Strien G (1995) Post-operative management of flexor tendon injuries. In: JM Hunter, EJ Mackin & AD Callahan (1995) *Rehabilitation of the hand: surgery and therapy* St Louis, Mosby,

Stewart KM (1991) Review and comparison of current trends in post-operative management of tendon repair. *Hand Clinic 7:447-460*

Strickland J & Glogovac SV (1980) Digital function following flexor tendon repair in zone II: comparison of immobilization and controlled passive motion techniques. *Journal of Hand Surgery 5: 537-43*

Strickland JW (1985) Results of flexor tendon surgery in zone II *Hand Clinic 1(1): 167-179*

Strickland JW (1989) Biological Rationale, clinical application and results of early motion following flexor tendon injuries. *Journal of Hand Therapy 12: 71-83*

Sturzenegger M, Heitmann D & Buck-Gramcko D (1988) Assessment of treatment results of extensor tendon injuries *Handchir.Mikrochir.Plast.Chir, 20(3): 137-140*

Sylaidis P, Youatt M & Logan A (1997) Early active mobilization for extensor tendon injuries: The Norwich Regime**.** *Journal of Hand Surgery 22B: 594-596*

Tang JB, Gu YT, Rice K, Chen F & Pan CZ (2001) Evaluation of four methods of flexor tendon repair for postoperative active mobilization. *Plastic Reconstructive Surgery 107(3): 742-749*

Taras JS & Lamb MJ (1999) Treatment of flexor tendon injuries: Surgeons' perspectives. *Journal of Hand Therapy 12(April-June): 141-148*

Thien TB, Becker JH & Theis J-C (2004) Rehabilitation after surgery for flexor tendon injuries in the hand (Protocol) **Cochrane Database of Systematic Reviews** In preparation

Thomas D, Moutet F & Guinard D (1996) Post-operative management of extensor tendon repairs in zones V, VI and VII. *Journal of Hand Therapy 9(4): 309-314*

Thomes LJ & Thomes BJ (1995) Early mobilisation method for surgically repaired zone III extensor tendons. *Journal of Hand Therapy 8: 195-198*

TRASH (Trent Regional Audit for Surgery of the Hand) (2001) *Flexor Tendon Audit.* In-house publication.

Tuncay I, Ege A, Akpinar F, Tosun N (2002) Flexor tendon injuries of children in zone II (FDS repair or not) *Chirurgia Degli Organi di Movimento, 87(4): 241-8*

Valenti P & Gilbert A (2000) Two-stage flexor tendon grafting in children. *Hand Clinics 16(4): 573-8*

Verdan CE (1972) Half a century of flexor tendon surgery. *Journal of Bone and Joint Surgery 56A:472-491*

Walsh MT, Rinehimer W, Muntzer E, Patel J & Sitler MR (1994) Early controlled motion with dynamic splinting versus static splinting for zones III and IV extensor tendon lacerations: a preliminary report. *Journal of Hand Therapy 7: 232-236*

Wang AW & Gupta A (1996) Early motion after flexor tendon surgery *Hand Clinic 12(1): 43-55*

Warren RA, Norris SH & Ferguson DG (1988) Mallet finger: a trial of two splints *Journal of Hand Surgery 13B: 151-153*

Wehbe & Schneider (1984) Mallet Fractures *Journal of Bone & Joint Surgery 66A:658-659*

White WL (1956) Secondary restoration of finger flexion by digital tendon grafts- an evaluation of 76 cases. *American Journal of Surgery 91: 662-668*

Widgerow AD (1990) Full house /spaghetti wrist injuries. *South African Journal of Surgery 28:6*

Wilson SW & Khoo CT (2001) The Mexican Hat splint- a new splint for the treatment of closed mallet finger. *Journal of Hand Surgery 26: 488-489*

Wolock BS, Moore JR & Weiland AJ (1987) Extensor tendon repair: a reconstructive technique. *Orthopedics 10: 1387-1389*

Yii NW, Urban M & Elliot D (1998) A Prospective study of flexor tendon repair in zone V. *Journal of Hand Surgery 23B: 642-648*

Zander CL (1987) The use of early active mobilisation following injury to extensor tendons. *Journal of Hand Therapy Oct-Dec: 38-41*

Appendix 1
BAHT Tendon Injuries Effectiveness Bulletin
Protocol for evaluating the clinical evidence within papers exploring treatment/ interventions.

Author………………………………………………………………………………..

Title…………………………………………………………………………………..

…………………………………………………………………………………………

Source (Journal, conference, hospital location, date, volume, page etc)………………..

……………………………………………………… Reference ID number…………...

Network Subgroup…………………………Reviewer's name…………………………

Methodology	State the research question………………………………………………… ………………………………………………………………………………... State the target population…………………………………………………. What were the inclusion criteria for participants/data?............................... …………………………………………………………………………….. What were the exclusion criteria?.. ……………………………………………………………………………… How were subjects recruited? (purposive, convenience sampling etc).......... ………………………………………………………………………………. Sample size (state no.)……….. Response rate (state %) ……… Attrition rate (state %)……….. Any important comments on sampling…………………………………… …………………………………………………………………………….. What type of research Quantitative □ Qualitative □ State methodology (e.g. case study, phenomenology etc)…………………… ……………………………………………………………………………….. What was the study design (in brief)…………………………………………. ………………………………………………………………………..

Protocol	What protocol/s were being investigated?.. ………………………………………………………………………….. If changes to the protocol were made what were these?.......................... ……………………………………………………………………………. How were intra or inter rater reliability assured? ………………………. ……………………………………………………………………………… How were protocols standardised?...................…………………………….. ……………………………………………………………………………….
Findings:	What was the baseline measurement?... …………………………………………………………………………….. How were outcomes measured?... ……………………………………………………………………………… Who carried out the measurement?.. ……………………………………………………………………………… Where appropriate, what were the intervention and control groups?............ ………………………………………………………………………………. Were the intervention and control groups matched?..................................... ……………………………………………………………………………….
Results	Briefly state the main findings of the study? 1……………………………………………………………………………… 2……………………………………………………………………………… 3……………………………………………………………………………… 4……………………………………………………………………………… 5………………………………………………………………………………
Discussion	What clinical implications or other related issues were identified? 1………………………………………………………………………………..

	2……………………………………………………………………………….. 3……………………………………………………………………………….. 4……………………………………………………………………………….. 5………………………………………………………………………………..
Clinical relevance	What clinical relevance is suggested?... ………………………………………………………………………………… …………………………………………………………………………………
Comment PTO if necessary	

Appendix 2
BAHT Tendon Injuries Effectiveness Bulletin
Protocol for appraising the research rigour of the article.

Author……………………………………………………………………………………..

Title………………………………………………………………………………………..

…………………………………………………………………………………………..

Source (Journal, conference, location, date, volume, page etc…………………………

………………………………………………………… Reference ID number……..

Network Subgroup…………………………Reviewer's name…………………………

Methodology	Was the research question/problem clearly stated?	Yes □ No □
	Was the research context stated? (e.g. type of unit/s)	Yes □ No □
	Was research design appropriate?	Yes □ No □
	Was the method performed as stated?	Yes □ No □
	Was sample size adequate?	Yes □ No □
	Was the sampling procedure appropriate?	Yes □ No □
	Were the research inclusion & exclusion criteria appropriate?	Yes □ No □
	Were issues of validity adequately addressed?	Yes □ No □
	Were issues of reliability adequately addressed?	Yes □ No □
Protocol	Was the hand therapy protocol/s under investigation stated?	Yes □ No □
	Were the hand therapy protocols altered or adapted?	Yes □ No □
	Were these adaptations described clearly?	Yes □ No □
	Were the therapy protocols followed reliably in the study	Yes □ No □
Ethics	Did the article deal satisfactorily with ethical issues?	Yes □ No □
Results	Were the measurements used appropriate?	Yes □ No □
	Were the measurement tools validated?	Yes □ No □
	Did the results appear to be presented accurately?	Yes □ No □
	Were the results provided relevant and explained?	Yes □ No □
Analysis	*Was the method of analysis appropriate?	Yes □ No □
	*Were the findings analysed effectively?	Yes □ No □
	Were confounding factors addressed?	Yes □ No □ N/A □
	Was attrition dealt with appropriately?	Yes □ No □ N/A □
	Were the results further validated by participants?	Yes □ No □ N/A □
	*Was clinical relevance addressed?	Yes □ No □ N/A □
Discussion	Was the discussion based on the findings and results?	Yes □ No □
	Were the aims of the study met?	Yes □ No □
	Were issues of trustworthiness addressed satisfactorily?	Yes □ No □

Evaluation of the quality of the research.
Tick the category, which this article best fits. Tick the category which this article best fits. You are required to tick the category, which best fits the paper.

Appraisal score	Type of evidence	Tick one
1	Randomised controlled trial	
2	Quasi-experimental studies	
3	Other types of rigorous research evidence- case studies, cohort studies, qualitative studies	
4	Clinical series/practice evaluation	
5	Expert opinion	
6	Literature review	

Comments
Any additional, important information about the quality of the paper.

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………….

…………………………………………………………………………………….

…………………………………………………………………………………PTO