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Hand-based swing traction splinting for intra-articular proximal interphalangeal joint fractures

Melissa J Hirth[1,2], David J Jacobs[1] and Kate Sleep[2]

Abstract

Introduction: Acute intra-articular fractures of the proximal interphalangeal joint have always presented as a difficult injury to manage for the treating surgeon and therapist. Traction management enabling ligamentotaxis and motion is a popular method to manage these injuries. This case series presents the design and results of hand-based swing traction splinting which is less cumbersome for patients than other forms of traction splinting.

Methods: Five patients presenting with intra-articular proximal interphalangeal joint fractures underwent surgery whereby a transverse K-wire was inserted across the middle phalanx. The treating Occupational Therapist fabricated a hand-based swing traction splint to provide a distraction force from the K-wire to the splint. Range of motion and patient satisfaction were the primary outcome measures.

Results: All five patients reported satisfaction with their hand function following therapy involving swing traction splinting. Furthermore, range of motion was comparable to other forms of traction management reported in the literature with an 88° mean arc of motion at the proximal interphalangeal joint.

Conclusion: This case series demonstrates that hand-based swing traction splinting is a viable treatment option for the management of intra-articular proximal interphalangeal joint fractures. With similar outcomes to other forms of distraction that enable early movement, such as the pins and rubber traction system, this design is an alternative. The less cumbersome splint design is the main advantage over other splinting methods that apply distraction whilst also enabling early motion.

Keywords

Swing traction splinting, distraction splinting, intra-articular proximal interphalangeal joint fractures, hand therapy

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Introduction

Acute intra-articular proximal interphalangeal (PIP) joint fractures have always presented as a difficult injury to manage for the treating surgeon and therapist. Poor outcomes following this injury can be debilitating for the patient and significantly impact on their participation in activities of daily living, work and leisure pursuits.

The surgical options to reconstruct these challenging fractures are open reduction and internal fixation (ORIF), external fixation or traction.[1] Hemi-hamate arthroplasty has also been advocated,[2] as has extension block splinting[3] and extension block pinning.[4] Conservative management via splint immobilisation has been deemed to produce unsatisfactory results[5] and is not recommended.[6]

Applying traction to the injured joint has the benefit of ligamentotaxis,[7] a term used to describe the reduction of fracture fragments and realignment of joint surfaces via a distraction force on the ligamentous and volar plate attachments. Interventions that enable both traction and movement of the joint are considered superior to those that only enable traction or only allow movement.[8,9] Hence, this report will focus on outcomes

[1]Occupational Therapy Department, Austin Health, Melbourne, Victoria, Australia
[2]Malvern Hand Therapy, Malvern, Melbourne, Victoria, Australia

Corresponding author:
Melissa Hirth, Occupational Therapy Department, Austin Health, PO Box 5444, Heidelberg West, Victoria 3081, Australia.
Email: melissa.hirth@austin.org.au

following interventions that implement both traction and motion.

These interventions can be classified into one of two categories: traction provided via an external splint following Kirschner wire (K-wire) insertion; or traction provided by surgical intervention, that is those not requiring a thermoplastic splint in order to provide traction, including the pins and rubber traction system (PRTS) introduced by Suzuki et al.[10] in 1994 and various external fixation devices.[11–15] The surgeons working in our centre currently prefer traction provided by external splint application; hence, this case series came about in an attempt to improve splint design.

Traction splinting was first introduced in 1946 by Robertson et al.[16] Labelled the Banjo splint, three wires and rubber bands enabled traction; however, the system was effectively static and did not enable PIP joint movement. Forty years later, in 1986, Schenck[17] described the first splint enabling both traction and passive motion of the PIP joint. With the preservation of articular symmetry and joint space, along with pain-free range of motion, outcomes were positive; however, the splint which was fabricated around a 10½ inch pizza pan has been considered too bulky.[18] Haines et al.[18] in 1991 decreased the splint size by 50% and used a spring rather than a rubber band to apply the traction, which the authors stated would allow more reliable tension. Dennys et al.[19] in 1992, moved away from the arcuate splint design and introduced a far more compact design utilising a lateral hinge at the PIP joint in conjunction with a dorsal forearm-based splint. In 1995, Murray and McIntyre[20] published a dorsal-based traction splint similar to the splint described by Dennys et al.[19] with the addition of a profundus pulley strap to maximise motion at the PIP joint and used a rivet system for the lateral hinge to further streamline the splint. Byrne and Yau,[21] also in 1995, modified the lateral hinge design to a volar forearm-based splint and used rivets rather than the larger thermoplastic material hinges described by Dennys et al.[19] A further improvement to the splint design came in 2006 when Kadelbach[22] modified Byrne and Yau's[21] splint design and rather than using rivets, simple lateral hinges designed by van Veldhoven[23] were implemented. Koul et al.[24] described in 2009 an alternative traction splint design with a high profile 4-inch outrigger providing traction from elastic connected to a hook glued to the nail plate. The first hand-based design was described in 2010 by Baier and Szekeres.[25] Whilst the splint enabled free wrist motion, the splint design was a modified version of the original Schenck[17] design and utilised a high profile hand arc traction component rather than the more popular and more streamlined swing traction design.

O'Brien and Presnell[26] explored patient experiences of distraction splinting using a dorsal forearm-based swing traction splint similar to the Murray and McIntyre[20] design. These authors highlighted that 'almost all patients have described the splint as confronting in appearance' (p. 250) and the major theme to emerge from their study was the patients disconnect between the perceived complexity of the injury and treatment.[26]

Following a review of the literature, we were keen to explore if further improvements could be made to swing traction splinting in order to improve splint appearance, enhance hand function whilst the splint was in situ and reduce the amount of disconnect between the perceived complexity of the injury and the treatment.

Subsequently, a smaller hand-based swing traction splint was designed and implemented. This case series presents the results of its use with the first five patients.

Methods

This study was approved by the Austin Health Office for Research as an Audit Activity. Five patients were referred for therapy following comminuted, intra-articular PIP joint fractures and were treated between October 2010 and September 2012. Fractures were classified according to the descriptive classification system outlined by Morgan et al.[27] Inclusion criteria were intra-articular fractures of the base of the middle phalanx with surgical intervention of a transverse K-wire inserted. The K-wire enables a distraction force to be applied via fabrication of a swing traction splint. Surgeons from the Austin Health Plastic Surgery Unit and the Melbourne Institute of Plastic Surgery performed all K-wire insertions and patients were referred to Occupational Therapy at Austin Health and Malvern Hand Therapy for post-operative management. Details of the therapy protocol and splint design are outlined below.

Treatment protocol

Patients identified by the treating Surgeon as candidates for swing traction splinting had a transverse K-wire inserted followed by an hour-long hand therapy session as soon as possible to fabricate the swing-traction splint. Three hundred grams of traction was applied as per previous recommendations.[8,17–19] Following splint application, an X-ray was obtained to check the position of the fracture fragments and traction tension was adjusted if required. Subsequent therapy sessions were half hour in length and were conducted weekly whilst the swing traction splint was in situ and then continued either weekly or fortnightly depending on progress. All patients attended therapy for three to four months following injury. Initial exercises following splint application were to perform passive flexion (held for 2 minutes at end range), and 10 repetitions of active assisted (moving the swing traction with the unaffected hand) and active motion, in both flexion and extension, four times per day. Frequency and number of repetitions of the hand exercises were varied depending on pain levels and range of motion achieved. As required, a dorsal static finger extension splint fastened with Velcro was fabricated separately and worn overnight in conjunction with the swing traction splint to address any early extensor lag, PIP joint contracture or as an extension block for particularly unstable fractures whereby full extension is to be prevented. Patients were encouraged to use their uninjured fingers and thumb for light functional activities, but avoid any functional use of the injured finger. Patients were instructed to avoid activities that required greater than an arbitrary amount of 300 g of force to avoid injury. Following removal of the K-wire and swing traction splinting, therapy continued to enhance functional hand use and maximal range of motion via standard interventions of exercise, use of a flexion strap and static night extension splinting to address any PIP joint contracture or extensor lag.

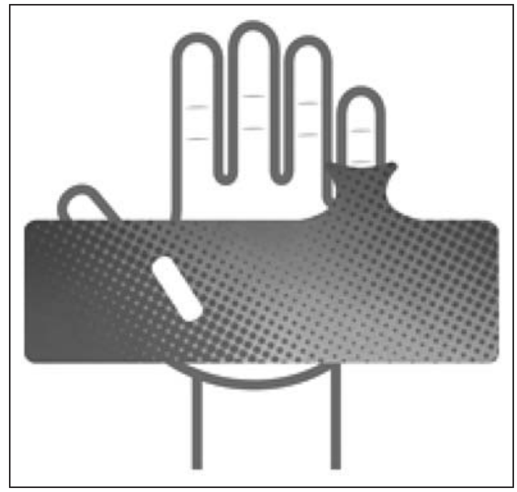

Figure 1. Little finger – pattern.

Figure 2. Little finger– splint design.

Splint design

The circumferential hand splint is fashioned via a volar approach and fastened with Velcro using either 1.6 mm or 2.0 mm solid or perforated thermoplastic material, with metacarpo-phalangeal (MCP) joint flexion of the injured finger between 30 and 40°. Velcro is added over the proximal phalanx and immobilisation of the MCP joint ensures flexion force is transmitted through the PIP and distal interphalangeal (DIP) joints during exercise. Additional small circles of thermoplastic reinforcement with holes punched in the centre were bonded to the splint base at the level of the PIP joint. This enabled the 'swing' component to stay in place and not 'jump out' of the splint. Two-millimetre copper wire was bent to shape with the proximal ends of the outrigger bent inwards at a 90° angle and cut to a length of 3 mm to allow for the 'swing' with thermoplastic moulded over the distal end, providing a platform for the adhesive-backed loop Velcro to be applied. Medium density elastic was used to provide the distraction force from the K-wire to the swing platform with hook Velcro tabs. A little finger injury splint pattern is displayed in Figure 1 and photos of the splint used for Case 3 shown in Figures 2 to 5. Figure 6 shows passive flexion performed by the therapist at week 5 with the same patient. A pattern for an injury to the ring finger is shown in Figure 7, and photographs of this splint used for Case 5 are seen in Figures 8 to 10. It is important when making the 'swing' that the finger continues to follow normal patterns of movement and the injured finger bends towards the base of the thumb as illustrated by the angle of the 'swing' in Figure 2. This is easily achieved if the ulnar-sided 'arm' of the swing is slightly longer than the radial arm when making the splint for the middle, ring or little fingers.

Outcome measures

X-rays were reviewed to estimate the percentage of joint involvement and joint congruency and fracture union. The lateral view was used to calculate the degree of articular involvement as a percentage of the entire joint surface.[27]

Figure 3. Little finger – dorsal view.

Figure 5. Little finger – active flexion.

Figure 4. Little finger – volar view.

Figure 6. Week 5 – passive flexion.

Active range of motion using a dorsal approach was measured using a 15-cm plastic goniometer at weekly intervals for the first six post-operative weeks, at eight and 12 weeks post-operatively and at a two-year review appointment. Measurements were also taken on the uninjured contralateral finger for comparison. Kleinert and Verdan's[28] total active motion (TAM) assessment system was then implemented to calculate the injured fingers' range of motion as a percentage of the contralateral uninjured finger. In order to compare with other studies, PIP joint arc of motion was also calculated.

Complications that arose throughout the treatment phase were documented.

Pain scores recorded on a 100-mm visual analogue scale (VAS)[29] were taken whilst the splint was on and the hand at rest, whilst undertaking prescribed exercises with the splint on, four weeks following splint removal and six weeks following splint removal. Patients returning for a two-year follow-up were also asked if they were experiencing any pain.

Figure 7. Ring finger – pattern.

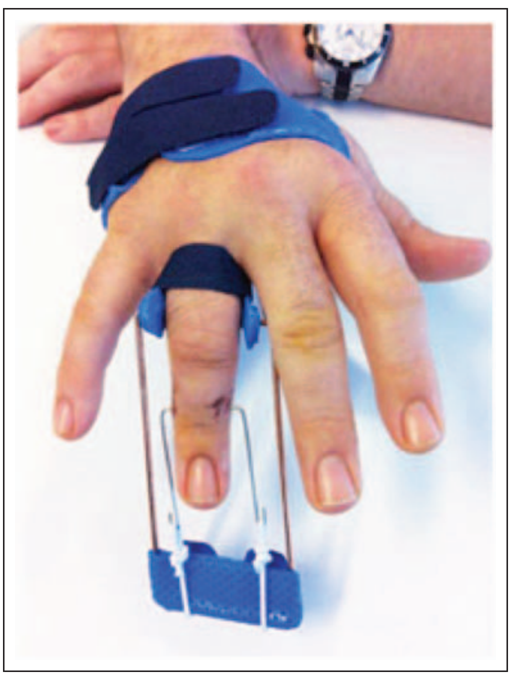

Figure 8. Ring finger – dorsal view.

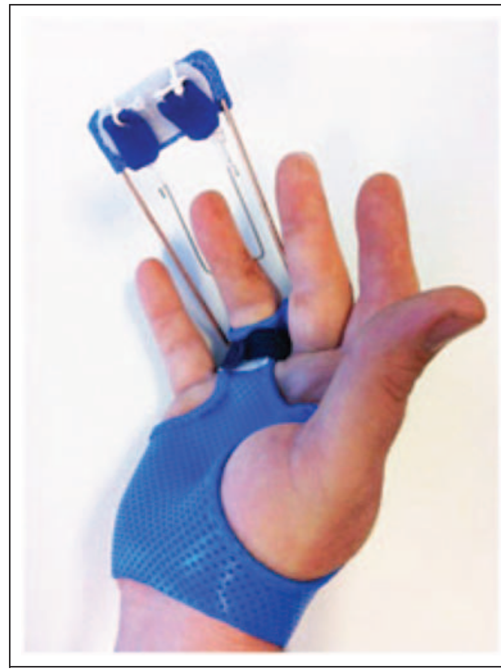

Figure 9. Ring finger – volar view.

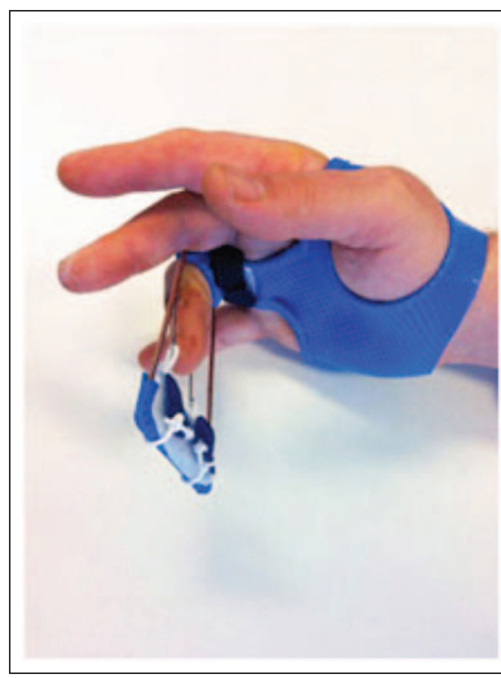

Figure 10. Ring finger – active flexion.

Grip strength measures using the second notch of the Jamar Dynamometer were taken at a two-year follow-up for those who had reached this milestone at the time of manuscript preparation utilising the American Society of Hand Therapists recommended standardised positioning as described by Mathiowetz et al.[30]

The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire[31] was administered as an outcome measure to allow patients to self rate the level of upper extremity disability and symptoms 12 weeks following surgery.

A patient questionnaire was implemented at week 6 (Figure 11) and week 12 (Figure 12) to ascertain splint comfort, and satisfaction levels with regards to splint appearance, hand appearance and hand progress. Data on splint wear compliance, use of the hand within splint for light or heavy activities and the number of occasions of knocking the hand to cause pain during the traction splinting phase were also collected. Return to work timeframes for both light and full duties were

QUESTIONNAIRE – WEEK 6 Date: ________ NAME: UR:

Please complete the following questions as honestly as possible.
Your answer will not change the treatment you receive in any way.

Your answers will be used to assist the research team to discover the best way to manage hand injuries like yours.

Please circle the number that best describes your answer

	Not at all	Slightly	Moderately	Very	Extremely
1. Did you find your splint comfortable?	1	2	3	4	5
2. How satisfied were you with the appearance of the splint?	1	2	3	4	5
3. Are you satisfied with how your hand looks now? (shape of finger/swelling etc)	1	2	3	4	5
4. How satisfied are you with the progress of your hand?	1	2	3	4	5

Please note any comments or concerns ________

	Not at all	Occasionally	Half of the time	Most of the time	All of the time
5. Did you keep your splint on at all times?	1	2	3	4	5
If not, tell us why ________					
6. Did the splint allow you to use your hand for 'light' activities? (less than 500 grams) *Eg. Using cutlery, doing up a button, shaving…*	1	2	3	4	5
7. Did you use your hand for heavy activities? (greater than 500 grams) *Eg. Carrying shopping, going to the gym, using a drill or hammer, playing sport…*	1	2	3	4	5

	Not at all	Less than 5 times	6 – 10 times	11 – 15 times	More than 16 times
8. Did you knock your hand enough to cause pain during the 6 weeks of splinting?	0	< 5	6 - 10	11 - 15	> 16

Thank you completing this survey. Please add any further comments.

Figure 11. Questionnaire – week 6.

QUESTIONNAIRE – WEEK 12 Date: ________ NAME: UR:

Please complete the following questions as honestly as possible.
Your answer will not change the treatment you receive in any way.

Your answers will be used to assist the research team to discover the best way to manage hand injuries like yours.

Please circle the number that best describes your answer

	Not at all	Slightly	Moderately	Very	Extremely
1. Are you happy with how your hand looks now? (shape of finger/swelling etc)	1	2	3	4	5
2. How satisfied are you with the progress of your hand?	1	2	3	4	5

Hand Function

Is there anything you can't do now because of your hand injury?
If yes, please provide details:

Employment – description of work:

How many days/weeks did you have off work after your injury?

When did you return to work on light duties?

When did you return to work on full duties?

Do you have any further comments or concerns regarding your hand or therapy received?

Figure 12. Questionnaire – week 12.

documented and a comments section enabled patients to note any other concerns or comments regarding their hand and therapy.

Results

Four males and one female aged between 22 and 64 formed our five cases. Patient demographics are summarised in Table 1 and surgical details are outlined in Table 2.

Radiological examination

All patients sustained comminuted intra-articular fractures of the middle phalanx. A selection of Case 3's X-rays are presented in Figures 13 to 15 and are typical of the patients included in this series. X-ray examination of all patients revealed fracture union and preservation of joint space at 12 weeks. Three of the patients completed a two-year review and there was no evidence of degenerative changes on any X-ray.

Range of motion

Range of motion measures are detailed for all cases in Table 3 and the TAM, % TAM and ratings are detailed in Table 4. TAM is calculated by the following formula: TAM = ([MCP + PIP + DIP flexion] − [MCP + PIP + DIP extension lag]).[28] Ratings are achieved via comparison to the contralateral finger with 'excellent' corresponding to an equal TAM, 'good' for TAM > 75%, 'fair' for a TAM > 50% and poor with a TAM < 50%.[28] Following swing traction splint removal at six weeks post-operatively, four of the five patients recorded greater than 66% of their contralateral finger movement, whilst one patient had more limited movement recording only 45% of the contralateral finger. All patients' range of motion continued to improve and measures taken eight weeks post-operatively indicated that four had greater than 83% of the contralateral finger (rating of 'good') whilst the fifth recorded a 'fair' rating at 70%. Further measures were taken at 12 weeks post-operatively and all patients recorded a 'good' result of greater than 90% movement when compared to the contralateral finger. The mean total active arc of motion at the PIP joint was 88° at the 12-week measure. At their two-year follow-up, all three patients reported normal range of motion compared to the other hand and measured 94%, 99% and 104% of movement in comparison to the contralateral finger.

Complications

One patient required oral antibiotic treatment for a superficial infection at the pin sites. Skin irritation at the web space of the injured finger was noted in two patients due to splint friction.

Pain

Pain scores from the VAS varied between patients as reported in Table 5. Interpretation of the VAS ratings as described by Jensen et al.[29] suggests ratings of 0–4 mm can be considered as no pain, 5–44 mm as mild pain, 45–74 mm as moderate pain and 75–100 mm as severe pain.

Four patients recorded mild pain whilst one recorded moderate pain when at rest with the splint on. Whilst undertaking exercises an increase in pain levels was evident, with two recording mild pain and three moderate pain. Following splint removal, pain scores decreased for all patients at 10 weeks post-operatively with four of the five patients reporting mild pain and one patient reporting a moderate level of pain. By 12 weeks, a further decrease in pain was reported with all experiencing mild to no pain at all. One patient reported occasional mild pain in his finger two years following surgery upon heavy use of his hand.

Grip strength

Grip strength, measured two years post-operatively was obtained for three patients and is presented in Table 6. All three patients reported their grip strength had returned to pre-injury levels.

DASH

The DASH questionnaire with the optional modules for work and sports/performing arts was administered 12 weeks post-surgery in accordance with its guidelines for use by Kennedy et al.[31] The scale of disability ranges from 0 (no disability) to 100 (most severe disability) and scores in this case study are displayed in Table 5. A mean score of four was achieved with a range of 0.8–6.5 for our five patients. This score indicates an extremely low level of disability. Four of the patients completed the work module with a mean score of 6.25 (range 1–12.5) also indicating a low level of disability. Two workers whose occupations involved heavy duties (Cabinet Maker and Prison Guard) recorded some difficulty undertaking work duties at the week 12 assessment.

The Sports/Performing Arts module was completed by two patients with a mean score of 0 indicating no disability in their chosen sport or performing arts activity.

Patient questionnaire – splint comfort and compliance/satisfaction/return to work

The responses following administration of the questionnaire at six weeks and 12 weeks are detailed in Table 7. Most patients reported the splint to be moderately comfortable and all were moderately or extremely happy with the appearance of the splint. Four patients were moderately to extremely happy with the appearance of their hand at both the six- and 12-week assessment. One patient was unhappy with the appearance of his finger and noted on the six-week questionnaire that his knuckle still had severe swelling from the original injury. On the 12-week questionnaire this subject commented that, due to the type of injury, his finger will never appear as it did previously and he reported that he was only slightly satisfied with the appearance of his hand. All patients were at least moderately satisfied with their progress at six weeks, and at the 12-week assessment, three were extremely satisfied, one moderately satisfied and one slightly satisfied. With regards to splint compliance, two patients reported removing their splint: one only once during the fifth week to wash his hand and the second removed his splint to wash his hand a couple of times per week during weeks five and six. Whilst light activities were encouraged with the splint in situ, one patient felt that she was unable to perform any light activities whilst the other patients varied in their frequency of hand use. Patients were advised not to use their hand for heavy activities and all except (who reported occasional use of his hand for heavy activities) complied with this recommendation. No more than 10 occasions of knocking the hand to cause pain was reported during the six weeks of splinting by any the patients.

Return to light duties and full duties is reported in Table 5. Four patients were working at the time of injury whilst the fifth was on extended long service leave. Of the four working subjects, one manual labourer (landscaper) injured his non-dominant hand and returned to work after splint removal. A prison guard whose dominant hand was injured at work also sustained additional injuries and was unable to return to work for three months post-injury. The heavy nature of Cabinet Making kept one patient who injured his dominant hand from returning to work for a similar length of time. A patient in a clerical role who injured his

Table 1. Patient demographics.

Case	Gender	Age	Mechanism	Classification	Articular surface	Hand	Dominant	Finger	Occupation
1	Male	22	Football: Finger kicked	Pilon fracture	100%	Right	Yes	Ring	Cabinet maker
2	Male	58	Impact drill	Pilon fracture	100%	Right	Yes	Little	Sports manager (clerical)
3	Male	26	Cricket: Ball hit finger	Pilon fracture	100%	Left	No	Little	Landscaper
4	Female	64	Fall	Palmar fracture dislocation	50%	Left	No	Little	Radiologist (long service leave)
5	Male	45	Assault: Finger twisted	Dorsal fracture dislocation	30%	Right	Yes	Ring	Prison guard

Morgan et al. JHS 1995 classification: dorsal fracture dislocation, palmar fracture-dislocation, pilon fracture, or both surface fracture.[27]
% of articular surface involvement calculated from lateral X-ray films.

Table 2. Surgical details.

Case	Days from injury to surgery	Time to splint application from surgery	Surgical procedure	Time traction applied	Complications
1	12 days	1 day post-op	Single transverse 1.0 mm K-wire across P2. Dorsal blocking k-wire.	43 days (6.1 weeks)	Nil
2	11 days	Day of surgery	GAMP #P2. Single transverse 1.2 mm K-wire across P2	44 days (6.3 weeks)	Nil
3	9 days	1 day post-op	Single transverse 1.2 mm K-wire across P2	47 days (6.7 weeks)	3/52 post-op. superficial infection at pin sites treated with Keflex (Cephalexin) Web space skin irritation
4	2 days	2 days post-op	Single transverse 1.2 mm K-wire across P2	41 days (5.9 weeks)	Web space skin irritation
5	2 days	7 days post-op	Single transverse 1.2 mm K-wire across P2	45 days (6.4 weeks)	Nil

dominant hand was the only patient able to return to work with the splint in situ and returned three weeks after surgery.

Discussion

The five patients who underwent hand-based swing traction splinting had satisfactory outcomes.

Radiological examination

The fractures sustained by patients in this case series are comparable to those found in other series examining traction management of PIP joint injuries. There were no cases of non-union or joint collapse.

Range of motion

Range of motion outcomes were similar to other studies. Schenck[17] with 10 cases and Morgan et al.[27] with 14 cases using an arcuate splint design reported an arc of motion at the PIP joint of 87° and 89°, respectively. Stern et al.[6] reported a mean of 80° in six subjects, one subject whom was treated with an arcuate splint and the other five subjects with a banjo splint. The mean 88° arc of motion achieved in our case series at 12 weeks post-operatively also compared similarly to the forearm-based swing traction splinting reported by Dennys et al.[19] who in their series of 13 cases reported a mean total arc of motion at the PIP joint to be 81°. With the high profile traction design by Koul et al.,[24] the mean TAM of 223° at eight weeks was similar to our TAM of 217° at the same time point.

Many small series have reported use of the PRTS with a mean arc of motion at the PIP joint ranging between 66° and 86°.[9,10,32–37] Modified versions of the PRTS such as the system described by Deshmukh et al.[38] with a mean arc of 85° at the PIP joint and two studies[39,40] with a mean arc of 88° at the PIP joint also yield similar results.

With regards to external fixation devices, results again are similar with an arc of motion at the PIP joint averaging 92° with the S-Quattro device[41] and an average of 77° with Allison's[14] dynamic external fixation device and 72° with Johnson et al.[15] modified Allison device. These techniques however have the disadvantage of higher costs for the external fixateurs and/or higher profile designs.

Figure 13. Pre-operative.

Figure 14. Within swing traction splint.

Complications

Pin track infection was reported in two studies regarding traction splinting.[19,27] Unfortunately, in other traction splinting literature using K-wires, the articles were either descriptive on splinting design[18,20–22] or did not report on absence or incidence of infection.[17] With regards to PRTS, modified PRTS and other forms of traction via external fixation devices infection rates were similar and ranged from 6 to 45%.[9,15,32–36,38–40]

Agarwal et al.[34] analysed complications of the PRTS and noted that infection rates were 'especially noted at the proximal 'traction pin' site subject to rotation of the pin' (p. 494). Less K-wires are typically required when utilising traction splinting when compared with PRTS or similar external fixation traction devices and it could be postulated that there is a decreased risk of infection with the former. In our series, the patient who did acquire a superficial infection had the elastic component of the splint rubbing against the pin site as shown in Figures 3 to 5. Following this incident, the K-wire configuration was improved with the K-wire bent to avoid the elastic component touching the skin, as shown in Figures 8 to 10. No infections occurred with this revised design.

Figure 15. Two years post-injury.

Skin irritation in the web space of the injured finger in two patients was also noted in the study by Dennys et al.[19] This was easily managed by applying an adhesive non-woven fabric bandage such as Fixomull® tape over the skin. We have since adopted this method prophylactically as shown in Figures 3 to 5.

Pain

In a study by O'Brien and Presnell[26] exploring the patient experience of distraction splinting, a subtheme of unexpected levels of pain early in the post-operative phase emerged. In our case series, pain did increase when undertaking exercises compared with at rest in the splint; however, patients did not report having difficulty in performing the exercises, nor did they report experiencing unexpected levels of pain. As our case series commenced shortly after publication of the O'Brien and Presnell paper, we were able to implement their recommendation to 'prepare the patient... that exercise can be painful in the early stages' (p. 258).[26] This education may well have influenced the patients' perceptions and expectations regarding pain and hence we support and encourage use of this recommendation. Further to this, all patients were prescribed analgesia for the first post-operative week, also in-keeping with recommendations made by O'Brien and Presnell.[26]

VAS scores were used by Ellis et al.[39] in a pins and rubber band system study that recorded in eight patients an average of 0.6 on the scale with an average follow-up length of 26 months which was similar to our 0.8 reported at 12 weeks. As only three patients have reached the two year milestone post-operatively, data for longer-term pain outcomes are limited in this study.

Reporting of some pain in subjects post-operatively is common within the literature. With regards to traction splinting, Dennys et al.[19] reported most patients

Table 3. Range of motion.

		Swing traction splint in situ											
Case	Day no/Joint measure	Splint applied	1 w (7 days)	2 w (14 days)	3 w (21 days)	4 w (28 days)	5 w (35 days)	6 w (42 days)	8 w (56 days)	12 w (84 days)	PIP ARC 12 w	Approx. 2 years	Contralateral finger
1	Day no.	Day 1	Day 8	Day 14	Day 22	Day 29	Day 36	Day 46	Day 53	Day 96		100 w	
	MCP							0/87	0/88	0/86	99	0/84	0/85
	PIP	15/36	15/58	15/58	15/63	15/70	13/86	4/94	4/104	5/104		−6/106	2/107
	DIP	10/15	08/17	05/18	05/20	0/20	0/25	0/40	−8/55	−12/58		−12/62	−7/62
2	Day no.	Day 0	Day 4	Day 10	Day 22	Day 28	Unseen	Day 45	Day 58	Day 94		92 w	
	MCP							0/98	0/98	0/98	75	−10/100	0/97
	PIP	15/50	15/65	15/70	20/67	15/67		14/72	15/75	15/90		15/93	0/90
	DIP	10/20	10/30	10/32	10/32	10/32		10/34	10/35	10/65		10/67	0/75
3	Day no.	Day 1	Day 6	Day 15	Day 19	Day 29	Day 33	Day 47	Day 60	Day 90		100 w	
	MCP							−7/67	−7/85	−8/85	98	−8/87	−8/85
	PIP	20/58	15/47	11/74	15/60	0/66	6/61	0/80	0/95	0/98		−2/98	−2/96
	DIP	20/32	20/32	14/61	20/45	19/53	22/60	26/49	15/60	10/76		10/78	2/78
4	Day no.	Day 2	Day 5	Day 12	Day 20	Day 27	Unseen	Day 41	Day 70	Day 95			
	MCP							10/70	0/95	0/95	84	Not yet reached	0/95
	PIP	16/45	18/60	16/60	16/60	14/60		16/52	10/82	5/89			5/90
	DIP	10/30	10/30	10/30	10/30	10/30		10/30	5/53	5/62			5/84
5	Day no.	Day 7	Day 7	Day 14	Day 25	Day 32	Day 36	Day 49	Day 60	Day 96			
	MCP							0/84	0/84	0/87	85	Not yet reached	0/83
	PIP	10/75	10/75	5/97	5/90	5/90	6/84	14/92	12/96	12/97			−5/109
	DIP	−10/14	−10/14	−10/25	−10/25	−10/20	−10/32	0/32	0/34	−5/32			−2/34

w: weeks post-operatively.

Table 4. TAM, %TAM and rating.

Case	TAM contralateral	6 w TAM	6 w, % TAM/rating	8 w TAM	8 w, % TAM/rating	12 w TAM	12 w, % TAM/rating	2 years TAM	2 years, % TAM/rating
1	259	217	84% Good	251	97% Good	255	98% Good	270	104% Excellent
2	262	180	69% Fair	183	70% Fair	228	87% Good	245	94% Good
3	267	177	66% Fair	232	87% Good	257	96% Good	263	99% Good
4	259	116	45% Poor	215	83% Good	236	91% Good	Not yet reached	Not yet reached
5	233	194	83% Good	202	87% Good	209	90% Good	Not yet reached	Not yet reached

TAM = [(MP + PIP + DIP flexion) – (MP + PIP + DIP extension lag)].[28]
% TAM = TAM of the injured finger/TAM of the contralateral finger.[28]
Excellent: TAM = contralateral finger; Good: TAM > 75%; Fair: TAM> 50%; Poor: TAM< 50%.[28]

experienced some discomfort early in the treatment program and Morgan et al.[27] reported half of their 14 subjects reported mild discomfort in their injured finger at an average follow-up of 24 months. Use of surgically applied traction devices also reported similar incidences of post-operative pain, although comparison is difficult due to varying lengths of follow-up and varying categories of pain levels documented.[9,10,14,34,36,39,41]

Grip strength

With range of motion being the primary outcome in all studies, few reported on other outcome measures such as grip strength which was reported in only two other studies. Both of these PRTS studies[38,39] reported that grip strength of the injured hand was 92% when compared to the unaffected hand. Whilst the mean length of follow-up was similar for these studies to our own, 34 months for the Deshmukh et al.[38] study and 26 months for the study by Ellis et al.,[39] unfortunately neither study reported hand dominance, and hence results are difficult to interpret as the dominant hand commonly has a stronger grip than the non-dominant hand.[42] The three patients in our study assessed at two years post-operatively all reported their grip strength felt the same as their pre-injury levels and both patients who injured their dominant hand recorded grip strength greater than their non-dominant injured hand (average 103.5%) whilst the patient who injured his non-dominant hand recorded grip strength at 84% of his non-injured dominant hand.

DASH

No other studies have reported use of the DASH as an outcome measure. An extremely low level of disability was evident at 12 weeks post-intervention and the main functional impact was whilst the splint was in situ.

Patient questionnaire – splint comfort and compliance/satisfaction/return to work

The patient questionnaire covered several parameters and most notable was the positive responses to splint comfort and splint wear compliance, and the high levels of satisfaction with splint appearance, progress at six weeks and 12 weeks post-intervention. Majumder et al.[9] when using the PRTS administered a patient questionnaire and 12 of 13 patients reported satisfaction with their treatment. The unsatisfied patient reported the frame catching on his clothing.[9] Similarly, although small numbers of occasions were reported in our series, knocking of the traction system to cause pain can be problematic in both forms of traction management. One advantage of the traction splint over PRTS or external fixateurs is the existence of a ‘frame’ to protect the K-wire/s. Fortunately, knocking of the splint did not impact on alignment, nor adversely impact on outcomes. The patient in our series who was only slightly satisfied with the appearance of his hand and the progress of his hand at the 12-week assessment was the only patient who sustained his injury at work with no fault of his own. The nature of this injury along with the patient sustaining other injuries in the incident may have influenced satisfaction levels when compared to those who sustained injuries undertaking leisure pursuits. Return to work statistics are scant throughout the literature, with one study reporting 12 of 13 subjects returning to their original occupations.[38] Time away from work largely depends on the hand injured; dominant versus non-dominant and the type of work undertaken by the patient. The

Table 5. Pain scores, DASH scores and return to work details.

Case	VAS week 6 (Whilst splint on, mm)	VAS week 6 (Whilst undertaking exercises, mm)	VAS week 10 (first month following splint removal, mm)	VAS week 12 (6 weeks following splint removal, mm)	DASH week 12			Return to work (light duties)	Return to work (full duties)
					30 questions	Work module	Sports/performing arts module		
1	10	18	5	0	2.5	12.5	N/A	12 weeks	12 weeks
2	73	73	59	35	5	0	0	3 weeks	3 weeks
3	19	49	5	0	0.8	0	0	7 weeks	7 weeks
4	24	40	18	9	6.5	N/A	N/A	On leave	On leave
5	42	50	20	0	18.3	31.25	25	11.5 weeks	16 weeks

Table 6. Grip strength in kilograms force – two years post-operatively.

Case	Left	Left: average	Right	Right: average	Percentage of uninjured hand
1	75, 73, 69	72	78, 74, 72	75[a]	104
2	66, 64, 60	63	68, 64, 63	65[a]	103
3	56, 54, 51	54[b]	66, 64, 62	64	84

[a]Injured dominant.
[b]Injured non-dominant.

Table 7. Questionnaire results.

Case	6 weeks								12 weeks		
	Splint comfort	Splint appearance	Hand appearance	Satisfaction with progress	Splint compliance	Light activities in splint	Heavy activities in splint	Knock hand to cause pain	Hand appearance	Satisfaction with progress	Hand function/comments
1	3	3	5	5	4	5	2	<5	5	5	No limitations
2	2	5	4	4	5	2	1	6–10	4	5	No limitations still sore
3	3	5	5	5	4	3	1	6–10	5	5	No limitations
4	3	3	3	3	5	1	1	<5	3	3	Less power
5	3	5	1	3	5	3	2	6–10	2	2	Pain when knocked

Five-point Likert scale (low to high) was used for questions except for the number of times the patient knocked the hand to cause pain which was categorised as '0, <5, 6–10, 11–15 or >15.'

clerical worker in our series was able to return to work fastest at three weeks post-surgery, the manual labourer with his non-dominant hand injury at seven weeks and the two manual workers with dominant hand injuries at three months post-injury.

Splint design

According to authors of forearm-based traction splinting, the wrist is included in the splint to prevent distal migration of the splint when traction is applied.[17,19,21,22] In our hand-based design, distal migration of the splint was not observed and we believe that: the circumferential design of the splint, support around the base of the thumb and the volar thermoplastic support under the proximal phalanx along with Velcro to hold the MCP joint in flexion, significantly reduces the likelihood of distal migration.

The adaptation from a forearm-based splint to a hand-based splint makes tasks such as writing, feeding oneself and putting arms through sleeves much easier to manage due to free wrist motion. Hence, the functional advantage of this design is vast. Further to this is the improved aesthetics and splint comfort with the smaller design. O'Brien and Presnell[26] highlighted that some patients found the forearm-based splint out of proportion to the injury; however, with positive responses to the questionnaire and discussion with patients in our small series, this was not raised as an issue. Similarly, with three patients reporting they were extremely satisfied with the appearance of the splint and the other two moderately satisfied, the hand-based design did not elicit the 'confronting appearance' notion that was reported by most patients in the study by O'Brien and Presnell.[26]

Supporters of the PRTS commonly site bulkiness to be the main disadvantage of traction splinting.[9,10,33,35,37,40] Having debulked the splint significantly by making it hand-based, tips were taken from the literature on traction splinting to further enhance the design. The lateral hinge[19] was chosen as it is more compact than earlier designs.[17,18] Rivets and brass fasteners were avoided to maintain a streamlined and less costly approach with the use of swing design.[23] Small hole-punched circles of thermoplastic bonded to the splint addressed the potential problem alerted by Kadelbach[22] of the wire sliding out of the thermoplastic.

The elastic thread attached to the swing frame via Velcro tabs was chosen as it is a simple method of applying traction and precise force can be applied and measured by use of a Haldex gauge. Adjusting the force applied is as simple as lifting the tab and stretching or relaxing the elastic thread and reapplying it to the Velcro loop in a slightly longer or shorter position. Adjusting force can be difficult to achieve when using elastic bands or springs, or designs with set attachments points on the swing frame such as embedded dressing hooks. No instances of the Velcro coming off the swing frame or any instances of patients self-adjusting the tension occurred in our case series. This system avoids the pitfalls associated with fatigue of smaller elastic bands used in the PRTS and some traction splint designs.

Further application of this splint design could be to modify the swing and volar splint base to enable hand-based swing traction for two or more concurrently injured fingers.

Conclusion

As highlighted by Chinchalker and Gan,[43] the goal of treatment of PIP joint injuries is the restoration of joint congruity and stability and a pain-free normal anatomic arc of motion. Applying continuous traction throughout the range of motion is the current preferred treatment option. Comparable results have been achieved via traction splinting and application of devices such as the PRTS and either option is valid. It appears that the application of PRTS or like systems is more technically demanding for the surgeon whilst fabrication of traction splinting is more demanding for the therapist. Ultimately, surgeon and therapist preference will determine the treatment modality implemented. For those who choose traction splinting, we advocate hand-based splinting over the larger forearm-based designs.

Conflict of interest

None declared.

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