

Pre-published Version

Accepted for Publication in **Irish Journal of Occupational Therapy** (ISSN 2398-8819)

Post-operative management of flexor tendon injuries at zone II and flexor pollicis longus— a survey of Irish practice

Authors:

Michelle Spirtos. Discipline of Occupational Therapy, University of Dublin Trinity College, Ireland.
(Corresponding Author)

Mary Naughton. (Department of Occupational Therapy, Beaumont Hospital, Dublin, Ireland.

Emma Carr. Department of Physiotherapy, St Vincent's University Hospital, Dublin, Ireland

Tadhg Stapleton. Discipline of Occupational Therapy, University of Dublin Trinity College, Ireland.

Michelle O'Donnell. Department of Occupational Therapy, Saint James's Hospital, Dublin, Ireland.

Abstract

Purpose: The post-operative management of flexor tendon injuries has been the focus of considerable exploration and there continues to be variation in approaches and methods of mobilisation. This study sought to explore therapy management following repair to flexor tendons at zone II and flexor pollicis longus (FPL) (all zones) in Ireland.

Methodology: A descriptive survey questionnaire design through an online format was used.

Therapists were recruited through the Irish Association of Hand Therapists, the national bodies for occupational therapy and physiotherapy and therapy managers in acute hospitals, with 29 therapists participating in the study. Descriptive statistics were used to analyse the survey data.

Findings: Patients were generally seen three to five days following surgery. Early active mobilisation approaches were favoured by all but one therapist, with 62% using the Belfast protocol and 34% the Manchester Short Splint (MSS) protocol. Each early active protocol exercise session commences with passive motion followed by graded active flexion. Tenodesis is incorporated by the majority of respondents within the first four weeks. Therapy programme and splints are modified based on patient presentation. Resistance exercises are commenced from week seven. Patient compliance was identified as the most influential factor in the post-operative intervention approach taken.

Originality: This study provides the first Irish profile of current practice in the post-operative management of flexor tendon repairs at zone II and FPL which has not previously been reported.

Further research should explore the reasoning behind the interventions chosen and also the implications for practice of changes to surgical techniques.

Key Words

Zone II, Flexor Pollicis Longus, flexor tendon post-operative rehabilitation

Introduction

Flexor tendon laceration is a relatively common injury which consistently requires surgical repair and a period of therapeutic intervention. Advanced understanding of tendon healing, developments in suture materials and techniques, and a growth in empirical research on outcomes, has resulted in post-operative interventions moving from immobilisation, to passive motion, to passive flexion and early active extension and to the introduction of controlled active mobilisation (Neiduski and Powell, 2018, Small *et al.*, 1989). While there is consensus that early mobilisation is preferred, there continues to be considerable variation amongst the approaches used in practice, including follow up pathways and exercise protocols (Chesney *et al.*, 2011).

The management of repaired flexor tendons has been evolving since the 1940's when a period of immobilisation was recommended based on the work of Mason and Allen (Amadio, 2005). This remained the approach of choice until the 1970's when the work of Duran (passive extension and passive flexion) and Kleinert (passive flexion and active extension) protocols were introduced and began to demonstrate improved outcomes (Chesney *et al.*, 2011). In the 1980's early active motion protocols were introduced (Indiana, Belfast and Sheffield protocols) which involve the commencement of controlled active mobilisation within the first week post-operatively (Cullen *et al.*, 1989, Neiduski and Powell, 2018, Small *et al.*, 1989, Strickland and Schmidt, 1998). Early active mobilisation has been demonstrated to have a positive impact on reducing adhesion formation and increasing tendon gliding with subsequent improved functional outcomes (Duran *et al.*, 1976, Pettengill, 2005, Tang *et al.*, 2017). Based on bio-mechanical and animal studies Tang and colleagues have developed specific surgical and post-surgical protocols (Tang *et al.*, 2017). Peck *et al.* (2014) published their results on the Manchester Short Splint (MSS) proposing that allowing controlled wrist extension reduces the work of flexion.

Studies outlining specific protocols for the post-operative management of Flexor Pollicis Longus (FPL) repairs are limited. Sirotakova and Elliot (2004) described the findings following surgical repair to FPL in a United Kingdom hospital over a 13 year period. Their initial post-operative positioning involved wrist flexion and the thumb only, but was later modified to include all digits. Pan *et al.* (2017) describe a short dorsolateral splint from mid forearm to the tip of the thumb with moderate pronation and the MCP and IP joints held in extension (other digits not included). Both studies describe early active motion protocols.

There are multiple factors influencing the choice of post-operative intervention protocol used including perceptions of the person's ability to comply, the type of injury sustained, the integrity of the sheath, the surgical repair technique, the suture strength and the timing of the repair (Pettengill and van Strein, 2011). However, the specific protocol utilised does appear to be primarily guided by the surgeon's preference and the established protocol within a hand therapy service (Groth, 2008).

Published early active motion protocols for both flexor tendons at zone II and FPL recommend commencing exercise periods with passive motion first prior to any active motion, commencing with partial range (Lalonde and Martin, 2013, Peck *et al.*, 2014, Small *et al.*, 1989, Tang, 2007, Tang *et al.*, 2017). The progression of exercise programmes varies, however, almost all of the specific flexor tendon intervention protocols link progression to specific timeframes (Pettengill and van Strein, 2011). The merits of practice being strongly dictated by the passing of time has been

questioned, and the pyramid of progressive force application described by Growth (2004) bases progression on individual tissue responses to identify optimal timing of tendon loading. Patient education is of particular importance yet there is limited specific guidance in the published literature in relation to these components.

Methods

The aim of this study was to examine the post-operative interventions used in Ireland following repair of flexor tendons at zone II and flexor pollicis longus (FPL) (all zones). An overall descriptive design (Cresswell, 2014) employing a survey format was chosen. Survey methodology provides a useful mechanism for presenting an overview of current interventions to inform practice development and has been utilised recently in an Irish study of hand therapy practice (Harmon and Spirtos, 2020). The online survey platform, Survey Monkey was utilised for ease of administration, completion and analysis. It has been identified that response rates for online surveys can be lower than other survey data collection methods (Fan and Yan, 2010). To positively influence the response rate, attention was given to piloting the questionnaire and adopting approaches such as reminder emails two weeks following the survey dissemination and information sharing with therapists working in the area (Couper, 2000). The survey remained open for four months.

Using purposeful sampling, dissemination of the survey was completed in 2018 through the Irish Association of Hand Therapists (IAHT) who agreed to be gatekeepers to the study; IAHT membership (n = 40) included therapists working within each of the seven plastic surgery units in Ireland. Although it was anticipated that therapists in the area of hand injuries would be members of the IAHT, other avenues were used to attempt to contact all Irish hand therapists. This included dissemination of the survey to members of the Association of Occupational Therapists of Ireland (AOTI), the Irish Society of Chartered Physiotherapists (ISCP) and therapy managers of acute hospitals. Survey information included an introductory email, a respondent information letter and a link to the online survey.

The questionnaire was informed by the practice experience of the research team, published literature, and a discussion completed by therapists specialising in this area at an IAHT study day on flexor tendon post-operative care. The survey was piloted first in paper format by two experienced therapists and then online by a further two therapists. The final questionnaire had 48 questions over five sections: demographic profile, content and timing of first appointment, protocol and interventions in the first six weeks including splint position and patient education, interventions and progression from six weeks, and finally information on changes to practice. The questions were structured for respondents to indicate their practice approach, i.e. what they do 80% of the time. The returned questionnaires were analysed descriptively using Microsoft Excel by the first author with contributions from all authors.

All questionnaires were anonymous with no identifying information sought. Ethical approval for the study was received from the School of Medicine Research Ethics committee, Trinity College Dublin.

Results

Twenty-nine completed questionnaires were returned (Occupational Therapists 55%, n=16), Physiotherapists 45%, n=13) representing a potential response rate of up to 73% if based on IAHT membership (n=40). Of these, 38% (n=11) indicated that they were practicing as a generic hand

therapist. The mean years of experience working in the area of hand therapy was 10 years (range 2 – 24 years).

First therapy appointment

Table 1 presents the timing of the first therapy appointment, the protocols used for zone II, splinting positions for both zone II and FPL and the interventions completed by therapists in their first post-operative appointment.

Table 1: Timing and content of first post-operative therapy appointment

Timing			
21% (n=6) days 1-2	65% (n=19) days 3-5	10% (n=3) days 6+	3% (n=1) no response
Protocol used zone II			
62% (n=18) Belfast	35% (n=10) Manchester Short Splint	3% (n=1) Early Controlled Passive Motion	
Zone II Splint position for Belfast Regime		Zone II Splint position for Manchester Short Splint	
Wrist neutral, MCP's 70°-90° (n= 11)		Wrist 45° extension, MCP's 30° (n= 6)	
Wrist neutral, MCP's 50°-70° (n= 1)		Wrist 30-45° extension, MCP's 30° (n= 2)	
Wrist neutral, MCP's 40°-50° (n = 1)		Wrist 40° extension, MCP's 30°-50° (n= 1)	
Wrist 10°-20° flexion, MCP's 70° (n = 3)		Wrist 30° extension, MCP's 70° (n=1)	
No responses (n=2)			
FPL Post-operative splinting			
83% (n=24) Wrist and thumb only	17% (n=5) Wrist, thumb and digits		
Strapping used to secure digits			
61% (n=17) Strapping	18% (n=5) Elastic Wrapping	21% (n=6) Tubigrip	
Interventions			
100% (n=29) Exercise programme			
100% (n=29) Patient education			
100% (n=29) Oedema management			
72% (n=21) De-bulking the dressing			
Patient education			
100% (n=29) Timeframes of tissue healing			
86% (n=25) Importance of attending therapy appointments			
72% (n=21) Smoking			
66%(n=19) General exercise e.g. gym attendance			
66% (n=19) Shoulder and elbow exercise			
62% (n=18) Single handed activities of daily living			
55% (n=16) Vitamin C			
24% (n=7) Alcohol consumption			
40% (n=12) Other *			
* Other includes work and sports, scar management, hygiene, pain, signs of infection and adherence to programme			

Interventions in first 6 weeks:

Table 2 presents the splint wearing schedule, the timing and frequency of home programmes and results related to the exercise programme content and modifications during the first six post-

operative weeks. Almost all of the respondents (93%, n=27) commence each exercise period with passive flexion of the digits (93%, n=27), one therapist commences with active flexion-protected extension and one therapist with place and hold flexion. For FPL repairs, all respondents started with passive flexion with variations of isolated and composite active flexion, protected extension and place and hold.

Table 2 Interventions first six weeks

Full time splint wearing schedule

Zone II 97% (n=28) **6 weeks** 3% (n=1) **4 weeks**

FPL 86% (n=25) **6 weeks** 10% (n=3) **5 weeks** 3% (n=1) **4 weeks**

Timing and frequency of home programmes

Zone II

14% (n=4) 1 hourly

76% (n=22) 2 hourly

7% (n=2) 1 hourly

3% (n=1) Other (depends on presentation)

FPL

14% (n=4) 1 hourly

76% (n=22) 2 hourly

7% (n=2) 3 hourly

7% (n=3) 4 hourly

Use of tenodesis zone II

Manchester Short Splint 100% (n=10)

Belfast 44% (n=8) weeks 1-4

Commencement of tendon gliding zone II

3% (n=1) Week 3

14% (n=4) week 4

24% (n=7) week 5

59% (n=17) week 6

Modifications to exercise programme within first six weeks if PIP joint contracture zone II

79% (n=23) Passive PIP joint extension

79% (n=23) Blocked Extension

52% (n=15) Digital extension splint within the DBS

Format of home exercise programmes

79% (n=23) Written information sheets with photographs of exercises/splints

10% (n=3) Video of patients own hand

7% (n=2) Demonstration and verbal information

3% (n=1) No answer

The majority of respondents (79%, n = 23) indicated that they would modify their intervention programme for zone II if there was evidence that the tendon was not gliding in the first six weeks post operatively, 18% (n=5) stated that they would not and 3% (n=1) did not respond. For respondents (n=20) providing detail regarding modifications made if there was evidence of the tendon not gliding, 35% (n=10) increased repetitions and intensity of exercises, 27% (n=7) introduced IPJ flexion blocking at week four , and 10% (n=3) would discontinue the DBS at week 4. The key factors provided by the respondents for influencing the modification introduced were

consideration of the strength of the repair and the potential for rupture, optimal healing time and changing to the MSS protocol.

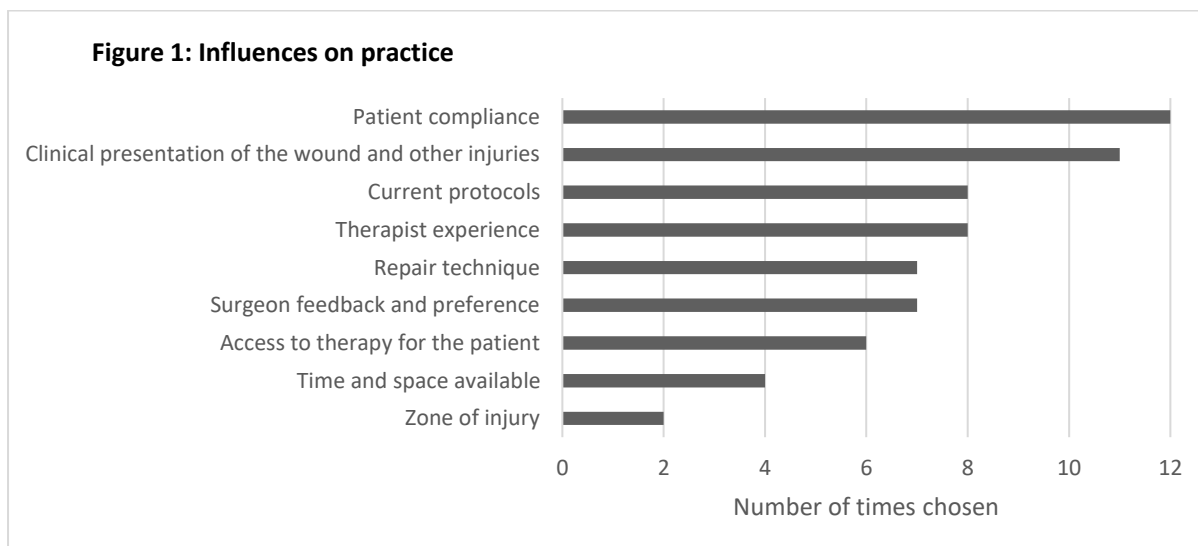
Interventions post 6 weeks

Continued night time use of the DBS after six weeks was reported by 75% (n=21) of respondents, 17 of which continued for a further 2 weeks. Other splints introduced post six weeks included digital based, volar hand based or forearm based extension splints. They were indicated to decrease flexion contractures (n=15), to decrease extrinsic tightness (n=3), and if there was an extension lag (n=2).

The timing of the introduction of resistive exercise for zone II and FPL varied from as early as week 7 (3%, n=1), but the majority introduced resistive exercise at week 8 (72%, n =21) and at week 10 by 21% (n=6) of respondents, the latest introduction of resistive exercise was reported in week 12 by one respondent (3%). Ultrasound was frequently used by 24% of the respondents (n=7, 4 PT, 3 OT). Ultrasound was used to manage scar adhesion limiting tendon glide, with one respondent using it when there is chronic inflammation. When providing advice in relation to return to driving 69% (n=20) stated that they advise return 10 weeks post-operatively, 28% (n=8) stated 12 weeks (n=1 no response). The advice given was dependent on the clinical presentation of the person and insurance reasons. Four respondents indicated that generally patients make their own decision on the timing of resumption of driving.

General practice questions

The factors influencing how therapists treat flexor tendon injuries are outlined in Figure 1.



The majority of respondents (67%, n=18) indicated that changes had been introduced in their practice over the previous five years. The reasons for changed practice were attributed to the introduction of the Manchester regime (37%, n=10), changes in practice guidelines (7%, n=2), modifications to the Belfast regime (3%, n=1), and changes required to customise their treatment based on individual patient presentations (3%, n=1).

Discussion

Intervention approaches

This study examined current post-operative management of flexor tendons at zone II and FPL. Early active mobilisation is the approach of choice with only one of the respondents indicating that their practice favours early passive mobilisation. This is in contrast to previous international surveys of practice, (Gibson *et al.*, 2017) identified that almost half of their respondents were using an early passive motion approach. However, recent publications on surgical outcomes in the USA, Asia and Europe indicate a strong shift towards early active motion (Lalonde, 2019, Lalonde and Martin, 2013, Pan *et al.*, 2020, Tang *et al.*, 2017) and these developments are reflected in the practice reported by the respondent in this survey. This development in intervention protocols has been linked to advances in suturing techniques (Pettengill, 2005), the use of the WALANT (wide awake local anaesthesia no tourniquet) surgical approach (Lalonde and Martin, 2013) and to increasing use of the extension-flexion test during surgery (Lalonde, 2019, Tang *et al.*, 2017).

Practice in Ireland has been influenced by the Belfast regime from Northern Ireland since the late 1980's and our findings indicate that the post-operative intervention following the Belfast regime continues to be the most widely used in practice. There was variation in the wrist and digit position used within the Belfast regime splint among the respondents in our study and this has received limited attention in the literature. However, the variances reported by the respondents in this study are consistent with the limited research that is available where others have described wrist positioning in neutral/slight flexion (up to 20°) (Pan *et al.*, 2017, Tang *et al.*, 2017) to comfortable extension (Lalonde and Martin, 2013). Interestingly, in a letter to the editor of the European Journal of Hand Surgery Lalonde (Lalonde, 2019) indicated that his practice is now proposing switching to the MSS from two weeks post-surgery. This proposed shift to the MSS protocol is perhaps reflected in our findings where the MSS protocol was identified as the approach of choice by 10 of the 29 respondents. In the management of FPL repairs 83% of the respondents include the wrist and the thumb only which is similar to the approach of Pan, Qin, Zhou and Chen (2017). The findings indicate that while there may be some slight variance in practice with respect to immobilisation positions post-surgery, this variance among the Irish therapists is aligned with the international research and practice.

Interventions in the first six weeks

Commencement of therapy three to five days post repair reported in our study is consistent with recommendations in several recent publications highlighting that this allows time for decreasing oedema and a reduction in the risk of bleeding at the repair which can contribute significantly to adhesion formation (Lalonde and Martin, 2013, Tang, 2007). This time frame also coincides with the commencement of collagen production which increases the risk of adhesions (Lalonde, 2019). As survey respondents were not asked for their reasoning in relation to the timing of commencement of early mobilisation it is not possible to determine why six of the respondents indicated that they commence therapy 1-2 days post operatively. However, four of these six respondents indicated that they followed the Belfast regime and this early commencement of therapy may have been guided by the initial Belfast protocol study where passive and active motion was commenced at 48 hours post-surgery (Cullen *et al.*, 1989). It is possible that the earlier start to intervention also relates to where the patients live and the organisation of services nationally. Without concurrent complicating medical history or injury these surgeries generally do not require in-patient admissions and it may be that patients living at greater distance from the treating hospital remain

as inpatients for a short period and receive guidance and intervention from their specialist team prior to returning home.

Exercise programmes

Almost all of the respondents begin exercise sessions with passive mobilisation consistent with previous studies (Lalonde and Martin, 2013, Peck *et al.*, 2014, Tang, 2007) and this is completed to prepare the tendons and to decrease the friction and work which will be required of the tendon during active motion (Lalonde and Martin, 2013, Peck *et al.*, 2014). Use of synergistic wrist and digit protocols have been described by Boyer *et al.* (2005), although studies exploring effectiveness have been primarily animal-based (Neiduski and Powell, 2018, Zhao *et al.*, 2002). The use of synergistic wrist and digit motion is a key component of the MSS regime (Peck *et al.*, 2014) and as expected all of the Irish therapists following this approach included tenodesis in their programmes. A number of therapists using the Belfast/Modified Belfast approach also included tenodesis/synergistic wrist and digit motion within their interventions in the first four weeks post repair. This may also be reflective of a synergy of approaches where therapists are combining elements within the Belfast and the MSS regimes to best support and encourage recovery within the context of current service delivery.

Restricting the range of active motion permitted at the PIP and DIP joints during early treatment is in line with other studies (Gratton, 1993, Lalonde and Martin, 2013, Pan *et al.*, 2017, Tang *et al.*, 2017). The frequency of exercise completion varied although the majority of the respondents identified that they recommend a two hourly pattern which reflects the protocol provided by the Belfast approach (Small *et al.*, 1989). There is no consensus regarding either frequency of exercise sessions or number of repetitions within sessions in the literature and justification for what has been completed is rarely provided. Using the pyramid of progressive force exercises, Groth (2004) suggests completing as often as is feasible but at least four or five times a day, Higgins and Lalonde (2016) recommended hourly, Pan *et al.* (2017) and Yen *et al.* (2008) two to four sessions daily and several authors suggest five to six times a day, for example Tang *et al.* (2017). While these guidelines show some variance in the recommended exercise frequencies during tendon rehabilitation, our findings indicate that the exercise frequencies recommended by the Irish therapists is aligned with international practice and guidance.

Influences on practice

Almost all of the respondents described that patient compliance with the protocol was a key influence on practice and it is then not surprising that all of the respondents provide education to their patients in relation to time frames for tissue healing. The majority of the respondents reported that they primarily use written information sheets with photographs (62%), while a small proportion (11%) reported that they use videos of the patients own hand where they record the patient completing the exercises and the patient can refer to the recordings to guide their home exercise programme. Recent advances in the use of technology indicate that there is a growing preference amongst patients for video self-modelling (Ouegning and Valdes, 2018) and this could be considered in future practice development. Throughout the findings it is clear that although the respondents are following the established protocols within the Belfast and MMS regimes, these established protocols are acting as a guide to practice as programs are modified within the first 6 weeks based on individual patient's progress and response to intervention. This level of clinical reasoning and decision making among the Irish therapists in overseeing and adapting tendon repair

rehabilitation is supported and advocated for in the international literature (Groth, 2004, Groth, 2008).

Limitations:

The sample size of this survey is small and calculating a potential sample size was not possible. This is a specialised area of practice and based on the membership of IAHT the response rate indicates that the findings are representative of therapists working in this area in Ireland. While the questionnaire used has not been validated, it was designed based on structured discussions with therapists attending a flexor tendon injury study day, the professional experience of the authors who include experienced certified hand therapists, and relevant published literature. Due to the nature of online surveys and the questions used, the clinical reasoning behind some of the responses could not be explored in greater depth.

Conclusion

The study highlights that early active mobilisation in a controlled manner is the protocol of choice in Ireland. The findings provide the first profile of the current post-operative interventions following flexor tendon injury at zone II and of FPL in this country. While the study had highlighted some variance in practice, all these variances are identified in the published literature indicating that Irish practice in the management of flexor tendon rehabilitation of zone II and FPL is aligned with international literature and practice. Therapists are demonstrating clinical reasoning in relation to the progression of, and modifications to, patients' treatment programmes thereby judiciously adjusting the treatment protocol appropriate to the individual patient. The study findings provide a detailed overview of therapist intervention which should be useful in informing future practice and research in this area.

References

- Amadio, P.C. 2005 Friction of the gliding surface. Implications for tendon surgery and rehabilitation. *Journal of Hand Therapy* **18**(2), 112-119.
- Boyer, M. J., Goldfarb, C. A. & Gelberman, R. H. 2005 Recent progress in flexor tendon healing. The modulation of tendon healing with rehabilitation variables. *Journal of Hand Therapy* **18**(2), 80-85.
- Chesney, A., Chauhan, A., Kattan, A., Farrokhar, F. & Thoma, A. 2011 Systematic review of flexor tendon rehabilitation protocols in zone II of the hand. *Plastic and Reconstructive Surgery* **127**(4), 1583-1592.
- Couper, M. P. 2000 Web surveys: A review of issues and approaches. *Public Opinion Quarterly* **64**(4), 464-494.
- Cresswell, J. W. 2014 *Research design: Qualitative, quantitative and mixed methods approaches*, Sage, California.
- Cullen, K. W., Tolhurst, P., Lang, D. & Page, R. E. 1989 Flexor tendon repair in zone 2 followed by controlled active mobilisation. *The Journal of Hand Surgery* **14**(4), 392-395.

- Duran, R. J., Houser, R. G., Coleman, R. & Stover, M. G. 1976 Management of flexor tendon lacerations in zone 2 using controlled passive motion postoperatively. *Journal of Hand Surgery Am* 178-182.
- Fan, W. & Yan, Z. 2010 Factors affecting response rates of the web survey: A systematic review. *Computers in human behaviour* 26(2), 132-139.
- Gibson, P. D., Sobol, G. L. & Ahmed, I. H. 2017. Zone II Flexor Tendon Repairs in the United States: Trends in Current Management. *The Journal of hand surgery* 42(2), e99-e108.
- Gratton, P. 1993 Early active mobilization after flexor tendon repairs. *Journal of Hand Therapy*, 6(4), 285-289.
- Groth, G. 2004 Pyramid of progressive force exercises to the injured flexor tendon. *Journal of Hand Therapy* 17(1), 31-42.
- Groth, G. 2008 Clinical decision making and therapists' autonomy in the context of flexor tendon rehabilitation. *Journal of Hand Therapy* 21(3), 254-259.
- Harmon, D. & Spirtos, M. 2020 An investigation of the acute management of closed intra-articular fractures of the proximal interphalangeal joint in Ireland. *Irish Journal of Occupational Therapy* 48(1), 55-68.
- Higgins, A. & Lalonde, D. H. 2016. Flexor tendon repair postoperative rehabilitation: The Saint John protocol. *PRS Global Open*.
- Lalonde, D. H. 2019 True active motion is superior to full fist place and hold after flexor tendon repair. *Journal of Hand Surgery Eur* 44(8), 866-867.
- Lalonde, D. H. & Martin, A. L. 2013 Wide-awake flexor tendon repair and early tendon mobilization in zones 1 and 2. *Hand Clinics* 29(2), 207-213.
- Neiduski, R.L. & Powell, R.K. 2018 Flexor tendon rehabilitation in the 21st century. *Journal of Hand Therapy* 32(2), 165-174.
- Ouegning, A. & Valdes, K. 2018 Client preferences and perceptions regarding a written home exercise program or video self-modeling: A cross-sectional study. *Journal of Hand Therapy* 33(1), 67-72.
- Pan, Z. J., Pan, L., Xu, Y. F., Ma, T. & Yao, L. H. 2020 Outcomes of 200 digital flexor tendon repairs using updated protocols and 30 repairs using an old protocol: experience over 7 years. *Journal of Hand Surgery Eur* 45(1), 56-63.
- Pan, Z. J., Qin, J., Zhou, X. & Chen, J. 2017 Robust thumb flexor tendon repairs with a six-strand M-Tang method, pulley venting, and early active motion. *The Journal of Hand Surgery Eur* 42(9), 909-914.

Peck, F., Roe, A. E., Ng, C. Y., Duff, C., McGrouther, D. A. & Lees, V. C. 2014 The Manchester short splint: A change of splinting practice in the rehabilitation of zone II flexor tendon repairs. *Hand Therapy* **19**(2), 47-53.

Pettengill, K. & Van Strein, G. 2011 Postoperative Management of Flexor Tendon Injuries. In: *Rehabilitation of the Hand and Upper Extremity* 6th edn. (Skirven, T. M., Osterman, A. L., Fedorczyk, J. M. & Amadio, P. eds) Elsevier Mosby, Philadelphia, PA. 457-478.

Pettingill, K. M. 2005 The evolution of early mobilization of the repaired flexor tendon. *Journal of Hand Therapy* **18**(2), 157-168.

Sirotkova, M. & Elliot, D. 2004 Early active mobilization of primary repairs of the flexor pollicis longus tendon. *The Journal of Hand Surgery* **29**(6), 531-535.

Small, J. O., Brennan, M. D. & Colville, J. 1989 Early active mobilisation following flexor tendon repair in zone 2. *The Journal of Hand Surgery* **14**(4), 388-391.

Strickland, J. W. & Schmidt, C. 1998 Repair of flexor digitorum profundus lacerations: The Indiana method. *Operative Techniques in Orthopaedics* **8**(2), 73-80.

Tang, J. B. 2007 Indications, methods, postoperative motion and outcome evaluation of primary flexor tendon repairs in zone 2. *The Journal of Hand Surgery* **32**(2), 118-129.

Tang, J. B., Zhou, X. & Oan, Z. J. 2017 Strong digital flexor tendon repair, extension-flexion test, and early active flexion: Experience in 300 tendons. *Hand Clinics* **33**(3), 455-463.

Yen, C. H., Chan, W. I., Wong, J. W. C. & Mak, K. H. 2008. Clinical results of early active mobilisation after flexor tendon repair. *Hand Surgery* **13**(1), 45-50.

Zhao, C., Amadio, P., Zobitz, M. E., Momose, T., Couvreur, P. & An, K.-N. 2002. Effect of synergistic motion on flexor digitorum profundus tendon excursion. *Clinical Orthopaedics and Related Research* **396**, 223-230.