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COMPARISON OF EXCURSION-BASED APPROACH WITH FORCE-BASED APPROACH IN REHABILITATION OF REPAIRED FLEXOR TENDONS IN ZONE II AND III

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DECLARATION

I, Michelle Suzanne Coates (neé Hellyar) hereby declare that this dissertation is my own work. It is being submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Occupational Therapy. It has not been submitted before for any degree or examination at this or any other university.

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__________day of _____________________ 2017

DEDICATION

I dedicate this to all those out there who want to change the world,

and are crazy enough to believe that they can.

We can!

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ABSTRACT

This study explores the implementation of two different synergistic wrist motion approaches in the treatment of flexor tendon injuries, the excursion-based approach and the force-based approach. A prospective, quantitative, comparative intervention research design was used to compare the two approaches and determine their effectiveness in a public hospital in South Africa.

The five participants' range of motion, independence in activities of daily living and satisfaction levels were measured throughout the 12 week treatment programme. The excursion-based group showed significant improvement in passive Strickland and Glogovac scores over the rehabilitation period. The excursion-based group also achieved better final place-and-hold and active Strickland and Glogovac scores than the force-based group which showed a decline in these scores over the 12 weeks. Both groups had a poor result for active movement at the final session due to the development of adhesions, but were found to have an improvement in their upper limb function measured on the Disabilities of the Hand, Shoulder and Arm questionnaire in all activities except for those related to work. These results were not statistically significant.

The poor results may be attributed to the unique challenges experienced by patients with flexor tendon injuries, living in under-resourced South African communities. The small sample and the fact that the excursion-based group received isolated flexor digitorum profundus tendon repairs while the force-based group received combined flexor digitorum profundus and flexor digitorum superficialis repairs may also have had an impact on the results. The outcomes of this study indicate that despite yielding successful results in research studies performed in developed countries, it is unlikely that either of these approaches will be suitable in the rehabilitation of patients with flexor tendon repairs in a public hospital in South Africa.

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OPERATIONAL DEFINITIONS

Adherence – The act of following the medical practitioner's instructions by returning for all treatment sessions and as well as following the home programme as advised (Tilson, 2004).

Adhesions – Collagen formation which occurs around a repaired flexor tendon connecting it to the tendon sheath and other surrounding structures. This prevents the flexor tendon from being able to glide in the sheath, resulting in the patient being unable to actively flex their fingers (von der Heyde & Evans, 2011).

Buddy strapping – A simple type of soft orthosis which connects the injured finger to its adjacent finger. The less affected finger provides support and assistance to the injured finger which helps it to regain range of motion (Beasley, 2011).

Composite flexion/extension - When all joints in the fingers and hand are flexed or extended at the same time. I.e. making a fist is composite finger flexion (May, et al., 1992).

Contractures – A complication where the structures at a joint shorten resulting in the joint becoming unable to be passively flexed and/or extended throughout its full range of motion (Tufaro & Bondoc, 2011).

Elastic traction – This is part of a splint used in the treatment of repaired flexor tendon injuries. Elastic traction is added to each finger in the dorsal blocking splint to bring the fingers passively into flexion, and to allow them to actively extend (Pettengill & Van Strien, 2011).

Epitendinous suture – This is an additional suture which surrounds the entire circumference of the flexor tendon repair. Its purpose it to enhance the strength of the repair as well as to improve gliding and prevent gap formation of the repair (Rust & Eckersley, 2008; Pretorius, et al., 2008).

Gapping – When excess tension at the flexor tendon repair site causes the two end of the tendon to pull away from each other leaving a gap between the two ends, which are still connected by suture material (Evans, 2012).

Hook fist – An exercise where a patient bends the proximal and distal interphalangeal joints of their fingers while keeping the metacarpophalangeal joints extended. This is a the tendon gliding exercises (Pettengill & Van Strien, 2011).

Isolated/blocking joint mobilization- An exercise where only one joint of the finger is exercised at a time e.g. the proximal interphalangeal joint is held in extension and the DIP joint is actively flexed and extended (Pettengill & Van Strien, 2011).

Straight fist – An exercise where the patient flexes their metacarpophalangeal and proximal interphalangeal joints of their fingers, but keeps their distal interphalangeal joint extended. This is one of the tendon gliding exercises (Pettengill & Van Strien, 2011).

Strickland and Glogovac Formula- A formula which uses the range of motion scores of the proximal and distal interphalangeal joints to calculate the patient's percentage of normal finger motion (Strickland & Glogovac, 1980).

Suture strands - The strands of suture material that cross the flexor tendon repair site. The number of strands is important as they have an effect on the strength of the repair as well as the amount of friction that the repaired tendon experiences (Amadio, 2005).

Tendon gliding – A series of exercises that starts with fully extended fingers, then proceeds to a hook fist, a straight fist and finally a composite fist. It encourages the tendon to glide in the sheath (Pettengill & Van Strien, 2011).

Tenodesis – The balance of muscle forces crossing the wrist and fingers causes the fingers to move passively when the wrist is moved actively. When the wrist is moved into flexion it causes the fingers to extend and when the wrist is moved into extension it results in finger flexion (Colditz, 2011).

Tenolysis – A surgical procedure which releases adhesions (scar tissue) around a flexor tendon repair so that the tendon can glide freely within the tendon sheath (Pretorius, et al., 2008).

Zone – The palmar/volar surface of the hand is divided up into 5 areas/zones. Each zone is anatomically different, which affects the way in which surgical and therapeutic treatment is carried out (Pretorius, et al., 2008).

ABBREVIATIONS

ADL	-	Activity of daily living
DASH	-	Disabilities of the arm, shoulder and hand
DIP	-	Distal interphalangeal
EAM	-	Early active motion
EPM	-	Early passive motion
FDP	-	Flexor digitorum profundus
FDS	-	Flexor digitorum superficialis
FTI	-	Flexor tendon injury
FTR	-	Flexor tendon repair
IF	-	Index finger
IOD	-	Injury on duty
IP	-	Interphalangeal
LF	-	Little finger
MF	-	Middle finger
MP	-	Metacarpophalangeal
PIP	-	Proximal interphalangeal
RF	-	Ring finger
ROM	-	Range of motion
SES	-	Socioeconomic status
SG	-	Strickland & Glogovac Formula
SWM	-	Synergistic wrist motion
TAM	-	Total active movement
TMH	-	Tambo Memorial Hospital

CHAPTER 1: INTRODUCTION

1.1 Introduction

The hands are of particular importance in the performance of everyday activities of daily living (ADLs) to enhance participation in occupations in the home, workplace, and other settings (American Occupational Therapy Association, 2014). These occupations are classified in occupational therapy as productivity, leisure and personal management. The use of the hands in ADLs is facilitated by many components including the balance between larger and smaller muscles, bones and joints as well as a rich supply of sensory receptors, proprioceptors and blood vessels (Pratt, 2011). These components are responsible for the strength, flexibility and precision movements necessary to carry out ADLs (National Library of Medicine, 2016). Unfortunately these components are vulnerable and can be easily damaged during daily use of the hand while carrying out various occupations.

It is only when an individual's upper limb is injured with resultant loss of function of their fingers, hand or arm that they appreciate how severely an upper limb injury can affect their ability to perform ADLs independently. Health professionals understand this and prioritise the restoration of function to the injured hand. The role of the occupational therapist in hand therapy is to rehabilitate the injured hand to enable the patient to regain independence in their ADLs (Pettengill, 2011). A close relationship, with a good exchange of information, is essential within the treating team of doctors, surgeons, wound clinic sisters, occupational therapists and physiotherapists to ensure the most effective outcome of the patient after flexor tendon injuries (FTIs) (Pettengill & Van Strien, 2011; Rigo & Røkkum, 2016).

Flexor tendon rehabilitation is an essential part of ensuring a patient regains their independence in carrying out ADLs, after receiving a flexor tendon repair (FTR) (Pettengill & Van Strien, 2011). There is however controversy in the literature regarding which of the various approaches are the most effective in rehabilitating FTIs after a repair. Initially FTIs were immobilized post-operatively for three to four weeks, but this resulted in many complications, including tendon adhesions and contractures, which led to researchers discouraging the use of this approach

(Strickland, 2005; Taras, et al., 2011) Then came the development of early passive motion (EPM) and early active motion (EAM) approaches, which were more effective in mobilising the flexor tendons and thus avoiding adhesions (Trumble, et al., 2010). There are several factors to consider when choosing an approach to treat a patient with a FTI, including the patient's adherence to their home programme and attending therapy, the type of repair done, as well as the experience and skill of the treating surgeon and hand therapist (Pettengill & Van Strien, 2011).

There are several different types of EPM and EAM approaches, but it is the synergistic wrist motion (SWM) approach, one of the active approaches, which has shown to produce successful outcomes in rehabilitation of FTIs (Pettengill & Van Strien, 2011). The success of SWM can be attributed to the increased amount of tendon gliding that it achieves, resulting in considerably fewer adhesions and improved range of motion (ROM) (Lieber, et al., 1999). The treatment of repaired FTIs with the use of SWM can be carried out using one of two approaches. The first is known as the excursion-based approach (Active place-and-hold mobilization approach) (Cannon, 1993), while the second is a force-based approach (the Modified pyramid approach) (von der Heyde, 2008), which introduces exercises according to the amount of force they exert on the healing tendon.

1.2 Statement of the Problem

A SWM approach had not previously been used at Tambo Memorial Hospital (TMH), in the rehabilitation of FTIs in occupational therapy, despite there being literature to prove that it has shown to be effective in the treatment of FTIs in developed countries. The excursion-based approach and the force-based approach were the two SWM approaches that were studied and their outcomes evaluated in this research. There is however, no published literature available that compares these two approaches to determine which would be more effective in treating repaired FTIs in a South African context. It was also not known if the personal demographic and medical factors of the patients receiving flexor tendon rehabilitation at TMH have an effect on their outcomes.

1.3 Purpose of the Study

The purpose of this study was to introduce an excursion-based and a force-based SWM approach to treat repaired FTIs in the occupational therapy department at TMH. The outcomes of each approach was then be explored and compared to determine if there were any differences between them in terms of the participants' recovery over 12 weeks. The outcomes that were measured include the ROM of the fingers, calculated using the Strickland & Glogovac (SG) formula (Strickland & Glogovac, 1980), the participants' ability to use their affected upper limb functionally, measured with the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire (Solway, et al., 2002), and the participants' satisfaction with the surgical and therapeutic treatment received. The outcomes of the approaches were considered in light of the participants' demographic and medical history. The results from this study provided information on the effectiveness of these two approaches in participants from under-resourced environments that were being treated in a public hospital in South Africa.

1.4 Research Aim

The aim of this research was to compare the outcomes and determine the effectiveness of an excursion-based approach versus a force-based approach in the treatment of participants after a FTR, throughout a 12 week rehabilitation programme.

1.4.1 Research Objectives

- To determine the passive, place-and-hold and active ROM of participants who are being treated with either the excursion-based approach or the force-based approach using the SG formula (Strickland & Glogovac, 1980).
- To determine the upper limb functioning of participants who are being treated with either the excursion-based approach or the force-based approach, using scores obtained from the DASH questionnaire (Solway, et al., 2002).
- To determine participant satisfaction with surgery, therapy and outcomes between participants being treated with the force-based approach and those being treated with the excursion-based approach.

- To explore the effect that an under-resourced South African context has on the outcomes of participants who have been rehabilitated with the use of an excursion-based or force-based SWM approach.

1.5 Null Hypothesis

There will be no difference in the outcomes of patients being treated using the excursion-based approach and those treated with the force-based approach, in terms of passive, place-and-hold and active ROM, their upper limb functionality and participant satisfaction.

1.6 Justification for the Study

This research will provide a comprehensive analysis of the excursion-based and force-based approaches, which will include important information on the risks and benefits of using these approaches in flexor tendon rehabilitation at TMH. Most importantly this research will provide invaluable information on the effectiveness of implementing each of these approaches on patients from under-resourced communities that are receiving treatment at public hospitals in South Africa.

1.7 Layout of Dissertation

Chapter 1 Introduction

This chapter serves as an introduction to the role of the hand therapist in rehabilitating a repaired FTI. It also gives a good overview of the FTI related problems in a South African context and an explanation of how this study aims to address and improve these problem areas.

Chapter 2 Literature review

This chapter considers the causes, surgical treatment, rehabilitation and complications associated with FTIs. It discusses in detail the components that contribute to a successfully rehabilitated FTI, including glide, force and excursion as well as the various rehabilitation approaches in use.

Chapter 3 Methodology

This chapter explains in detail the manner in which this study was conducted. It highlights the outcomes used in this study, and includes ROM measurements, DASH questionnaire and participant satisfaction questionnaire, and discusses how they were measured and analysed.

Chapter 4 Results

The results chapter summarises the analysed results for each outcome, as well as the participants' personal demographic and medical history data. The data is presented in graph and table format and shows the effect, size and statistical significance between the two groups.

Chapter 5 Discussion

This chapter gives a comprehensive explanation of the results presented in the previous chapter. It explains the effect that the various outcomes have on one another as well as the similarities and differences between the outcomes obtained in this study and those explained in the literature. It is in this chapter that the results are analysed with regard to the purpose, aims and limitations of the study.

Chapter 6 Conclusion

The conclusion chapter briefly summarises the most important findings of the research and the effect that these findings will have on the future of flexor tendon rehabilitation in a public hospital in South Africa. It also provides recommendations for future FTI related research carried out in an under-resourced South African context.

CHAPTER 2: REVIEW OF THE LITERATURE

2.1. Introduction

This chapter consists of a review of flexor tendon literature that discusses flexor tendon related injuries, surgical repairs, rehabilitation approaches and postoperative complications. The relationship between the glide, force and excursion of a repaired tendon and how these aspects differ between the excursion-based and the force-based SWM approaches is explained in detail in this chapter. The literature discussed in this chapter was sourced from a number of databases including EBSCO Host, Pubmed, Science Direct and Ovid. The majority of the literature reviewed is supplemented by a variety of international literature sources. This is due to the fact that there is insufficient quality literature on FTIs and their associated repairs and rehabilitation in a South African context. Much of the literature included in this review is from more than 15 years ago, as many important studies were conducted during the 1980's and 1990's. These studies have not since been repeated, and their findings are still highly relevant to current research that is being done on repaired FTIs.

2.2 Flexor Tendons and their Associated Injuries

'Flexor tendon' is a term used to describe the strong connective tissue bands found below the volar surface of the palm and fingers of the upper limb (Pratt, 2011). The flexor tendons which will be discussed throughout this dissertation, are those of the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP) muscles. These tendons serve as a strong connector between the muscle body and the bone and they assist the muscle body to flex the fingers at the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints (Pretorius, et al., 2008; Pratt, 2011). These muscle-tendon pairs also assist other muscles such as the lumbricals, the flexor carpi ulnaris and flexor carpi radialis to flex the metacarpophalangeal (MP) and wrist joints (Hill & Chan, 2013).

The flexion of fingers made possible by these muscle-tendon pairs is necessary to close or bend one's finger in order to hold or manipulate an object. These muscle-tendon pairs are therefore extremely important in controlling the fine motor function of the hand required to carry out ADLs. There are several other important anatomical structures surrounding the FDS and FDP tendons which provide them with support and nourishment. These include intrinsic muscles, ligaments, nerves, blood vessels and flexor tendon sheaths, which are made up of several annular and cruciform pulleys surrounding the tendons (Pratt, 2011). These tendon sheaths play a very important role in preventing bowstringing of the tendons, but their repair, when lacerated along with the flexor tendons, is difficult and often results in complications (Hill & Chan, 2013).

Despite sometimes only affecting one finger, FTIs are one of the most difficult and highly debated upper limb injuries to treat. They occur most frequently in young, working-age men, and can cause considerable permanent disability if not treated optimally (Amadio, 2011). The prognosis of a FTI varies greatly as a result of several personal and medical factors. These include the age and personal characteristics of the patient, the severity and zone of the injury, the surgeon's skills and type of surgical repair performed and the type of therapy approach used to rehabilitate the injured finger/s (Chesney, et al., 2011). The amount of time required to rehabilitate a FTI is dependent on the prognosis of the injury, but it can take from three months to 12 months for a patient to regain optimal ROM and function (Baktir, et al., 1996; Libberecht, et al., 2006; Amadio, 2011; Moriya, et al., 2015)

2.3 Surgical and Therapeutic Management of Flexor Tendon Injuries

Successful management of a FTI requires both surgical repair and post-operative therapeutic rehabilitation. The surgical repair should be strong, but not cause undue resistance to the gliding of the repaired tendon through the sheath during rehabilitation (Pretorius, et al., 2008). The chosen rehabilitation approach should encourage movement of the tendon, without exceeding the repair site strength (Silva, et al., 2002; Amadio, 2005).

2.3.1 Surgical Management

There is much debate around the type of surgical repair that should be used to repair a FTI, and the optimal number of strands in the surgical repair. "The strength of a tendon repair is roughly proportional to the number of suture strands that cross the repair site" (Cannon, 1993, p. 3). Boyer, Gelberman, Burns, Dinopoulos, Hofem and Silva (2001) recommend a repair with more than four strands, as their research found that an eight strand repair was 42% stronger than a four strand repair, and this resulted in a significantly lower incidence of gapping (Boyer, et al., 2001). However, an increase in the number of strands is associated with increased tendon trauma caused during the repair as well as an increase in the bulk of the repair, which causes the gliding resistance to be higher (Tanaka, et al., 2004). Thurman, Trumble, Hanel, Tencer, and Kiser (1998) found, however, that the increase in gliding resistance between a repair with a two, four and six strand repair was not significant (Thurman, et al., 1998).

Other aspects that also have an effect on the resistance of the repair includes the number of knots and their location, the number of loops present on the outside of the repair (Zhao, et al., 2001a), the addition of an epitendinous suture, the suture method and the type of suture material used (Strickland, 2005). Repairs with a higher resistance have been found to result in an increased number of adhesions when compared to those with lower resistance (Amadio, 2005). It is therefore optimal for the surgeon to compromise by performing a tendon repair with adequate tensile strength to withstand the chosen therapeutic approach, but with the least possible amount of bulk.

2.3.2 Therapeutic Management

Hand therapy after a FTR is essential to ensure that the repaired tendon/s regain adequate excursion, strength and functioning (Howell & Peck, 2013). An effective flexor tendon rehabilitation approach should include elements of patient education, a graded clinic and home exercise programme and equipment, such as splints and pressure garments (Groth, 2005). These elements are incorporated into the patient's treatment sessions to encourage a gradual improvement in functioning which will eventually lead to independence in ADLs. The outcomes that should be considered during flexor tendon rehabilitation include active and passive ROM, muscle strength, fine motor control, participant satisfaction and independence in ADLs such as gripping and manipulating a pen or toothbrush (Trumble, et al., 2010).

The goal at the end of the flexor tendon rehabilitation programme is that the patient is satisfied with their ability to return to premorbid ADLs without any adaptations. There are, however, many complications that may occur, including tendon re-ruptures, adhesions or contractures, which threaten the achievement of this goal (Taras, et al., 2011). Such complications can be avoided by ensuring that the safe zone of the FTR is respected at all times throughout the rehabilitation programme (Amadio, 2011).

2.4 The Safe Zone

In order to gain excursion of the FTR, without gapping or re-rupturing the repair, force should be applied to the tendon within the constraints of the safe zone (Tanaka, et al., 2005). Force is applied within the safe zone when it is more than the gliding resistance experience by the tendon repair, but less than the suture breaking point (Tanaka, et al., 2004; Tanaka, et al., 2005; Amadio, 2005). If force is applied between these two limits, it will effectively allow movement of the tendon, without causing damage to the tendon repair (Tanaka, et al., 2004).

In two separate studies on cadaveric human hands, authors found the peak gliding resistance after FTR to be approximately 1.1N (Zhao, et al., 2001a; Tanaka, et al., 2004). Amadio (2005) highlighted that the upper limit of the safe zone should be the amount of force necessary to cause a gap at the tendon repair site, and not the ultimate tensile strength of the repair, as these value of 6.4N and 39.82N respectively differ considerably (Amadio, 2005). Gapping should be avoided due to its ability to cause considerable complications in the rehabilitation of FTIs, and therefore the theoretically recommended safe zone of a FTR is between 1.1N and 6.4N.

The safe zone may, however, vary between patients, and is dependent on several personal and surgical factors including the severity of the injury, the individual's healing rate and the type of surgical repair performed (Groth, 2004). Research by Zhao, Amadio, Zobitz, Momose, Couvreur, and An (2001b) highlighted this by demonstrating that the gliding resistance of the Modified Kessler suture, with two strands, four loops and one knot inside was low (0.81N) and that of the Augmented Becker suture, with six strands, 24 loops and three knots outside, was significantly higher (1.52N) It is thus essential for the treating therapist to have a good understanding of the relationship between resistance, force and excursion to ensure that these components are managed within the safe zone to benefit the patient optimally (Zhao, et al., 2001b)

2.4.1 The Effect of Gliding Resistance

Gliding resistance is the minimal force required to mobilise a flexor tendon in order to gain finger flexion. Resistance to gliding is caused by intrinsic factors, such as the friction between the tendon repair and the tendon sheath and extrinsic factors (Zhao, et al., 2002a; Zhao, et al., 2004). The extrinsic factors include damage to the gliding surfaces, weight of the finger, stiffness of surrounding joints (Tanaka, et al., 2005; Amadio, 2005), resistance in antagonist muscles, adhesions and oedema present in the finger (Zhao, et al., 2001b).

It is important to note that the gliding resistance of a flexor tendon will differ as the angle of the joint changes. The resistance will be less at a smaller angle, such as 45° flexion than it would be at a greater angle of 90° flexion (Amadio, 2005). A study by Tang (2007) showed that gliding resistance can increase by five to 10 times when the finger flexes through the final one third of its ROM. It is thus evident, as a result of the increased gliding arc, that re-ruptures will most likely occur in the final third of the finger’s ROM (Tang, 2007a).

Surgeons have an important role in decreasing the gliding resistance of a FTR by ensuring careful handling of the tissue during surgery (Amadio, 2005) and choosing a repair technique which is both strong and has a low gliding resistance (Tanaka, et al., 2004).The bulk of the eight strand repair has been found to decrease tendon excursion by 9% when compared to a four strand repair technique (Boyer, et al., 2001). Some recommended surgical repairs that fit the optimal criteria are the Double Modified Kessler suture, the Pennington suture or the Modified Pennington suture (Tanaka, et al., 2004).

In a study using human cadaver hands Zhao et al. (2001b) found the gliding resistance of an intact FDP tendon within the A2 pulley to be approximately 0.3N, and this increased significantly to 1.1N after a FTR (Zhao, et al., 2001b). However, another study by Zhao, Amadio, Zobitz and An (2001a) published in the same year, performed on the forepaws of dogs, found the average gliding resistance of an intact tendon to be 0.09N, and after FTR it significantly increased to 0.64N. The considerable differences in these values can be attributed to the different subjects being used in each of the two studies. (Zhao, et al., 2001a)

2.4.2 The Importance of force

It is evident that a minimum amount of force is necessary to overcome the gliding resistance of a repaired tendon in order to gain excursion (Tanaka, et al., 2005; Amadio, 2005). What is uncertain is whether or not an additional increase in force applied to the repaired tendon will benefit the healing tendon further. Literature states that repaired flexor tendons that are subjected to force in the form of early active movement during the initial weeks of rehabilitation regain strength quicker than FTRs that are immobilized initially (Hitchcock, et al., 1987).

Boyer et al. (2001) later found that an increase in force applied to the FDP tendons of the forepaws of dogs from 5N to 17N did not result in an increased strength or stiffness of the repair, nor did it appear to speed up tendon healing (Boyer, et al., 2001). Studies by both Amadio (2005) and Goldfarb, Harwood, Silva, Gelberman, Amiel and Boyer (2001) performed on the forepaws of dogs agreed with the findings of Boyer et al. (2001). They found that receiving higher force rehabilitation in the first six weeks post repair did not significantly affect the biochemical composition of the repaired tendon (Goldfarb, et al., 2001; Amadio, 2005). There is thus little evidence to prove that increasing the force on a repaired tendon above that required for movement will provide accelerated results or a stronger flexor tendon (Goldfarb, et al., 2001; Amadio, 2005; Tanaka, et al., 2005).

Research conducted on the forepaws of dogs found that in the first 21 days, eight strand tendon repairs had a significantly higher ultimate force and rigidity than tendons repaired with a four strand repair. However, after 42 days there was no longer a significant difference between the two repair techniques (Boyer, et al., 2001). The results of a study by Thurman et al. (1998) performed on 12 human cadaveric hands are in accordance with those of Boyer et al. (2001). They found that the ultimate tensile strength of a two strand repair was 33.9N, a four strand repair (with epitendinous suture) was 43.0N, and that of a six strand repair was 78.7N. The difference between these groups was found to be significant (Thurman, et al., 1998).

Force is evidently a very important factor in the rehabilitation of repaired FTIs. However, whether it is more, less or as important as the role of tendon excursion in flexor tendon rehabilitation is still very much being debated in recent literature (Pettengill & Van Strien, 2011).

2.4.3 The importance of excursion

Excursion is the movement of the flexor tendon within the tendon sheath, gained by an exertion of a force higher than the gliding resistance. It has an important role in improving the quality and strength of the repaired tendon and preventing the formation of adhesions (Boyer, et al., 2001; Evans, 2012). It is thus an essential component in improving active ROM and thus overall functionality of the hand in ADLs (Amadio, 2005).

Some researchers claim that the greater the increase in excursion, the quicker the tendon will heal and the fewer adhesions will form (Strickland, 2005). Silfverskiöld and Andersson (1993) found in a study on 46 injured human fingers, that a maximum of 6-9mm of excursion was necessary to encourage tendon healing, and any more excursion than that had an insignificant effect (Silfverskiöld & Andersson, 1993). More recently Silva, Boyer and Gelberman (2002) argued that as little as 1.7- 2mm of excursion is sufficient to prevent adhesions from occurring and allow excellent recovery in a canine FDP tendon (Silva, et al., 2002). Although most early motion approaches encourage more than 2mm of tendon excursion, this is said to have no significant functional or structural benefits to the repaired tendon (Silva, et al., 1999; Boyer, et al., 2001; Evans, 2012).

An effective way of varying the amount of excursion gained by the healing tendon, is by adjusting the therapeutic approach used to rehabilitate the repaired FTI. The position of the wrist during rehabilitation can have a considerable effect on the amount of force and excursion achieved by the healing tendon (Lieber, et al., 1996). Cooney, Lin and An (1989) found that more effective excursion is achieved with the use of a SWM approach than with the use of a wrist fixation approach (Cooney, et al., 1989). This will be further discussed in detail in section 2.6. As with all surgery and therapy there is still a risk of complications, such as adhesions, which will further increase the gliding resistance of the repaired tendon (Zhao, et al., 2002b).

2.4.4 Complications Commonly Associated with Flexor Tendon Repair

When force is applied to a FTR outside the limits of the Safe Zone, it results in a problematic amount of excursion of the tendon which can lead to complications. Complications that are commonly found in repaired FTIs during the rehabilitation period cause a restriction of the normal movement of the tendon (Hill & Chan, 2013; Hsiao, et al., 2015). The complications most commonly seen in FTI literature are gapping, re-rupturing of the tendon, flexion contractures of the PIP joints and adhesions between the tendon and sheath (Kotwal & Ansari, 2012).

Complications such as gapping or re-rupture of the tendon repair are usually the result of a force being exerted on the tendon that is above the maximum limit of the safe zone (Groth, 2005). In the literature it was found that re-ruptures occurred in approximately 3-7% of repaired FTIs, irrespective of the type of suture and rehabilitation approach used (Elliot, 2007; Starr, et al., 2013). Hitchcock, Light, Bunch, Knight, Sartori, Patwardhan and Hollyfield (1987) found that gaps of 5mm or larger resulted in a FTR to be weaker, have increased oedema and be more likely to develop adhesions (Hitchcock, et al., 1987). More recent literature indicated that a gap of more than 3mm was detrimental to the ultimate force and rigidity of a tendon repair, by causing the repair to be up to 50% weaker and by delaying healing and strength of repair (Boyer, et al., 2001; Silva, et al., 2002).

Proximal interphalangeal joint flexion contractures are common after a FTR, especially in zone II where the scar runs over the volar surface of the PIP joint (Pettengill, 2005). Kitis, Buker and Kara (2009) suggest that the rate of flexion contractures of the interphalangeal (IP) joints varies between patients treated with different approaches. Their results show that there is a significantly increased rate of PIP flexion contractures in the passive finger extension group (21%), when compared to the active finger extension group (12%). Repaired FTIs that are rehabilitated with elastic traction are also more likely to acquire PIP flexion contractions, due to the PIP joint being in flexed position at rest (Kitis, et al., 2009)

A lack of tendon excursion is the result of force being applied to the healing tendon that is lower than gliding resistance (Groth, 2005). This will often result in tendon adhesions, which are caused by excessive proliferation of extrinsic cells in a healing FTI (von der Heyde & Evans, 2011). These are present to some extent in all healing tendons but participate more in the healing of tendons that have been crushed or severely injured (Tang, 2007b). Starr, Snoddy, Hammond and Seiler (2013) have found that tendon adhesions occur in about 6-9% of FTRs (Starr, et al., 2013). The rate of complications, especially adhesions, may vary depending on the zone in which the tendon injury occurred (Hill & Chan, 2013).

2.4.4.1 Zone II is 'No Man's Land'

When literature refers to Zone II or 'no man's land' this is the area between the distal palmar skin crease and the DIP joints (Hill & Chan, 2013). This zone is called no man's land because it possesses digital tendon sheaths made up of multiple pulleys, through which the FDS and FDP tendons interweave (Kotwal & Ansari, 2012; Hill & Chan, 2013). This sheath results in injuries in zone II being more difficult to repair and rehabilitate and the prognosis for these injuries is poor due to their increased likelihood of adhesion formation and PIP flexion contractures (Hill & Chan, 2013).

2.4.4.2 Addressing Complications

Once complications have developed after FTR, the majority of them will require surgical treatment such as tenolysis or tendon reconstruction (Battiston, et al., 2013). Ideally, the surgeon, therapist and patient should work together to prevent complications from occurring, rather than treating them after they have occurred (Kotwal & Ansari, 2012). They should ensure that a strong and meticulous surgical repair (Elliot, 2007) is performed and that a suitable early mobilisation rehabilitation approach is chosen and strictly adhered to by the patient (Pettengill, 2005; Baskies, et al., 2008).

2.5 Therapy Approaches Used to Rehabilitate Repaired Flexor Tendon Injuries

The success of a repaired FTI is dependent not only on the surgical repair, but more importantly on the post-operative approach used to rehabilitate the hand (Silva, et al., 2002). There are a variety of post-operative approaches available that exert varying amounts of force on the healing tendon while gaining a wide range of excursions. There is still much debate as to whether force or excursion or a combination of both is important for gaining the best results after a FTR. It is vital to have a comprehensive understanding of the effects of force and excursion on a healing flexor tendon, as well as the complications that may occur when these are not correctly balanced with the repair strength or gliding resistance.

Treatment of FTIs both surgically and therapeutically has made remarkable strides over the past several decades. Research has facilitated a better understanding of anatomy, healing and biomechanics of the flexor tendon, which has led to improvements in the available surgical techniques and therapy approaches (Baskies, et al., 2008). However there is still controversy as to which splint, hand position and mobilization approach is most effective in treating repaired FTIs (Kotwal & Ansari, 2012).

A strong cooperation between the surgeon and hand therapist is essential to ensure that the chosen surgical technique and therapy approach are compatible (Baskies, et al., 2008). Some approaches, such as the EAM approaches, should only be used when a tendon repair of four or more strands has been performed (Cannon, 1993; Zhao, et al., 2005). Other approaches including the immobilisation and EPM approaches are appropriate for FTIs repaired with as few as two strands, due to the minimal load placed on the repair in the initial 3 weeks (Clancy & Mass, 2013). Adding an epitendinous suture to a four strand repair will further increase the strength of the repair, thus allowing it to withstand higher loads (Viinikainen, et al., 2008).

The approaches used to treat repaired FTIs over the years include the immobilisation approach, the EPM approach, the EAM approach and more recently the SWM approach (Strickland, 2005; Vucekovich, et al., 2005; Clancy & Mass, 2013).

2.5.1 Immobilisation Approach

The immobilisation approach is based on preventing movement in the patient’s fingers and wrist by placing their hand in a splint. The splint usually positions the IP joints in full extension, the MP joints in flexion and the wrist in neutral or flexion (Pettengill, 2005; Baskies, et al., 2008). The patient’s hand remains immobilised for three to four weeks with possible EPM at regular therapy visits (Pettengill, 2005). For the next two to three weeks the patient continues to wear their splint day and night, except for when they are doing their hourly active and passive tendon gliding exercises (Pettengill, 2005; Baskies, et al., 2008). The splint is then discontinued at six weeks and the exercises are slowly upgraded to increase the strength and functioning of the hand (Baskies, et al., 2008).

The immobilisation approach is no longer commonly used as it has been found in many studies to be less effective than early mobilisation approaches (Hitchcock, et al., 1987; Coert, et al., 2009; Kotwal & Ansari, 2012). Hitchcock et al. (1987) highlighted some of these reasons, including that immobilisation is closely associated with decreased tenocyte activity, which slows down the intrinsic healing of the repaired tendon, and results in increased adhesions, oedema and scarring and decreased strength of the repair (Hitchcock, et al., 1987).

By day five the strength of the FTR rehabilitated with the immobilisation approach was significantly lower than the FTR treated with the early controlled motion approach. The strengths of the FTRs in the immobilisation group continued to decrease for the next 15 days, while the FTRs treated with early controlled motion continued to show a progressive increase in strength. In the immobilisation group 50% of participants had marked oedema and 33% had adhesions by day 10, whereas none of the participants in the early controlled motion group had developed adhesions or oedema by this time (Hitchcock, et al., 1987). Results presented by Gelberman Woo, Lothringer, Akeson and Amiel (1982) were in agreement of those of Hitchcock et al. (1987), in finding that FTRs exposed to early controlled motion had an ultimate load twice that of the FTRs treated with immobilisation at three weeks postoperatively (Gelberman, et al., 1982).

Furthermore the immobilisation approach is also associated with negative cerebral changes. These changes result in the patient unlearning or forgetting skills, due to the lack of input that their brain receives from their hand (Coert, et al., 2009). This can eventually result in the patient losing their premorbid fine and gross motor control of their injured hand despite adequate healing of the repaired tendon.

Despite there being disadvantages to using the immobilisation approach there are instances when it is recommended to rehabilitate a repaired FTI. These include treating patients who are unwilling or unable to follow early mobilisation approaches (Baskies, et al., 2008), such as children under the age of 10 years, patients who have cognitive impairments and patients with concurrent injuries in their hand and fingers (Vucekovich, et al., 2005; Baskies, et al., 2008; Clancy & Mass, 2013).

2.5.2 Early Controlled Motion

In most cases early controlled motion approaches are favoured above immobilisation approaches. Early controlled motion approaches are advised for patients who are motivated and can understand and be adherent to the exercise programme and the risks of not following it correctly (Baskies, et al., 2008).

Controlled mobilisation refers to any approach which includes either active or passive mobilisation of the tendon after repair. Early refers to an approach which is initiated in the first four to seven days postoperatively (Hitchcock, et al., 1987; Pettengill, 2005; Howell & Peck, 2013). Patients with FTRs that begin rehabilitation in the first week postoperatively show the lowest re-surgery rate, use the fewest resources and have a shorter rehabilitation period, when compared those treated with intermediate rehabilitation, started at one to six weeks or late rehabilitation, started more than six weeks after the FTI. These findings may have been affected by the late rehabilitation group having more concomitant fractures than the early or intermediate groups (Hsiao, et al., 2015).

Many researchers have demonstrated the positive effects of motion and tension on the healing tendon, such as having increased cellular activity and increased response strength at repair site (Hitchcock, et al., 1987; Kubota, et al., 1996; Boyer, et al., 2005; Baskies, et al., 2008). Research by Kubota, Aoki, Pruitt and Manske (1996) using biomechanical results and histologic evaluation at four weeks post repair, showed that tendons which were treated with motion and tension had a significantly higher breaking strength (8.80kgf), than those treated with only motion (6.49kgf), only tension (6.39kgf), or without motion and tension (5.13kgf) (Kubota, et al., 1996). However a more recent study by Boyer et al. (2001) disagreed with these results by showing that increasing the load does not improve the final tendon strength and motion (Boyer, et al., 2001). These findings led Evans (2012) to the conclusion that perhaps the motion rather than the load is the important factor (Evans, 2012).

Other positive effects of using early controlled mobilisation is that it encourages intrinsic healing, which decreases the risk of adhesions developing (Hitchcock, et al., 1987; Boyer, et al., 2005; Baskies, et al., 2008), it prevents stiff joints (Skirven, et al., 2011), improves tendon excursion (Boyer, et al., 2005) and is associated with a better scar formation when compared to FTRs rehabilitated with immobilisation (Baskies, et al., 2008).

There are however also concerns regarding the safety of using early controlled mobilisation. This type of rehabilitation has been found to result in more re-ruptures or gapping of the FTR, than in tendons which are rehabilitated using an immobilisation approach (Boyer, et al., 2005; Tang, 2007a).

The two main categories of early controlled motion approaches are the EAM and EPM. The difference between them lies in the way in which the movement of the finger is carried out, either by active contraction of the muscles of the injured finger (EAM), or by an external source passively moving the finger (EPM) (Clancy & Mass, 2013). These two categories are further divided into several different approaches including the Modified Kleinert's (Lister, et al., 1977), Duran (Duran & Houser, 1975), Indiana (Cannon, 1993) and Nantong (Tang, 2007a) approaches, to name a few.

2.5.2.1 Early Passive Mobilisation

Early passive mobilisation rehabilitation can be further divided into two main approaches, the first one uses the patient's unaffected hand or the therapists hand to move the injured finger into flexion as seen in the Modified Duran Approach (Duran & Houser, 1975; Strickland & Glogovac, 1980; Skirven, et al., 2011). While the second approach uses elastic traction attached to the splint to pull the injured finger/s into flexion, as recommended in the Kleinert's approach (Lister, et al., 1977; Skirven, et al., 2011). Many hand therapists use a combination of the splints and exercises from these two approaches to treat patients postoperatively (Skirven, et al., 2011).

Both of these approaches use a forearm based, dorsal blocking splint to position the wrist in slight flexion, the MCP joints in flexion and the IP joints in extension (Duran & Houser, 1975; Lister, et al., 1977; Strickland & Glogovac, 1980; Skirven, et al., 2011). This splint prevents the patient from extending more than their repair can handle, while allowing passive finger flexion (Skirven, et al., 2011). The recommended position of the wrist and finger joints within the splint varies between authors. The Kleinert's approach also includes the dynamic elastic attachment to flex the fingers (Lister, et al., 1977). As mentioned previously this dynamic aspect is known for its tendency to cause PIP flexion contractures.

Over the years many modifications have been made to these splints and their associated approaches. These include the addition of a palmar pulley to the Kleinert splint to increase DIP flexion (Clancy & Mass, 2013), lessening the degree of flexion of the wrist to improve comfort and mobility. The fingers of patients wearing the modified Kleinert splint were strapped in an extended position while they slept to prevent contractures (Skirven, et al., 2011) and the distal end of the dorsal blocking splint was shortened to the level of the PIP (May, et al., 1992). Some approaches were even adapted to include passive SWM exercises, performed by the therapist during their therapy sessions.

The exercises recommended by Duran and Houser were designed to gain between three and five millimetres of excursion, which they declared was enough to prevent adhesions after a FTR (Duran & Houser, 1975). The initial exercise recommended by this approach is passive isolated joint flexion and extension, while maintaining all other wrist and finger joints in flexion (Duran & Houser, 1975; Skirven, et al., 2011). May Silfverskiöld and Sollerman (1992) recommend that initially active finger extension, against the elastic traction, and passive finger flexion should be performed when wearing the modified Kleinert's splint (May, et al., 1992). After four weeks both approaches introduce light active flexion and extension exercises, and at about eight weeks postoperatively resisted flexion is introduced (Skirven, et al., 2011).

2.5.2.2 Early Active Mobilisation

Early active mobilisation includes any approach where the patient is required to actively contract his muscles to flex and extend his injured finger/s (Pettengill, 2005). This category also includes approaches which include place-and-hold flexion exercises or SWM exercises (Pettengill, 2005; von der Heyde, 2010).

Some EAM approaches splint the patient's hand in a dorsal blocking splint similar to that used in the EPM approaches, excluding the elastic traction (Hill & Chan, 2013). In this splint the patient performs passive flexion, and limited active flexion and extension exercises, every waking hour (Baskies, et al., 2008; Hill & Chan, 2013). Other EAM approaches are the SWM approach, where the patient then performs passive stretching exercises as well as SWM exercises (Cannon, 1993). Since the SWM approach is the focus of this study it will be reviewed in detail in Section 2.6.

2.5.2.3 Early Passive Mobilisation vs Early Active Mobilisation

Both EAM and EPM approaches have positive and negative features. These, along with the nature of the patient's injury and the repair performed should be closely considered before deciding on the most suitable approach (Evans, 2012). For example EPM can be used with patients who have had a two or more strand surgical repair (Clancy & Mass, 2013). However an EAM approach, with light active digital flexion, should only be used on patients with at least a four-strand repair with an epitendinous suture (Strickland, 1995; Strickland, 2005; Clancy & Mass, 2013). Epitendinous sutures play an important role in increasing the strength of a FTR to withstand active flexion (Cannon, 1993; Pettengill, 2005). Early active mobilisation approaches should also be reserved for patients who are motivated, adherent and have minimal to moderate amount of oedema (Clancy & Mass, 2013).

There is an ongoing debate around whether there is a significant difference between the outcomes of the EAM and EPM approaches. Some researchers state that the EPM approaches are not aggressive enough to gain good to excellent results (Tanaka, et al., 2005), while others have found that EAM approaches are too aggressive and have a higher risk of gapping or re-rupturing of the repaired tendon (Zhao, et al., 2005; Coert, et al., 2009; Kotwal & Ansari, 2012).

Chesney, Chauhan, Kattan, Farrokhyar and Thoma (2011) did a systematic review of 15 studies that used the Original Strickland System to measure ROM during rehabilitation post FTR from 1985 to 2006. They found that the EAM approach had the highest proportion of excellent and good results (94%), with the EPM approaches achieving a mean of 67- 73% of excellent and good results. The results were similar when using the Modified Strickland System to compare the outcomes (Chesney, et al., 2011). The results of a study by Baktir Türk, Kabak, Şahin, Kardaş (1996) were similar to those of Chesney et al. (2011), but statistically insignificant (Baktir, et al., 1996). Using Strickland's Original System

78% of the fingers treated with an EPM approach fell into the category of good or excellent, while in the EAM group 85% of the fingers achieved good or excellent results (Baktir, et al., 1996). One year postoperatively the grip strength in the EAM group was also significantly higher by 6% than that of the EPM group (Baktir, et al., 1996)

One of the first multicentre prospective randomised trials to compare the outcomes of EAM (specifically SWM) and EPM was carried out by Trumble Vedder, Seiler III, Hanel, Diao and Pettrone (2010) between 1996 and 2002 (Trumble, et al., 2010). Not only did the patients following the EAM protocol have significantly better active ROM of the fingers at every time interval but also significantly smaller IP contractions and increased satisfaction in their recovery. At the final therapy session it was noted that the mean combined IP joint ROM in the EAM group was 156° compared to 128° in the EPM group. There was however no significant difference in the DASH and dexterity scores (Trumble, et al., 2010).

The rate of tendon rupture was the same (4%) in both the groups following both EAM and EPM approaches (Trumble, et al., 2010). This was confirmed in a study by Baktir et al. (1996) where the rate of re-rupture was similar in the EPM and EAM groups (4.9% and 4.3% respectively), and no participants in either group required tenolysis (Baktir, et al., 1996). However in a study by Bainbridge, Robertson, Gillies and Elliot (1994) they found the rupture rate of the EAM group to be double that of the EPM (7.5% and 3.5% respectively) (Bainbridge, et al., 1994). Participants following an EAM approach returned to full duty work sooner, at 82 days on average, than those following an EPM approach, who returned to work at 103 days on average. As a result of the extended treatment period, the costs for participants who followed an EPM approach were higher, but not by a significant amount ($p=0.16$), than those who followed an EAM approach (Trumble, et al., 2010).

It is thus evident that EAM approaches commonly produce better outcomes than EPM approaches, and often without the risk of re-rupturing the FTR (Trumble, et al., 2010). The reasons for the better outcomes in patients following EAM approaches are said to be due to the increased amount of tendon excursion gained by active movement (Pettengill, 2005; Elliot, 2007). Active flexion achieves this by pulling the repaired tendon through the sheath (Pettengill, 2005) rather than attempting to push it proximally, as seen in EPM, which results in buckling of the tendon (Horii, et al., 1992). EPM approaches also do not always exert enough force to cause differential gliding between the FDS and FDP, which ultimately results in adhesion and thus poor outcomes (Kotwal & Ansari, 2012).

Another advantage that EAM approaches have over EPM approaches that utilise elastic traction, such as the Kleinert's approach, is that they yield fewer permanent contractures of the PIP and DIP joints (May, et al., 1992; Kotwal & Ansari, 2012). Finally, patients following EPM approaches have shown to have similar cerebral changes to that seen in patients treated with immobilisation. This occurs due to an absence of motor command, and thus the motor control areas of the brain are being deprived. Positron Emission Tomography imaging of patients following EPM approaches showed decreased blood flow in certain motor areas of the brain, indicating temporary motor control loss. Fortunately this can usually be reversed when a patient begins active flexion exercises and stimulates the motor areas of the brain again (Coert, et al., 2009).

Many authors have declared EAM approaches as being the most effective, and have moved away from using EPM (Bainbridge, et al., 1994; Baktir, et al., 1996; Amadio, 2005; Tang, 2007a; Clancy & Mass, 2013). Some believe that EPM approaches are on their way to being abandoned in hand therapy (Tang, 2007a). Others emphasise that immobilisation and EPM approaches have not been replaced by EAM approaches (Vucekovich, et al., 2005). It is recommended that rather than having one standard approach for all patients, it is essential that the surgeon and therapist discuss the patient's circumstances, severity of injury and the surgical repair performed prior to choosing an approach (Pettengill, 2005; Kotwal & Ansari, 2012).

2.6 Place-and-Hold Synergistic Wrist Motion

Synergist wrist motion is an EAM rehabilitation approach used to treat repaired FTIs. The benefits of this approach are that it has a good balance between the amount of force that it exerts on the repaired tendon and the amount of excursion that is gained by the tendon (Horii, et al., 1992). There are at least two different SWM approaches that can be used to rehabilitate the repaired FTI, including the force-based approach and the-excursion based approach. Unfortunately there is no available literature on the difference between these approaches and the results achieved by patients following them.

While some of these approaches have proved to be more effective than others, it is important not to rule out any approaches as certain circumstances call for a specific rehabilitation approach (Vucekovich, et al., 2005). The rehabilitation approach should be individually chosen and tailored to each patient based on their personality, age, compliance, level of understanding, surgical repair and concurrent injuries (Vucekovich, et al., 2005; Pettengill, 2005; Evans, 2012). The rehabilitation approach should be continually monitored and adjusted throughout the therapy process (Evans, 2012).

The synergistic exercise begins with active wrist extension which initiates tendon excursion at the proximal end (Zhao, et al., 2002a; Zhao, et al., 2002b; Tanaka, et al., 2005). Tendon excursion is then further encouraged by passive finger flexion, and then actively holding the fingers in a flexed position (Cannon, 1993; Tanaka, et al., 2005). Finally the wrist is flexed, which lowers the tension on the repair, and the fingers can then relax safely in an extended position (Cannon, 1993; Pettengill, 2005).

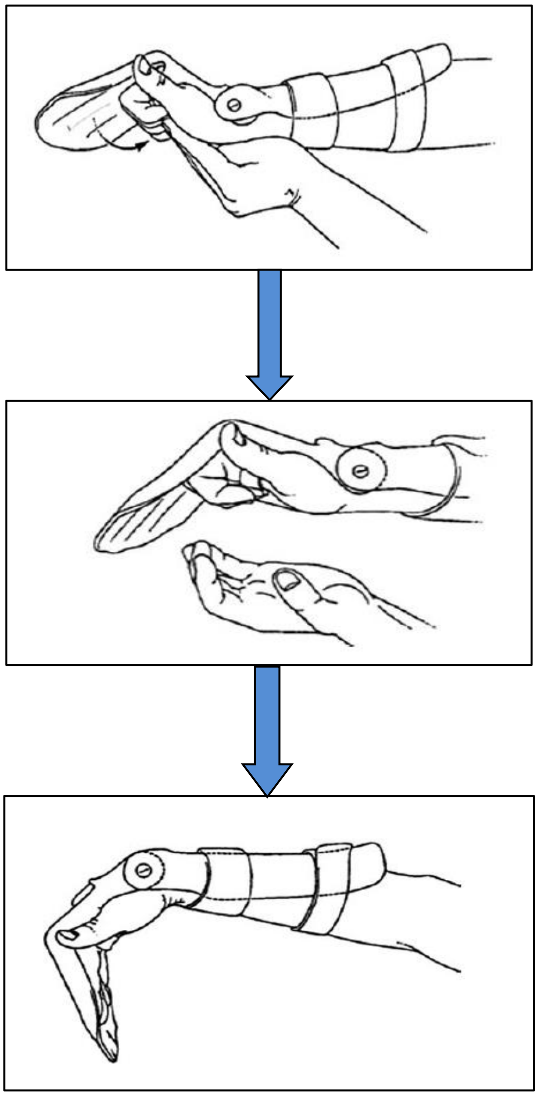

Figure 2.1 Active Place-and-hold Synergistic Wrist Motion Exercise Sequence

(Strickland, J.W. The Scientific Basis for Advances in Flexor Tendon Surgery. Journal of Hand Therapy. 2005;18:94-110)

Much of the earlier SWM research was done using passive SWM (Cooney, et al., 1989; Horii, et al., 1992), whereas more recent research encourages a place-and-hold SWM approach (Trumble, et al., 2010). The tension on the repaired tendon is altered mainly by changing the position of the wrist position. It is therefore believed that both active (place-and-hold) and passive SWM movements will yield similar tendon tension and excursion results (Zhao, et al., 2002a). Throughout the literature there are various SWM approaches, including the excursion-based approach and the force-based approach, which will be discussed in detail at a later stage.

2.6.1 The Effects of Wrist Position on Tendon Force

Research declares that during rehabilitation, a patient's wrist position has the largest effect on altering the force exerted on their FTR (Lieber, et al., 1996; Lieber, et al., 1999). The theory of SWM approach is based on the position of the wrist in relation to the fingers, and the effects of this on the force and excursion of the repaired FTI. Wrist position in flexor tendon rehabilitation has been a controversial topic for the past several decades, with approaches recommending varying wrist positions between 45°flexion and 45° extension.

Several authors have researched the effect of the position of the wrist on the amount of tension exerted on the repaired FTI (Savage, 1988; Lieber, et al., 1996; Tanaka, et al., 2005; Dennerlein, 2005; Kursa, et al., 2006). In a study on repaired canine tendons Lieber, Amiel, Kaufman, Whitney and Gelberman (1996) found that finger flexion combined with wrist extension yielded passive forces up to three times greater than a flexed wrist. There was no significant difference between the forces experienced by the tendon in the wrist flexion and the SWM groups, but both were significantly lower than the wrist extension group The results of this study may be limited as it was performed on canines, whose fore limbs have several kinematic differences to humans, specifically that the wrists of canines cannot be extended past neutral and they have extended metatarsals (Lieber, et al., 1996).

Conversely, Savage (1988) found that the lowest tension was found in participants who were splinted in 45° wrist extension and 90° MP flexion (Savage, 1988). This value was significantly lower than both the tension experienced by participants splinted with their wrist in neutral and their MP joints in 90° flexion, as well as those splinted in 45° wrist flexion and 90° of MP flexion (Savage, 1988). The findings from Kursa, Lattanza, Diao and Rempel, (2006) were similar to those of Savage in that the tension on the FDS tendon increased when the wrist was positioned in 30° of flexion, compared to when it was moved to a neutral position (Kursa, et al., 2006). Several other authors agree that the wrist should be positioned in a neutral to extended position while exercising the fingers to decrease the tension on the repair (Dennerlein, 2005; Tanaka, et al., 2005; von der Heyde, 2010; Evans, 2012). All of the studies recommending a neutral to extended wrist during finger exercises were performed on human subjects.

A positive aspect of the SWM approach is that it positions the wrist in extension for passive, place-and-hold and active exercises which minimises tension on the repair as well as the antagonist muscles (Evans & Thompson, 1993). It also allows the repaired tendon to rest with the wrist in a slightly flexed position (Cannon, 1993), which takes the tension off the repair between exercises.

2.6.1.1 Splinting to Encourage Synergistic Wrist Motion

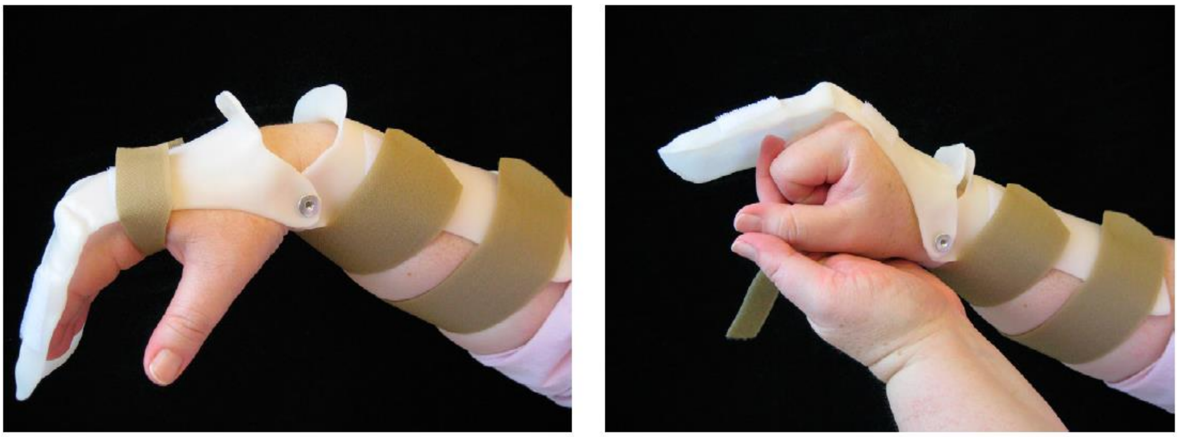

Figure 2.2 Dynamic, two-piece, dorsal, forearm based tenodesis splint illustrating synergistic wrist and finger movement
(Trumble, T.E; Vedder, N.B; Seiler, J.G; Hanel, D.P; Diao, E; Pettrone, S. Zone-II Flexor Tendon Repair: A Randomized Prospective Trial of Active Place-and-Hold Therapy Compared with Passive Motion Therapy. The Journal of Bone and Joint Surgery. 2010; 92A(6): p 1381-1389.)

Both the excursion-based and force-based SWM approaches utilise the same splint. A dynamic, two piece, dorsal, forearm based tenodesis splint that is joined at the wrist by two rivets (Cannon, 1993; Groth, 2004). This creates a hinge-like effect, which allows full wrist flexion, but it limits wrist extension to 30°, to prevent stretching the tendon past its suture breaking point. The splint allows full ROM of the IP joints, but blocks the MP joints in approximately 60° of flexion (Cannon, 1993). The flexed MP joints limit the amount of force exerted on the FTR by ensuring that the MP joints and wrist joint will at no time be simultaneously extended (Pettengill & Van Strien, 2011).

In the initial approach by Strickland and Cannon (1993), it was recommended that the tenodesis splint was only to be worn during exercise and a second static dorsal blocking splint was to be worn by the patient between exercises (Cannon, 1993; Klein, 2003). Due to confusion and risk of injury when changing the splints several times a day, it was recommended that the patient wore only one splint when exercising and resting. The dorsal blocking splint was eliminated and a rubber blocker was developed to fit between the two pieces of the tenodesis splint on the dorsal surface to maintain the wrist in a flexed position between exercise sessions (Dymarczyk, 2001; Clancy & Mass, 2013).

2.6.2 Synergistic Wrist Motion vs other Early Mobilisation Approaches

Synergistic wrist motion has been found to achieve significantly greater amounts of tendon excursion than other FTR rehabilitation approaches where the wrist position is fixed (Horii, et al., 1992; Zhao, et al., 2002a; Zhao, et al., 2002b). One of the reasons being that the wrist extension pulls the repair site through the pulley, rather than pushing it as seen in EPM (Zhao, et al., 2002b). The adjustable hinge of the SWM splint also allows the wrist position to be adjusted to gain maximal tendon excursion, while exerting a low force on the repaired tendon, as recommended by Zhao et al (Lieber, et al., 1999; Zhao, et al., 2002a).

A small research study was performed by Cooney et al. (1989) on the flexor tendons of four cadaver forearms. The findings of this study proved that an early SWM approach achieved significantly more passive excursion of the flexor tendons and differential excursion between the FDS and FDP than the Kleinert's and Brook Army Hospital splints for treatment of FTRs in zone II, III and V. In Zone II the SWM splint provided a differential excursion of 4.59 mm, whereas the Kleinert's splint had a differential excursion of 2.25 mm, and the Brook Army Hospital splint had a differential excursion of 1.93 mm (Cooney, et al., 1989). However a study by Horii, Lin, Cooney, Linscheid and An (1992) which compared the differential excursion using the same three splints found that the difference in excursion was not significant. The results of both these studies were limited by the fact that they were based on a small number of specimens - 4 and 6 respectively (Horii, et al., 1992).

Research by Zhao et al. (2002a) confirmed the findings of Cooney et al (1989) (Zhao, et al., 2002a). They demonstrated that SWM achieves higher excursion of the FDS and FDP than that achieved with the Kleinert's, the Brook Army Hospital Modification and the wrist fixation approaches (Zhao, et al., 2002b).

Silva, Brodt, Boyer, Morris, Dinopoulos, Amiel and Gelberman (1999) report that their study showed that both the SWM and the EPM wrist flexion group had similar outcomes with few adhesions and ROM similar to their controls. Their findings showed that SWM, and thus increased excursion did not achieve significantly increased tensile strength of the repair site when compared to the wrist flexion group. Their reasoning being that a minimum excursion of 1.7mm is required to gain movement and prevent adhesions after a FTR, anything more than this is not beneficial. Both the SWM and EPM wrist flexion approaches achieve this minimum excursion, and Silva et al. (1999) therefore recommend an EPM wrist flexion approach as it provides the necessary excursion with less force on the FTR (Silva, et al., 1999)

Lieber, Silva, Amiel and Gelberman (1999) compared the amount of force exerted on a tendon and the amount of excursion gained, in the rehabilitation of repaired FTIs with four different approaches (EPM approach- wrist in flexion, EPM approach- wrist in extension, SWM approach and EAM approach). The EPM (wrist flexion) measurements showed a low amount of tension on the FTR (4-8N) and also a low tendon excursion (1.5mm). The EPM (wrist extension) measurements indicated increased force (15-17N) and increased excursion (3.5mm). When the canines' forelimbs underwent SWM, less force (4N) was placed on the tendon, while gaining higher amounts of excursion (3.5mm) The EAM approach gained little excursion (1mm) with force fluctuating as the wrist was moved. The excursion was significantly higher in the SWM and wrist extension groups than the wrist flexion group (Lieber, et al., 1999) The results of the study by Zhao, Amadio, Zobitz, Momose, Couvreur and An (2002b) also showed that total excursion in the SWM group was significantly higher than the wrist fixation group at one, three and six weeks after a FTR (Zhao, et al., 2002b). The force was significantly less in the wrist flexion and SWM groups than in the wrist extension group, once again proving that SWM achieves great excursion, while exerting less force on the FTR (Lieber, et al., 1999).

Zhao et al. (2002a) reported that they experienced a significant increase in gap formation in participants who followed the SWM approach when compared to those who followed the EPM with wrist fixation approach. This was 30% and 6% gap respectively (Zhao, et al., 2002a). Other researchers noted that increased excursion (as found in the SWM approach), did not cause increased gapping or re-ruptures at the repair site, when compared to other EAM or EPM approaches (Silva, et al., 1999; Trumble, et al., 2010). This information is difficult to interpret as there are other variating factors that may contribute to gap formation or re-rupture. Using the active SWM approach on patients with FTRs of the little finger (LF), is not recommended as 75% of the re-ruptures that occurred in the SWM group in the Trumble et al. (2010) study occurred in the LF (Trumble, et al., 2010).

A study by Zhao et al. (2002a) showed that repaired FTIs treated using the SWM approach had no significant difference in adhesion grade to those treated with an EPM wrist fixation approach at one week post operatively. It was noted however, that at three and six weeks post operatively the SWM group had a significantly lower adhesion grade than the EPM wrist fixation group (Zhao, et al., 2002a). Results from several other researchers agreed with these finding in participants following the SWM approach who had fewer adhesions than participants who followed a fixed wrist approach (Silva, et al., 1999; Zhao, et al., 2002b).

2.6.3 Two common Synergistic Wrist Motion Approaches

2.6.3.1 Excursion Based Approach

The active place-and-hold mobilisation approach, also known as the 'Indiana Protocol', developed by Strickland and Cannon is an example of SWM used to treat repaired FTIs (Cannon, 1993). This is an excursion-based approach that focuses on introducing a series of exercises to the patient at specific times postoperatively (Cannon, 1993; Pettengill & Van Strien, 2011). This approach aims to decrease the tension on the FTR to the minimum and teach the patient exercises that will gain the most effective tendon excursion to minimize adhesions (Clancy & Mass, 2013). This approach is also time-based, but should be adapted by the therapist according to the needs and response of the patient (Cannon, 1993).

The effectiveness of this approach relies on a well-trained therapist and a motivated patient with a good understanding of their condition and treatment (Cannon, 1993; Cannon & Nancy, 2001). This approach is also more likely to be effective if the patient does not have wound complications or excessive finger oedema (Cannon, 1993). In order to avoid gapping or re-rupture it is advised that the excursion-based approach should only be followed by patients who have had a four or more strand FTR with an epitendinous suture (Cannon, 1993; Cannon & Nancy, 2001; Dymarczyk, 2001; Pettengill & Van Strien, 2011).

The excursion-based approach is a slightly modified version of a protocol written by Cannon (1993). For the initial four weeks, the patient follows an exercise programme comprising of passive protected digital extension as well as synergistic place-and-hold exercises, whilst wearing the splint (Cannon, 1993). Force is limited during the latter exercise by advising the patient to use minimum active force to actively hold their fingers in flexion (Pettengill & Van Strien, 2011).

From four weeks new exercises including active composite finger flexion and extension (with a neutral wrist), tendon gliding exercises and active wrist flexion and extension (with relaxed fingers) are added to the exercise programme. The splint is removed for these exercises, but worn the remainder of the time (Cannon, 1993).

At five weeks, composite wrist and finger extension exercises are added to the programme. After six weeks the splint is discontinued and the patient is encouraged to start using their injured hand for light ADLs and blocking exercises for the DIP and PIP are introduced into the exercise programme. At eight weeks gentle strengthening exercises can be started and slowly increased over the remaining four weeks as the patient gains strength (Cannon, 1993).

2.6.3.2 Force Based Approach

Groth (2004) recommends a force-based approach, which follows the Pyramid of Progressive Force Application, to rehabilitate repaired FTIs (Groth, 2004).

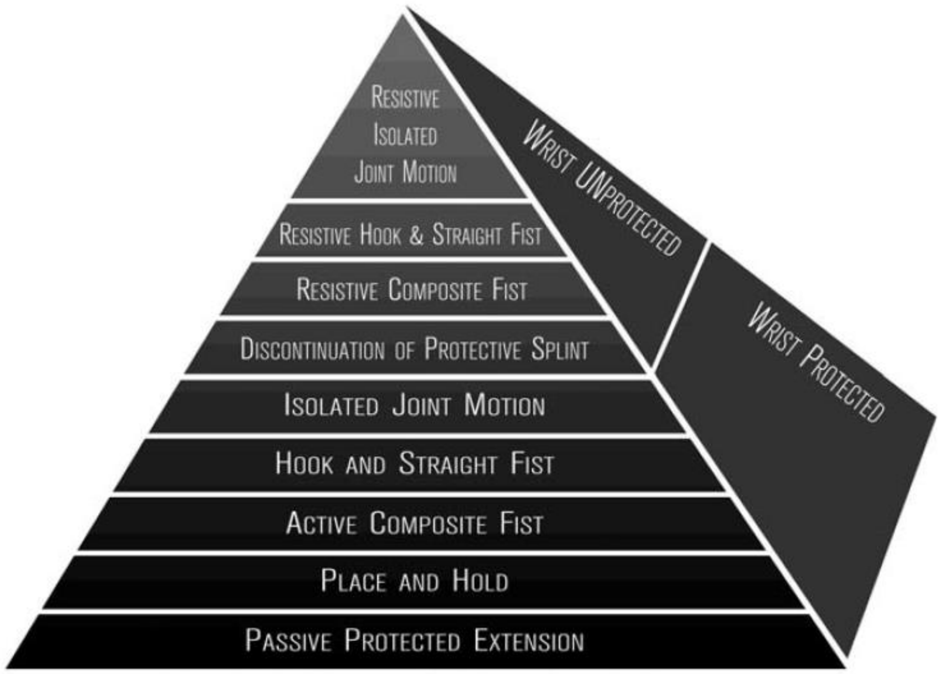

Figure 2.3 Pyramid of progressive force application
(Groth, G. Pyramid of Progressive Force Exercises to the Injured Flexor Tendon. 2004; 17: 31-42)

This approach is designed around the progressive strengthening of a FTR postoperatively, and it matches individual exercises to the appropriate stage of tendon healing (Amadio, 2005). Von der Heyde (2013) adapted Groth's Pyramid of Progressive Force Application slightly to develop a force-based approach called the Modified Pyramid Approach (von der Heyde, 2013). This approach is recommended for FTIs that have been repaired with four or more strands, and patients who are able to follow instructions well (Amadio, 2005).

Another differentiating factor between this approach and the excursion approach is that this approach is based on improvement, rather than time. It is therefore individualised for each patient to ensure that exercises with varying loads are only introduced to the patient based on their individual tissue response. If a patient has no adhesions present or their ROM is responsive from one session to the next they will continue doing the same exercises as previously If a patient's ROM is unresponsive between sessions, the next exercise in the sequence (with a higher load) will be introduced to their routine. Groth (2004) defines responsive as the resolution of active lag between sessions being greater than or equal to 10%, and unresponsive being less than or equal to 10% resolution of active lag between therapy sessions. When there is less than a 5° difference between active and passive finger flexion ROM it is evident that adhesions are absent (Groth, 2004).

Using the available literature Groth (2004) developed the Pyramid of Progressive Force Application. This is a series of eight therapeutic exercises arranged from those which exert the least internal force on the repaired FTI (at the base of the pyramid), to those which exert the most force (at the tip of the pyramid). According to Groth's pyramid, the patient should start at the base of the pyramid with passive protected digital extension and then move up through the remaining exercises as their ROM improves. The remaining seven exercises in order of ascending force exerted on the FTR are place-and-hold, active composite fist, hook and straight fist, isolated joint motion, resistive composite fist, resistive hook and straight fist and finally resistive isolated joint motion (Groth, 2004).

The force based approach adapted by Von der Heyde (2013) is as follows (von der Heyde, 2013):

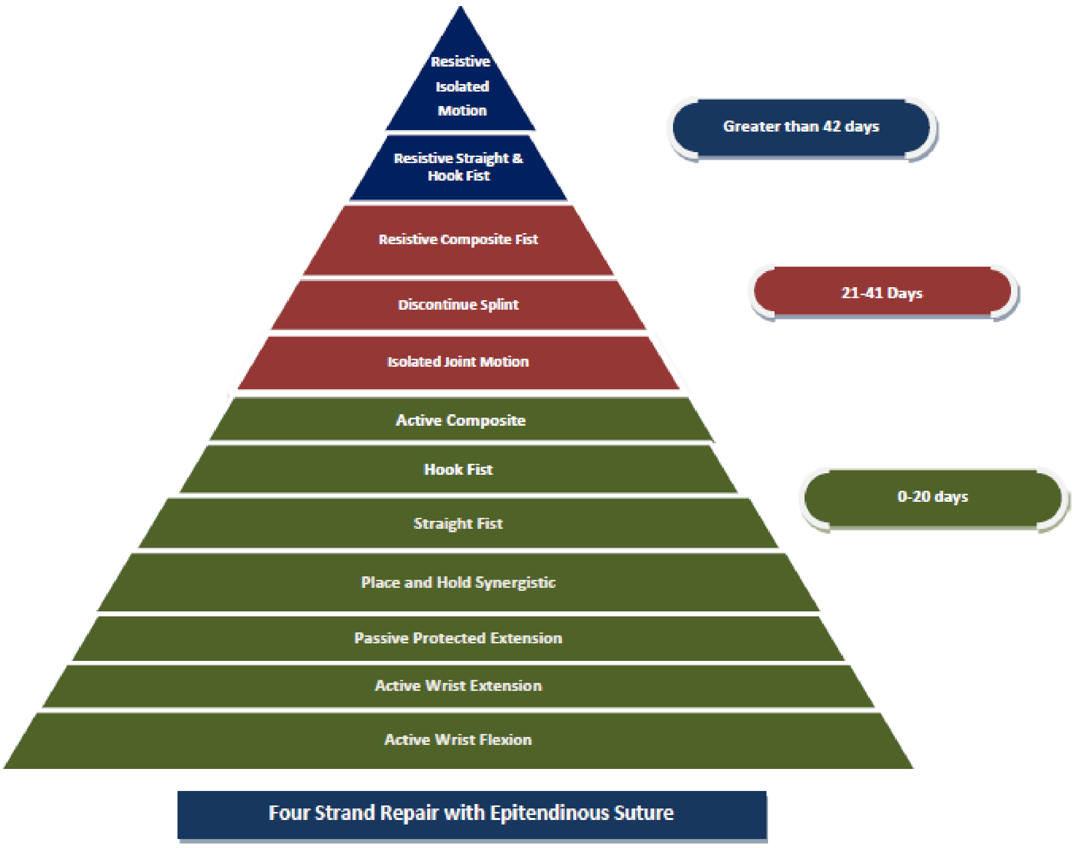

Figure 2.4 Modified pyramid of progressive forces: Safe timeline for progression
(R von der Heyde 2013, personal communication., 23 April)

At the patient's initial session, they will begin passive protected digital extension as well as synergistic place-and-hold flexion exercises (von der Heyde, 2008). This is done in the same way recommended in the excursion based approach (Cannon, 1993) and in Groth's pyramid of forces (Groth, 2004). Passive protected digital extension applies a minimal amount of force of 0.1- 3N to a healthy tendon (Schuind, et al., 1992), but it also achieves little excursion when the wrist is in flexion (Lieber, et al., 1999). This exercise is continued as long as the patient wears their splint (Groth, 2004).

At the follow-up session the patient's ROM is measured and compared to their previous ROM measurements. Depending on the responsiveness of their ROM, they will either be told to continue with the same exercises as before or a new exercise will be introduced to them (Groth, 2004). The sequence of exercises in Von der Heyde's programme continue with active straight fist, active hook fist, active composite fist, active isolated PIP flexion and finally active isolated DIP flexion. Once the patient has completed this sequence of activities, they can continue with muscle strengthening exercises (von der Heyde, 2008).

2.6.3.3. Excursion Based Approach vs Force Based Approach

Current literature states that both excursion and force have very prominent roles in the healing of a FTR (Lieber, et al., 1999). It fails to state whether excursion and force are equally as important or if one is more important in the treatment of repaired FTIs that the other (Silva, et al., 1999). It is also unknown if these two interact at all to facilitate or oppose one another in the recovery process (Lieber, et al., 1999). Further research is therefore necessary to determine whether an excursion based or a force based approach will have better overall results.

The benefits of using an approach that is based on improvement (force-based approach) over one that is based on time (excursion-based approach), has been discussed in literature (Groth, 2004). An approach that is adjusted according to an individual's healing response, or lack thereof, will account for any atypical physiological and biological tissue responses in patients (Groth, 2004; Vucekovich, et al., 2005). Individualised exercises are also said to allow a successful navigation between achieving a necessary amount of tendon excursion, while avoiding overloading the tendon (Groth, 2004). These will ultimately result in better functional outcomes (Vucekovich, et al., 2005).

2.6.4 Research Relating to Treatment of Flexor Tendon Injuries within a South African Context

There is currently no literature available in South Africa or internationally, which directly compares the outcomes of participants who followed an excursion-based approach to those who followed a force-based approach after a FTR. It is therefore not known if either of these approaches is beneficial to rehabilitate patients with repaired FTIs in developed or developing nations. Despite the lack of research on force-based and excursion-based approaches internationally, developed countries such as the United States of America has published numerous articles on studies relating to other aspects of flexor tendon repair and rehabilitation. There are however, only a handful of South African based studies that have been carried out and published on treatment of repaired FTIs over the past 30 years.

A recent study by Spark, Ntsiea and Godlwana (2015) at Chris Hani Baragwanath Academic Hospital in Johannesburg, South Africa, was found to have a similar percentage of good, fair and poor results for ROM measured one, three and six months after a FTR. It was noted that 83% of the participants experienced postoperative complications with 22% having to undergo further surgery. It was concluded that despite achieving some good results, there was a large variation in the outcomes and a very high number of complications. Both of these factors are unlike the consistent good and excellent results reported in similar studies in more developed countries (Spark, et al., 2015).

An old article by Singer and Maloon (1988) compared the flexion and extension deficits noted in a study carried out in Cape Town, South Africa with those obtained by Lister et al. (1977) in Louisville, United States of America (Lister, et al., 1977; Singer & Maloon, 1988). It was emphasised that it was difficult to compare these results due to the many uncontrolled variables in these two studies. The study carried out in Cape Town experienced a larger number of associated injuries, a lower level of participant adherence and higher number of fingers injured per participant, when compared to the similar study performed by

Lister et al. (1988) (Singer & Maloon, 1988). Severity of FTIs and non-adherence to attending therapy visits and carrying out home programmes are current problems that therapists believe are prevalent and are negatively affecting their patients' outcomes (Mncube & Puckree, 2014).

It was also noted that the surgeons performing the tendon repair surgery in Cape Town operated unassisted and had limited experience in hand surgery (Singer & Maloon, 1988). Mncube and Puckree (2014) also noted that 16% of the therapists who completed their questionnaire on treatment of FTIs had less than one year of clinical experience (Mncube & Puckree, 2014). Tang (2013) believes inexperienced surgeons performing FTRs is the main cause of severe adhesions (Tang, 2013). Due to a lack of experienced professionals, surgeons and therapists in public hospitals in South Africa are expected to handle patients despite not having adequate experience and/or training (Mncube & Puckree, 2014). All these factors lead towards a poor prognosis and ultimately contributed to participants achieving poorer outcomes than participants who received similar surgeries in Louisville.

Despite the study by Singer and Maloon (1988) being over 25 years old, therapists treating repaired FTIs in public hospitals in South Africa are still experiencing many difficulties mentioned in this study (Singer & Maloon, 1988). Mncube and Puckree (2014) reported that prior to their study, there was minimal research into the perspectives of therapists treating FTIs in public hospitals in South Africa (Mncube & Puckree, 2014). A questionnaire distributed to occupational and physiotherapists working in public hospitals in South Africa showed that regional hospitals used mainly the immobilisation approach, while the majority of therapists treating in rural clinics did not have access to clinical guidelines or protocols to guide their treatment of FTIs. The results showed an abnormally wide range in the results obtained from the questionnaire in areas such as initiation of therapy, initiation of active movement, number of therapy visits per week and initiation of resistance. The results also showed that half of the therapists felt unsure about the best therapy programme to administer to their patients (Mncube & Puckree, 2014).

The lack of published South African literature and inconsistent results relating to flexor tendon rehabilitation, indicate that there is a definite need for further research on this topic to be carried out and published in South African.

2.7 Summary

Over the past four decades there has been many changes in the way that FTIs have been treated, both surgically and therapeutically. The presence of adhesions in the immobilized tendon and re-ruptures in the unrestrained FTR, lead to the development of EAM approaches Statistics show that over 80% of patients with repaired FTIs gain normal motion of their injured hand within three months, when treated with EAM approaches post FTR (Amadio, 2005). Researchers have studied and continue to study various EAM approaches to determine which components lead to a more successful outcome, however “the mechanism by which mobilisation facilitates the recovery of digital function is not completely understood” (Lieber, et al., 1999, p. 1).

There is ongoing debate as to whether force or excursion are the most important aspects in flexor tendon rehabilitation, or whether they work together to obtain optimal results. Despite there being much research in this area of treatment, there is unfortunately insufficient evidence to ascertain which is more beneficial to tendon healing and restoring the patient’s independence in ADLs (Lieber, et al., 1999). Studies show that tendon approaches that incorporate increased amount of excursion with lower amounts of tendon load gain optimal end results (Zhao, et al., 2002a).

Synergistic wrist motion is an approach based on the concept of rehabilitating a repaired FTI using decreased tendon load and increased tendon excursion. Literature shows that both passive and active SWM approaches have proved to be very effective (Cooney, et al., 1989; Zhao, et al., 2002b; Trumble, et al., 2010). There is however, no literature in either South Africa or internationally that compared a SWM approach that follows a force-based exercise programme to one that follows an excursion-based exercise programme.

The current research articles that relate to rehabilitating repaired FTIs using SWM approaches cannot easily be compared to each other. The reason being that there are many variables around the nature of the FTI, including the zone of injury, hand dominance, number of fingers injured, whether or not the digital nerve was injured or there were any comorbid injuries (Libberecht, et al., 2006). There are also a variety of tools and techniques used to measure ROM and other outcomes in each article, resulting in data for these outcomes being reported in the literature in a non-uniform way (Chesney, et al., 2011).

As occupational therapists, our main aim is to assist a patient to gain the maximal amount of independence in carrying out their ADLs. This will improve their quality of life, which is the ultimate goal of occupational therapy. In order to achieve this in relation to rehabilitating repaired FTIs, the necessary research must be done to determine which factors lead to the most successful results in a South African context. It was therefore agreed that research should be carried out under controlled conditions in a public hospital in South Africa to determine the differences, if any, in various outcomes between patients with repaired FTIs who were treated with a force-based approach and those who were treated with an excursion-based approach.

CHAPTER 3- METHODOLOGY

3.1 Research Design

The study was based on an experimental prospective, comparative longitudinal intervention research design, to determine and compare the effectiveness of two groups of participants, who were treated with two different rehabilitation approaches recommended for treating repaired flexors tendons in zone II-III. Experimental designs are significant in that they are made up of two groups of participants who are randomly assigned to each of these groups (Kielhofner, 2006). These designs also test the possible effects of various interventions on the outcomes between two groups (Kielhofner, 2006). A comparative study is one in which two or more treatment groups are compared, to determine if there is a difference in the effect of the intervention (Kielhofner, 2006).

The two approaches used in the treatment of the groups were an excursion-based approach known as the 'Active Place-and-hold Mobilisation' approach and a force-based approach known as the 'Modified Pyramid' approach. These approaches were similar in that they used the same tenodesis splint, mentioned previously, and included an element of active place-and-hold exercises. The approaches differed in that one was excursion and time based, while the other was force and improvement based. There was no control group present in this study, only two intervention groups.

Prospective studies are those that measure variables once or several times in the future (Kielhofner, 2006). These are said to be more valid than retrospective studies as the necessary training and preparation can be done prior to carrying out measurements and variables that may affect them can be controlled (Kielhofner, 2006). This study followed a quantitative methodology using varying objective and subjective outcome measures. The objective measures included a ROM measured using a goniometer over the 12 week intervention period. The subjective outcomes reported by the participants based on the DASH questionnaire was used as a pre-test-post-test to determine the change in upper limb function between the first and the final treatment session (Solway, et al., 2002; Kielhofner, 2006). A participant satisfaction questionnaire was used at the final treatment session to record the participant's opinions about their therapy. All assessments were recorded numerically.

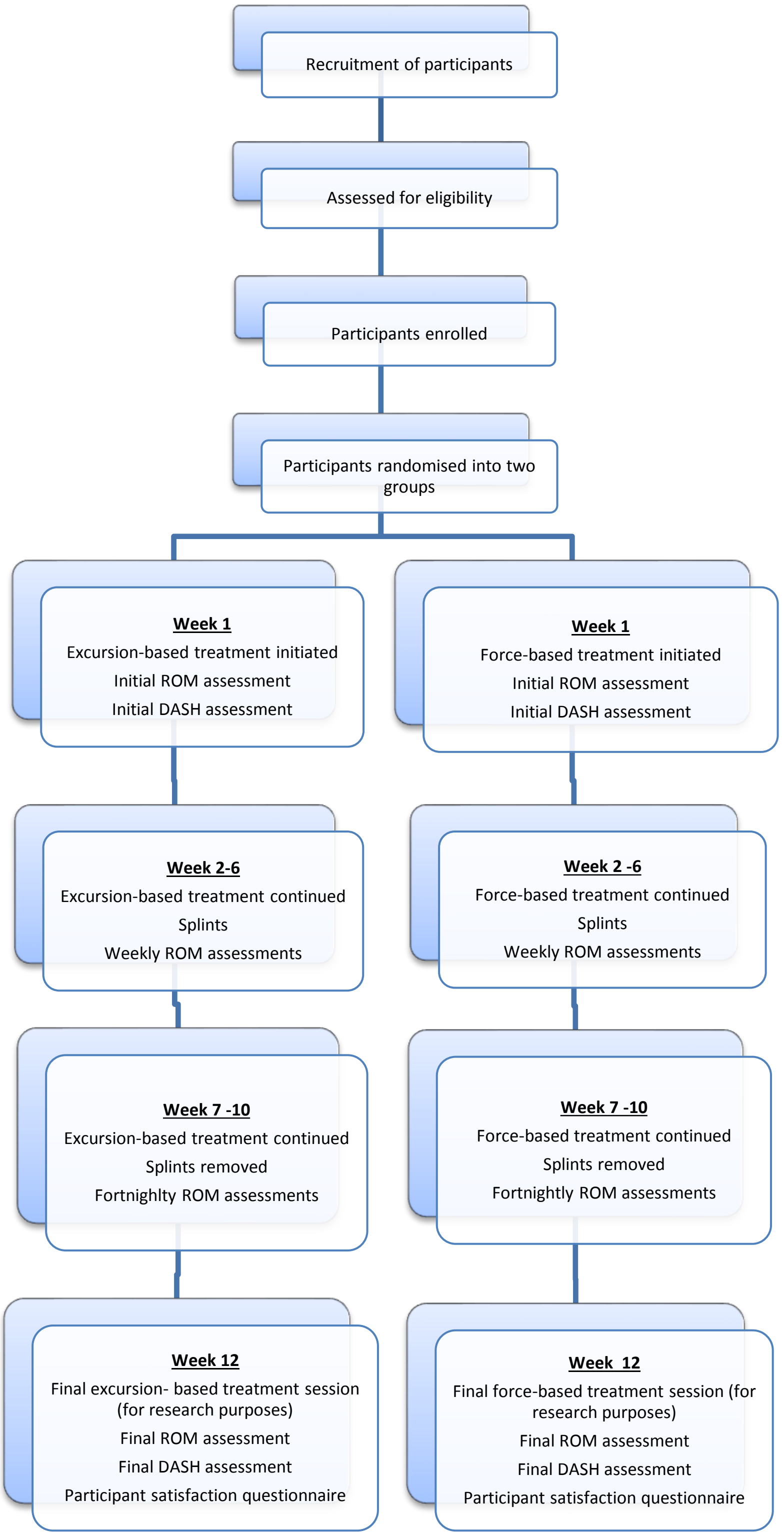

Figure 3.1 Outline of the study design

3.2 Population and Sampling

The population chosen for this research study were all patients with repaired FTIs who were treated in an East Rand public hospital in Gauteng, South Africa. A total population purposive sampling technique was used and the population included any patient who attended the hands clinic at TMH and fitted the inclusion and exclusion criteria. All the patients recruited into this study were dependent on the public health service for their care and came from similar backgrounds in terms of socio-economic status and culture.

All patients that fitted the inclusion and exclusion criteria, and were referred to occupational therapy at TMH, were included in the study.

3.2.1 Inclusion Criteria

All participants had to comply with the following inclusion criteria:

- Both male and female patients between the ages of 18 and 80 years.
- Patients who had received a FTR in zone II or III.
- Patients with a repaired complete laceration or partial laceration of more than 50%.
- Flexor tendon injuries of an individual finger or multiple fingers, on only one hand.
- Patients who had received a four or more strand FTR at TMH.
- The patient was able to attend weekly follow ups for the initial 6 weeks and fortnightly follow ups for the following six weeks.
- Patients who received a surgical FTR within the first 10 days after their injury.
- Patients who were referred to OT prior to surgery or within the first 6 post-operative days.

3.2.2 Exclusion Criteria

Any participants with one or more of the following criteria, were excluded from the study:

- Patients with comorbid injuries or previous conditions which resulted in decreased ROM in the fingers.

- Patients with bilateral FTIs or FTIs of the thumb.
- Patients with FTIs of the finger in zone I, IV or V
- Any FTR that was performed in casualty.
- A re-repair of the tendon after it has ruptured.

3.2.3 Sample Size

A power analysis was done on a similar study comparing two FTR rehabilitation approaches by Trumble et al. (2010) and a 21^0 difference in flexion (SD±19) was found. If a power of 80% is used then a sample of 13 fingers in each group is required to determine a difference between the two groups with significance set at an alpha of 0.05 (Trumble, et al., 2010). It was therefore initially planned to get a sample size of approximately 12 to 15 patients in a period of one year. It was estimated that 50% or more of these patients would have multiple fingers affected by FTI, which would results in the required 26 injured fingers.

Patient records were reviewed for a three year period prior to the initiation of the research. These showed that an average of 18.33 patients with FTIs in zone II and III were treated in the occupational therapy department at TMH each year. This was more than the required sample size of 12 to 15 patients in a one year period. The available patient records indicated the diagnosis of the patients previously treated at TMH, but did not give specific details around whether or not each of these patients would have met the inclusion criteria for this study.

Previous research showed that it would be more effective to assess individual fingers rather than patients as a whole, as the results of the individual fingers on the same hand may differ in ROM. It was decided that new participants would be continually introduced to the research study until the desired number of 26 fingers was reached or until one year of data collection had passed, whichever was reached first. Due to a lack of appropriate patients, fitting the inclusion criteria, after a period of one year of data collection, the total sample size was 5 participants, with a total of 10 fingers who fitted the inclusion criteria.

3.3 Ethical Considerations

The data collection aspect of this research was only started after the Wits Human Research Ethics Committee had provided ethical clearance to proceed with this study (M130941) (Appendix A). The CEO of TMH, Dr Christoforou, also signed a letter of permission to allow this research to be carried out at TMH (Appendix B).

The ethical principles were addressed by providing the patients with a detailed verbal explanation of what the research study entailed as well as a written Client Information Sheet which summarised the details of the study (Appendix C). The possible risks and benefits were explained to the participants and they were given the opportunity to ask questions about the study and discuss any concerns that they had. The participants were advised that their participation was voluntary and those that decided to participate in the study, were required to sign an informed consent form (Appendix D).

The patients were informed that they may withdraw from the study at any time during their 12 week treatment without any consequence to their treatment. All patient information was and still is kept confidential and safely stored in a locked cupboard. Confidentiality was ensured by labelling the patient's research information with only a patient code, while the name-code correlation list was kept at a different secure location by the researcher. The patients were also informed that they were entitled to feedback on their results on request.

3.4 Measurement Techniques

The measurements used in this study included personal and medical information, gained by interviewing the participants and doctors and viewing the hospital files, ROM measurements, the standardised DASH questionnaire as well as the participant satisfaction questionnaire.

3.4.1 Personal Demographic and Medical Information

After the participant agreed to take part in the study, the researcher documented their personal demographic and medical information on a questionnaire designed by the researcher (Appendix E). This was done by interviewing the participants to gain information on their personal demographics and the nature of their injury. Medical information was obtained by interviewing their treating orthopaedic surgeons and by reading the participant's hospital file to gain an overall understanding of the nature of their injury as well as of the treatment that they have received between being admitted to the hospital and being referred to occupational therapy.

The personal demographic and medical information form was updated regularly throughout the study to monitor any changes in the participants' conditions and to document whether the participants developed any complications throughout the course of their treatment. The information on this form was collected so that an analysis could be done to determine if there are any correlations between the participants' outcomes and their personal and medical information.

3.4.2 Range of Motion Measurement

Research shows that ROM, specifically combined active PIP and DIP flexion, is an important outcome measure, as it is a significant determinant of recovery after a FTR (Strickland & Glogovac, 1980). Passive, place-and-hold and active ROM of the MP, PIP and DIP joints of the affected finger/s was measured in flexion and extension at every session by the researcher (Appendix F), using a finger goniometer. For the initial three weeks, only passive and place-and-hold ROM were measured but from four weeks onwards passive, place-and-hold and active ROM were measured.

All joints were measured using the same standard North Coast metal finger goniometer. As advised by Libberecht, Lafaire and Van Hee (2006) each joint was measured with the remaining finger, hand and arm joints in a neutral position (Libberecht, et al., 2006). For example the MP joint was measured in maximum flexion and extension while the DIP, PIP and wrist joints were in a neutral position.

The same researcher performed the ROM measurements at all sessions. Once the flexion and extension ROM measurements were collected for each joint of each injured finger they were scored using the SG formula below (Strickland & Glogovac, 1980). The SG score obtained from this formula made it easier to analyse the data and compare the results of the participants in the two groups.

$$\frac{\text{PIP flexion + DIP flexion – extension lag}}{175^{\circ}} \times 100 = \text{\% of normal PIP and DIP motion}$$

(Strickland & Glogovac, 1980)

The SG score obtained from this formula was then classified according to Strickland's Original Classification below:

Excellent is 85-100%	Good is 70-84%
Fair is 50-69%	Poor is 0-50%

The results obtained from this calculation indicate the percentage of normal ROM of the participants' PIP and DIP joints of the finger. This shows the success of the approaches in improving ROM of the participants' fingers over the weeks of treatment when compared to the 175^0 accepted as the average range for the unaffected fingers. This measure has been found to correlate well with the Total Active Movement (TAM) reported in a number of studies on the outcomes of FTR rehabilitation (Libberecht, et al., 2006). The MP ROM measurements are not included in the SG formula and therefore these measurements were analysed separately.

3.4.3 Disabilities of the Hand, Shoulder and Arm Questionnaire

The participants' ability to use their upper limb functionally in ADLs such as cooking dinner, carrying a shopping bag or playing basketball was assessed by allowing them to complete the DASH Questionnaire, in either South African English or Afrikaans (Appendix G). All participants in this study chose to complete the South African English questionnaire. The DASH questionnaire is an instrument designed to quantify symptoms and physical disability in individuals with upper limb injuries and conditions (Solway, et al., 2002).

The self-report questionnaire was designed in a way that it is appropriate for a heterogeneous population, in terms of race, age, injury, gender, demands on upper limb and socioeconomic status (SES) (Solway, et al., 2002).

The first section is a 30 item-questionnaire where respondents are required to report on their ability to carry out general ADLs, over the past week, in a variety of areas. It also enquires about the participant's pain management and ability to sleep during the past week (Solway, et al., 2002; Trumble, et al., 2010). In addition, there are two optional four-item questionnaires which assess the individual's ability to participate in premorbid work activities and premorbid activities related to sports/playing musical instruments (Solway, et al., 2002).

Participants were instructed to only complete the second and third sections if they were employed at the time of their injury or playing a musical instrument/ participating in sport activities premorbidly.

The DASH requires individuals to rate their ability to perform an activity on a five point scale that ranges from no difficulty experienced (1) to unable to do the activity (5). The sum of the scores is then inserted into the calculation below:

$$\text{DASH disability/symptom score} = \left[\left(\frac{\text{sum of n responses}}{n}\right) - 1\right] \times 25$$

(Where n is equal to the number of completed responses)

This equation is taken from the DASH scoring manual and the higher the final score, the greater the degree of disability (Solway, et al., 2002)

The same equation above is used to calculate the final scores for the second and third sections. In order for the final score to be valid, a minimum of 27 of the 30 items must be completed for the first section and all items in both the second and third sections must be completed (Solway, et al., 2002).

Research by Beaton, Katz, Fossel, Wright, Tarasuk and Bombardier (2001) has found that the DASH correlates well with two joint-specific measures, the Brigham questionnaire for patients with wrist and hand conditions and the Shoulder Pain and Disability Index (r>0.90-0.95). The DASH also has also proved to have good construct validity, test-retest reliability (ICC=0.96) and responsiveness to change (SRM, 0.74-0.80) in the assessment of individuals with both proximal and distal upper limb injuries (Beaton, et al., 2001). The DASH questionnaire has been reported as a measure that can be successfully used in South Africa to assess upper limb function and has been translated into Afrikaans (De Klerk, et al., 2015).

3.4.4 Participant Satisfaction Questionnaire

Returning to a life where individuals are independent in their ADLs and satisfied with the way that they are able to do them is the ultimate goal of an occupational therapist. It is therefore important to include a participant satisfaction questionnaire as one of the outcomes in this study (Appendix H) (Trumble, et al., 2010). This assessment provides essential information on the participants' overall recovery, and how this compares to their expectations. Chesney et al (2011) found that despite being very useful these types of assessments are seldom included in research relating to treatment of upper limb injuries (Chesney, et al., 2011).

The Participant Satisfaction Questionnaire was developed by the researcher and contains five questions that examine the participants' satisfaction with their surgery, therapy, hand's appearance, functionality as well as their satisfaction with their ability to continue with ADLs. A rating scale of 1 to 5 was used to rate satisfaction with the above mentioned aspects where 1 is 'very satisfied', 3 is 'undecided' and 5 is 'very dissatisfied'. The participants were given the opportunity to add written comments at the end of the questionnaire if they wanted to elaborate on any of their answers.

3.4.4.1 Pilot study

The participant satisfaction questionnaire was piloted by allowing it to be reviewed by six experienced hand therapists and six patients that are currently attending TMH for hand therapy. They were asked to comment on aspects of the questionnaire including relevance, clarity, simplicity and ambiguity. Some adjustments were then made to the questionnaire based on comments and recommendations received from the therapists and patients.

The changes included altering medical jargon to more basic wording and adjusting the questions so that they were not repeated using different words.

3.5 Research Procedure

Once permission had been received from all the relevant authorities, the research was discussed with all the orthopaedic surgeons at TMH during a weekly team meeting. The aims and methodology of the study were presented to them. They were requested to refer all patients with FTIs to the occupational therapy department on admission to the hospital rather than only post-operatively, to be assessed by the researcher. However, this did not happen in all cases.

The patients were referred to occupational therapy either prior to their FTR or within the first six days postoperatively. After the patients were referred to occupational therapy the researcher reviewed their hospital file and discussed the case with their treating surgeon. Any patient who did not fit the inclusion criteria was not recruited into the study. Those patients who met the inclusion criteria were briefed verbally and presented with a written information sheet to explain the nature and purpose of this research study. Those who agreed to participate in the research were required to sign a written consent form. Any patients who did not agree to participate in the study were excluded from the study and received treatment in the occupational therapy using the standard FTR treatment techniques and approaches provided as routine care at TMH.

The patients who agreed to participate in the study were then randomly allocated to one of the two intervention groups, by the researcher, using a random numbers table. This was done by allowing the patient to choose a sealed envelope containing a card with a number on it. The cards had been prepared prior to the study with the use of a random number table, and the number on the card indicated the specific group to which the patient was allocated. The patient was then registered as a participant in the study and the researcher, with the help of the participant and their medical records, completed a form with all their personal demographics and medical information.

This was a non-blinded study as the researcher was the therapist who carried out the intervention approaches so the research was not blinded as to which group patients were assigned. The researcher was familiar with making this splint and carrying out both of these rehabilitation approaches as they had been used at TMH in treatment of FTIs for six months prior to the commencement of this research

3.5.1 Research Assistants

Two occupational therapists who worked in the occupational therapy department with the researcher were research assistants in the study. They were blinded as to which intervention the participants were receiving and measured the participants' ROM on three occasions to validate the measures taken by the researcher for all participants at the week one, six and 12 treatment sessions.

The research assistants were briefly trained in the use of the specific finger goniometer used in the assessment of the fingers in this study. A refresher tutorial was done with both research assistants to ensure that they were competent in measuring passive, place-and-hold and active ROM of the fingers. Both therapists had learnt to measure ROM as part of their undergraduate training, but did not yet have experience in measuring finger ROM on an injured hand. The researcher briefed both the research assistants on the aims and methodology of the study. They were also informed that in order to remain blinded they were not allowed to look at the participants' treatment notes or know to which group each participant had been allocated.

3.5.2 Data Collection

Treatment was started with each participant following the rehabilitation approach that was indicated on their chosen allocation card, between three and six days postoperatively. The excursion-based approach followed a specific time schedule, which guided the introduction of the next exercise in the programme to the participants at specific times postoperatively (Appendix I). The force-based approach guided the participants' progression through the exercises programme, based on their improvement in ROM (Appendix J).

Prior to the participant's first treatment session, the researcher read through the participant's hospital file, interviewed their treating surgeon and interviewed the participant, to gain information on their medical history, the nature of the injury and the surgical treatment received. At the initial treatment session the researcher and participant completed the personal demographic questionnaire together. An outcomes measure summary sheet was then allocated to each participant (Appendix K), where all data relating to their ROM, satisfaction, and DASH scores was summarized.

The participants' ROM was measured and recorded by the researcher at every therapy session. Passive and place-and-hold ROM was measured for the first three weeks after which active range of finger flexion was also measured. The PIP and DIP ROM results were then calculated using the SG formula in order to be presented in the results.

The participants were required to complete the DASH questionnaire (with assistance, if necessary) at their initial post-operative occupational therapy session. They were then asked to complete both the DASH questionnaire again and the participant satisfaction questionnaire during their final therapy session, 12 weeks post-operatively. The participants could choose to complete the DASH questionnaire in either South African English or Afrikaans.

The information gained from the DASH questionnaire was scored using the DASH manual, as this is a standardised test. The researcher had planned for all the participants to complete the participant satisfaction questionnaire independently and hand the completed copy back in a sealed envelope. This however was not possible as many of the participants had questions and wanted clarification on items throughout the questionnaire and thus the researcher was somewhat involved in the completion of this questionnaire. The participant satisfaction questionnaire was analysed by the researcher.

The data was reviewed by the researcher throughout the study to determine if the treatment approaches were causing the participants to have any adverse effects. Adverse effects such as splint induced discomfort, increased levels of pain or complications would have had a negative effect on the participants' adherence as well as their likeliness to continue attending therapy. Although the data was reviewed throughout the trial, no interim analysis was done during the course of the study.

The same custom-made splint was made for all participants for both approaches when intervention commenced. The splint is classified as a dynamic, dorsal, forearm-based, two-piece, wrist splint. This specific splint was chosen as it prevents the participants from extending their wrist, hand and fingers simultaneously, which would have put them at risk for a tendon re-rupture. Another benefit of the splint is that the participants are able to perform their exercises within the constraints of the splint by removing the Velcro from the volar surface of the hand.

The participants attended occupational therapy for a one hour session once a week for the first six weeks post operatively, and then for a one hour session, once every two weeks from six to 12 weeks. They were contacted the day before their appointment to be reminded of the date and time of their appointment. If they missed their appointment they were contacted on the same day to schedule a new appointment for hand therapy. Participants were reimbursed for their travel expenses, for the duration of the study.

3.5.3 Control of Variables

All the splints were designed, made and adjusted by the researcher and thus were standardised. All treatment and assessments were also done by the researcher which once again standardised these aspects of the study. This was beneficial as it ensured that all participants received the same instructions, answers to their questions and techniques used in assessment and treatment.

Two research assistants were incorporated into the study to gain a second ROM measurement of the participants at week one, six and 12 to ensure that the measurements done by the researcher were not biased.

Written home programmes, with detailed pictures of the exercises, were provided to all participants in the excursion-based (Appendix L) and the force-based groups (Appendix M). This acted as a reminder to participants who may have forgotten or didn't fully understand the verbal information given to them during their treatment session.

It is often the case in public hospitals that patients are unable to afford to pay for the transport to get to the hospital for their treatment sessions and missed therapy sessions have a negative impact on their recovery process. In order to control the variable of affordability of transport costs, the participants were refunded the cost of their transport to get to the hospital after every session.

3.6 Home Programme

The researcher compiled detailed home programmes, which were given to the participants at every treatment session that they attended. The information making up the excursion-based and force-based home programmes was taken from the treatment approaches as explained by Cannon (1993) and von der Heyde (2008; 2013) respectively (Cannon, 1993; von der Heyde, 2008; von der Heyde, 2013).

The home programmes were explained to the participants verbally with physical demonstration of aspects such as exercises and scar massage during their treatment sessions. The participants were then given the opportunity to ask questions and carry out their home programme in front of the researcher so that any necessary corrections and clarifications could be made prior to the participant leaving the hospital. The participants were then given a very detailed written programme at every session to take home with them. This included pictures and writing to remind the participant of the home programme after they left the hospital. The programmes were written in English.

The majority of the contents of both home programmes were very similar. Both included general precautions to remind the participant of the severity of their condition and the reality of their tendon re-rupturing with ease. A very detailed oedema management and wound care explanation was included in the home programme, along with the provision of the necessary wound care products. As soon as the wound had healed, the scar management techniques were introduced to the home programme and the participant was given pressure garments, silicone gel and taught to carry out scar massage. The participant was issued their splint at the initial session and thus from the first session the splint wearing routine as well as splint care was included in the home programme.

Although the exercises are similar for both the excursion-based and force-based home programmes, the nature in which they were carried out differed slightly. Both approaches required the participants to initially carry out very specific passive stretching and place-and-hold exercises, which were followed at a later stage by active exercises of the fingers and wrist. The home programmes were very detailed, explaining exactly how many repetitions and times each exercise should be done per day and in which position the hand and fingers should be when exercising each joint.

The approaches, and their related home programmes, differed in that the excursion-based home programme introduced certain exercises and activities to participants at specific dates post-operatively. The force-based home programme however was dependent on the participant’s improvement, or lack thereof, rather than the number of post-operative days. Participants in the force-based approach group were taught the initial exercises during the first session, similar to those in the excursion-based group. The following exercise in the series was however only introduced to the participant when it was noticed that there had been no improvement in his finger ROM from the previous session to the current session.

3.7 Data Analysis

Descriptive statistics in the form of frequencies were used to analyse the demographic and medical data.

The data of participants who did not attend occupational therapy as required, or who did not adhere to their home exercises programme as explained were analysed and an intention to treat analysis was performed. Missing data was excluded.

The ROM data was all analysed based on the SG scores. Within group changes were analysed based on the visual interpretation of the change in ROM for passive, place and hold and active range over a 12 week period.

The between group differences considered the median change in ROM over the intervention period. The groups were compared at the initial assessment to determine if the ROM was comparable using a chi-squared tests since the sample was small and the data was not normally distributed.

The statistical significance between the two intervention groups was determined by using the nonparametric Mann Whitney U Test as the data was not normally distributed. To determine clinical significance, confidence intervals and effect sizes using Cohen's r were calculated for the median change between the two groups. Data was represented visually over the 12 week period for visual interpretation.

The change in DASH median scores for all three sections of the DASH questionnaire were compared using Fishers exact tests due to the ordinal nature of the data and small sample size. To determine clinical significance, confidence intervals and effect sizes were calculated for the median change between the two groups.

The participant questionnaire was analysed using the raw data and the difference in satisfaction between the two groups was determined using a Fisher's exact test due to the small participant numbers in the groups.

Statistical V12 was used to analyse the data.

3.8 Conclusion

The planning of this research study was based on recommendations from various studies in the literature, many of which were carried out in more developed counties with better resources. These recommendations included the types of approaches, splints and outcomes used as well as the inclusion and exclusion criteria. There were however several adaptations made to the international recommendations to ensure that this study was appropriate to a South African population. These included carrying out a pilot study of the client satisfaction questionnaire on South African patients and occupational therapists, subsidising the patient's travel expenses, providing the patients with home programmes made up of pictures and simple written instructions and using a DASH questionnaire that had been adapted to a South African context.

These recommendations and adaptations allowed the researcher to get the most accurate understanding of the effectiveness of introducing SWM into the treatment of repaired FTIs in public hospitals in a South African context. It also allowed the researcher to get a better understanding of the effects that the force-based approach and the excursion-based approach had on a patient's ROM, independence in ADLs and satisfaction.

CHAPTER 4 - RESULTS

4.1 Introduction

The results of this study are presented under demographics, medical history and outcomes of participants in the areas of ROM, DASH and participant satisfaction. The total size sample for this study was five participants, with a total of 10 injured fingers. The participants were randomly divided into two groups, resulting in there being three fingers (30%) in the force-based group and seven fingers (70%) in the excursion-based group. Some results in this chapter are therefore based on the number of participants (n=5), and others such as the ROM measurements and nature of the injury are based on the number of fingers (n=10).

Due to a lack of participants who fitted the inclusion criteria in the allocated time period, it was not possible to recruit the desired number of 13 fingers in each group. At the conclusion of the 12 week treatment programme only one participant, with one injured finger, had been non-adherent to completing the full therapy programme. There was thus a dropout rate of 10% of the injured fingers and 20% of the participants participating in the study.

4.2 Demographics and Medical history

4.2.1 Personal Demographics

4.2.1.1 Age, home language and personal habits

Of the five participants in this study, four (80%) were male and the remaining one (20%) was female. The female participant was in the force-based group resulting in this group being 50% female and 50% male. The ages of the participants ranged from 24 to 34 years.

There was a variety of home languages spoken amongst the participants, none of which was English. All assessments and treatments were conducted in English. All participants were able to understand and speak a degree of English as a second language. According to the participants, 80% of them had a full understanding of English while one participant (20%) from the excursion-based group had only a partial understanding of English. There were no significant differences between the force and excursion group for age of home language (Table 4.1).

Table 4.1 Age, home language and personal habits of the participants (n=5)

Age groups		**Total Group**	**Excursion Group**	**Force group**	**p value**
		n (%)			
	24-26 years	2 (40%)	1 (20%)	1 (20%)	0.421
	27-29 years	0 (0%)	0 (0%)	0 (0%)	
	30-32 years	1 (20%)	1 (20%)	0 (0%)	
	33-35 years	2 (40%)	1 (20%)	1 (20%)	
Home language	Xhosa	1 (20%)	1 (20%)	0 (0%)	0.231
	Zulu	2 (40%)	1 (20%)	1 (20%)	
	Sotho	1 (20%)	0 (0%)	1 (20%)	
	Chichewa	1 (20%)	1 (20%)	0 (0%)	
Smoke Cigarettes	Yes	2 (40%)	1 (20%)	1 (20%)	0.615
	No	3 (60%)	2 (40%)	1 (20%)	

Significance $p \leq 0.05$ *
$p \leq 0.01$ **

Whether or not a participant smoked cigarettes during their healing and rehabilitation was found to have an effect on their overall results (Trumble, et al., 2010) and 40% of the participants in this research study, one in each group, did smoke prior to their injury and throughout their rehabilitation.

4.2.2.2 Level of education and employment status

In terms of highest level of education, 60% of participants had completed their final year of high school (Grade 12), while 20% completed Grade 11 and 20% completed Grade 10. The participants who had not completed matric were equally divided between the force-based and excursion-based groups. None of the participants had completed any form of tertiary education. At the time of the injury one participant, (20%) from the excursion group was studying a diploma at a business college.

Premorbidly one participant, (20%) from the excursion group was unemployed, while the remaining four participants (80%) were studying and/or working in various full-time or part-time positions. The positions held by the participants included a part time machine operator, full time laboratory technician and various piece jobs. These were classified as medium duty, light duty and heavy duty jobs respectively (Table 4.2).

Table 4.2 Highest level of education and employment status of participants (n=5)

	Variables	Total Group	Excursion Group	Force group	p value
		n (%)			
Highest level of education	Grade 10	1 (20%)	0 (0%)	1 (20%)	0.301
	Grade 11	1 (20%)	1 (20%)	0 (0%)	
	Grade 12	3 (60%)	2 (40%)	1 (20%)	
Employment Status	Unemployed	1 (20%)	1 (20%)	0 (0%)	0.246
	Piece Jobs	2 (40%)	1 (20%)	1 (20%)	
	Student and part time job	1 (20%)	1 (20%)	0 (0%)	
	Full time job	1 (20%)	0 (0%)	1 (20%)	

Significance $p \leq 0.05$ *
$p \leq 0.01$ **

4.2.2.3 Area of residence and resources at home

All participants were living within the hospital catchment area of Boksburg/ Benoni within the Ekurhuleni district. All but one (80%) of the participants lived in housing which was equipped with running water and electricity (Table 4.3). The remaining one participant, from the excursion-based group lived in an informal settlement without access to running water and electricity.

Table 4.3 Water and electricity resources available to participants (n=5)

	Variables	**Total Group**	**Excursion Group**	**Force group**	**p value**
		n (%)			
Electricity & water at home	Yes	4 (80%)	2 (40%)	2 (40%)	0.617
	No	1 (20%)	1 (20%)	0 (0%)	

Significance p≤ 0.05 *
p≤ 0.01 **

No significant differences were found between the force-based and the excursion-based groups for other demographic factors and therefore the groups were considered comparable.

4.2.2 Medical History

4.2.2.1 Number and type of fingers injured, injury of dominant hand, cause of injury and nature of the injury

The five participants had a total of 10 injured fingers assessed and treated throughout this study. The maximum number of fingers that any one participant had injured was three, and the minimum number was one. The most commonly injured fingers were the middle finger (MF) and ring finger (RF), which each made up 30% of the total of injured fingers. Two of the five participants (40%), both from the excursion-based group, injured the flexor tendons of their dominant hand. In the excursion-based group at least one finger from the four possible fingers on the hand was injured, while injuries in the force-based group were to the index fingers (IF), RF and LF (Table 4.4).

Table 4.4 Number and type of fingers injured, injury of dominant hand, cause of injury and nature of the injury (participants n=5, fingers n=10)

Medical history		Total Group	Excursion Group	Force group	p value
		n (%)			
Number of fingers injured	1	2 (40%)	1 (20%)	1 (20%)	0.245
	2	1 (20%)	0 (0%)	1 (20%)	
	3	2 (40%)	2 (40%)	0 (0%)	
Fingers injured	Index Finger	2 (20%)	1 (10%)	1 (10%)	0.142
	Middle Finger	3 (30%)	3 (30%)	0 (0%)	
	Ringer Finger	3 (30%)	2 (20%)	1 (10%)	
	Little Finger	2 (20%)	1 (10%)	1 (10%)	
Dominant hand Injured	Yes	2 (40%)	2 (40%)	0 (0%)	0.316
	No	3 (60%)	1 (20%)	2 (40%)	
Cause of Injury	Injury on duty	2 (40%)	1 (20%)	1 (20%)	0.632
	Assault	3 (60%)	2 (40%)	1 (20%)	
Nature of injury	Injured both FDS and FDP	9 (90%)	6 (60%)	3 (30%)	0.751
	Injured only FDP	1 (10%)	1 (10%)	0 (0%)	

Significance $p \leq 0.05$ *
$p \leq 0.01$ **

The cause of the injury for 60% of the participants was assault with a knife. The remaining 40% of participants were injured on duty (IOD), while carrying out piece jobs. These injuries included a participant falling onto a sharp aluminium sheet of metal and a coal stove falling onto the second participant's hand. Both treatment groups contained one participant who had an IOD and at least one participant who had been assaulted. None of the participants had any pre-existing medical conditions or prior injuries to their upper limbs that may have impacted their healing or rehabilitation (Table 4.4).

The information obtained from the surgeons regarding the nature and severity of the participants' injuries as well as the details of surgical procedures performed on the participants was very limited. The surgeons reported that all injured tendons involved in this study had a complete laceration in zone II. They recorded that all but one of the injured fingers experienced a laceration of both the FDS and FDP. One participant from the excursion-based group experienced a complete laceration of the FDP in zone II but the FDS was left intact. According to the surgeon's reports, none of the participants experienced any injuries to other significant structures in the hand, such as digital nerves or larger blood vessels. No significant differences were found between the force and excursion groups for medical history and therefore the groups were considered comparable.

4.2.2.2. Factors affecting surgery and occupational therapy

Table 4.5 indicates the percentage of participants operated on by the three different surgeons at the hospital. After interviewing the surgeons postoperatively, it was ascertained that all the participants were able to participate in this research study, as they had all received a four or more strand tendon repair. Surgeon B who operated on all the participants in the force-based group reported that he performed a full repair of both the FDS and FDP tendons. Surgeon A and C performed only a repair of the FDP tendon of all the participants in the excursion-based group.

The number of days between the injury and the surgery differed greatly between the participants. Three participants (100% of the force-based group and 33.33% of the excursion-based group) received their surgery within the first four days after their injury. One participant from the excursion based-group had surgery seven days after his injury and the final participant from the excursion-based group had surgery 10 days after his injury. According to the inclusion criteria of this study the participants could only participate in this study if they started therapy within the first six postoperative days. The difference in time between surgery and starting therapy was much less varied as indicated in Table 4.5.

No significant differences were found between the force and excursion groups for surgery and rehabilitation factors except for the tendons which were sutured. The groups were thus considered comparable for factors other than the repaired tendons.

Table 4.5 Factors relating to surgery and occupational therapy (participants n=5, fingers n=10)

Factors affecting surgery and occupational therapy		Total Group	Excursion Group	Force group	p value
		n (%)			
Surgeon who performed tendon repair	Surgeon A	1 (20%)	1 (20%)	0 (0%)	0.147
	Surgeon B	2 (40%)	0 (0%)	2 (40%)	
	Surgeon C	2 (40%)	2 (40%)	0 (0%)	
Tendons repaired	FDP and FDS	3 (30%)	0 (0%)	3 (30%)	0.008**
	Only FDP	7 (70%)	7 (70%)	0 (0%)	
No. of days between injury and surgery	1-4 days	3 (60%)	1 (20%)	2 (40%)	0.316
	5-8 days	1 (20%)	1 (20%)	0 (0%)	
	9-12 days	1 (20%)	1 (20%)	0 (0%)	
No of days between surgery and therapy	3 days	1 (20%)	0 (0%)	1 (20%)	0.342
	4 days	3 (60%)	2 (40%)	1 (20%)	
	5 days	1 (20%)	1 (20%)	0 (0%)	

Significance $p \leq 0.05$ *
$p \leq 0.01$ **

In terms of complications, the researcher noticed signs of adhesions in 100% of the fingers involved in this study, at varying times during their therapy. This was confirmed by the operating surgeons, who later referred all five participants to a specialist hand clinic at Charlotte Maxeke Hospital for revision surgery.

4.3 Intervention – Excursion and Force based Approaches

4.3.1 Adherence

Four of the five participants completed the 12 week programme and one participant in the force-based group did not return in the final week thus scores for the final assessment could not be analysed for this participant.

Table 4.6 Participant code, finger code, treatment group and adherence of each participant

Participant Code	Finger Code	Treatment Group	Adherence to home programme and attending Rx
1	A	Excursion	Good
2	B	Force	Good
	C	Force	
3	D	Excursion	Good
	E	Excursion	
	F	Excursion	
4	G	Force	Partial
5	H	Excursion	Good
	I	Excursion	
	J	Excursion	

4.3.1 Range of Motion-

The participants' ROM was measured at every session that they attended. Passive and place-and-hold ROM was measured from week one, whereas active ROM was only measured from week four. Measurements were done by the researcher at every session and by a blinded occupational therapist from TMH at week one, six and twelve. The ROM measurements were then inserted into the SG formula and classified according to Strickland's Original Classification (Strickland & Glogovac, 1980).

It was initially the intention to use the blinded ROM measurements to demonstrate a lack of bias in the researcher's measurements. However the blinded ROM measurements were excluded from the research study after they were reviewed.

There was a difference of 10% or more in a sixth of the comparisons between the SG scores of the research assistants and the researcher, who was an expert in the field of hand therapy. The therapist had less than one year of experience in occupational therapy practice and was in her community service year at TMH.

The inconsistencies in scores were further investigated to determine if there was a trend in these differences or if they favoured one group over the other. This was not the case as some of the differences were in favour of the excursion-based group, while others favoured the force-based group and it was clear that these were random. It was concluded that these score inconsistencies were not a result of researcher bias but rather of an inexperienced blinded occupational therapist measuring ROM. While it was not ideal to use newly qualified therapists to assist with the measurements for the study, there were no more experienced therapists available to perform the blinded ROM measurements.

It is a reality in public hospitals in South Africa that occupational therapists with less than one year of practical experience are often expected to treat FTIs and other hand injuries independently (Mncube & Puckree, 2014). This lack of experience is often evident in the inconsistent assessment and treatment results obtained by these therapists. (Groth, 2005; Mncube & Puckree, 2014).

4.3.1.1 Within group changes

Excursion group

Figure 4.1 below shows the median passive, place-and-hold and active SG scores for the seven fingers in the excursion group. According to the Strickland classification the initial median passive SG score was 48.57 (classified as poor). The passive SG score increased considerably from week 1 to week 2 to a score of 71.43, after which it gradually increased to a final score of 82.29, which was classified as good. Both the place-and-hold and active SG scores were classified as poor throughout the full period that they were measured (Figure 4.1).

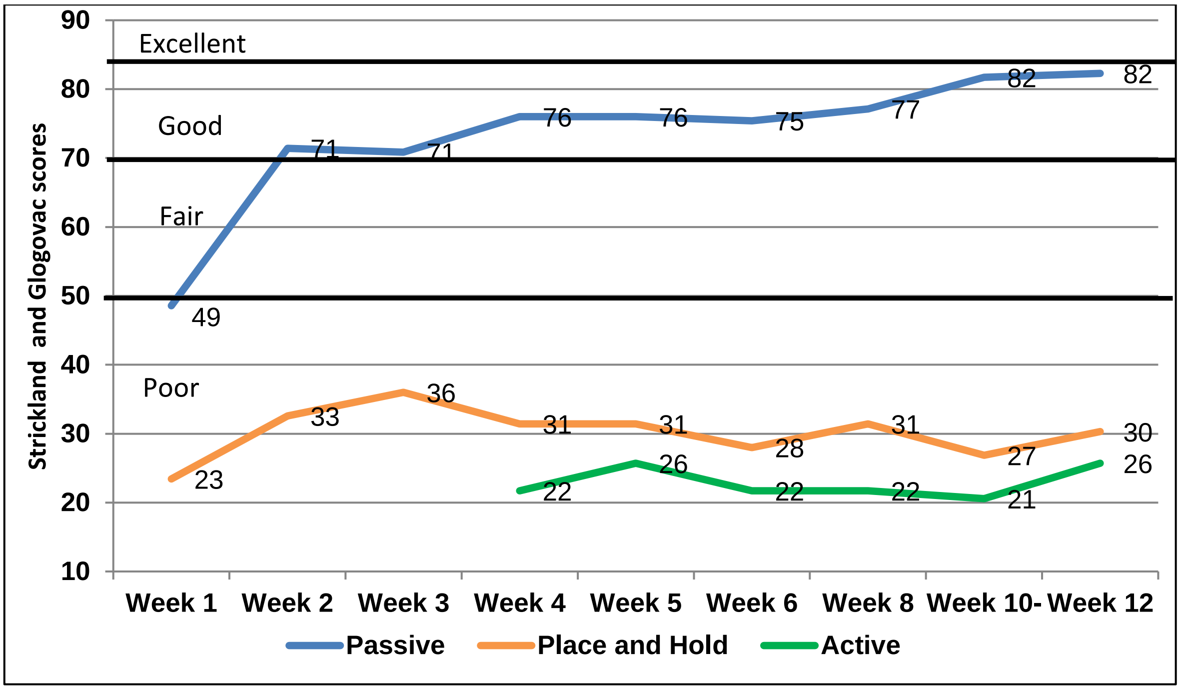

Figure 4.1 Changes in median Strickland and Glogovac scores over 12 weeks for passive, place-and-hold and active range for excursion-based group.

Over the first three weeks, the median place-and-hold scores increased from a SG score of 23.43 to a high of 36. The median place-and-hold scores then fluctuated over the next nine weeks with a final score of 30.29. The median active score showed very little change from week 4 to week 12 and all SG scores were classified as poor within a range of 20.57 to 25.71 during this period. From the initial to the final treatment session there was a slight improvement of four points.

Force group

The median passive SG score for the three fingers in the force group was 86.86 at week 1, which was classified as excellent. The passive SG score decreased to 76.57 and then increased again to 85.71 by week 5. Over the next seven weeks the overall score decreased, resulting in a final median passive score of 62, classified as fair.

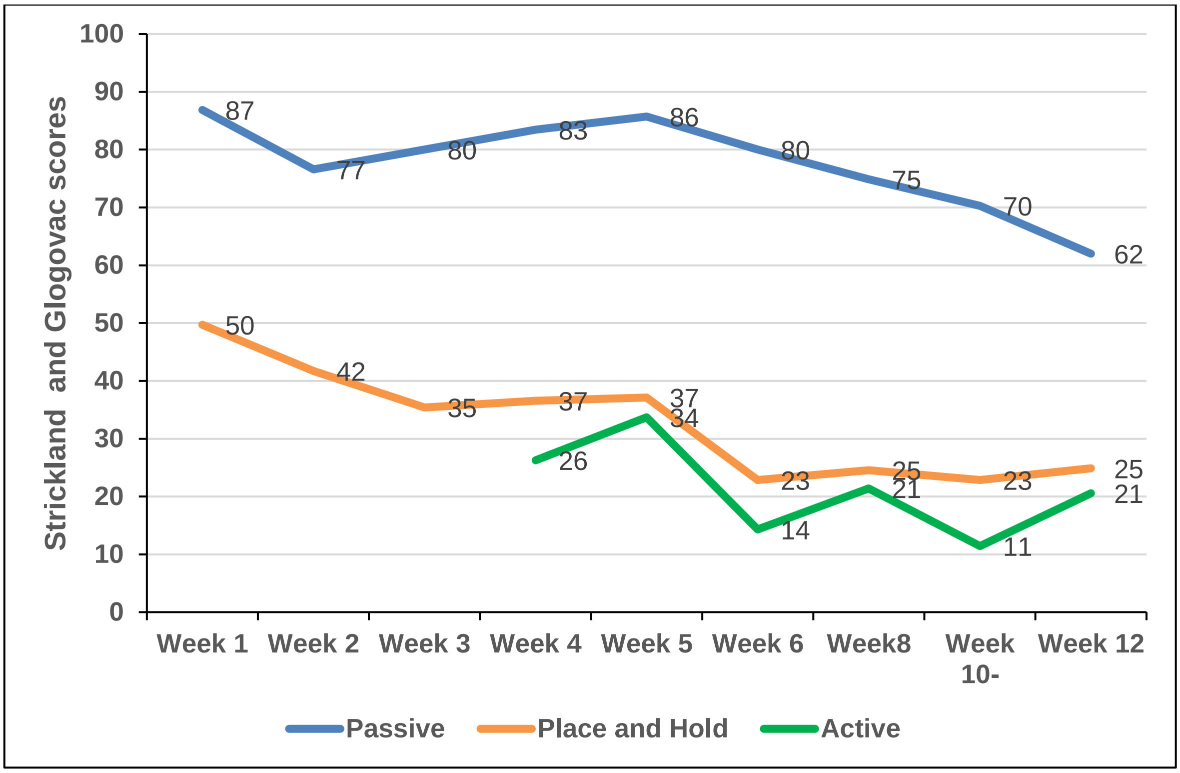

Figure 4.2 Changes in median Strickland and Glogovac scores over 12 weeks for passive, place and hold and active range for force-based group.

Similarly to the excursion-based group, both the median scores for place-and-hold and active ROM were in the poor range throughout the rehabilitation period for the force-based group. There was a constant decrease in the median place-and-hold SG scores over the 12 week rehabilitation period from a score of 49.71 to 24.86. A large drop in scores was seen from week 1 to week 3 and again from week 5 to week 6, after which the scores plateaued for the remaining six weeks. The active SG scores experienced an overall decrease from a median score of 26.29 at week 4 to a score of 20.58 at week 12. The active score increased slightly to a maximum score of 33.71 in the first week that it was measured. It then followed an alternating pattern of increasing and then decreasing at every treatment session. The active SG score reached its lowest score of 11.43 at week 10.

4.3.1.2 Between group changes

The SG scores of the excursion-based group on initial assessment were compared to those of the force-based group to establish if the groups were comparable. There was a significant difference in the scores on initial assessment with the force-based group having higher scores for passive and place-and-hold ROM. (Table 4.7).

Table 4.7 Comparison of the median Strickland and Glogovac Scores on initial assessment for both groups (n=10)

	Excursion Group		Force group		p value
	Median and lower and upper quartiles				
Passive SG scores– week 1	48.57	47.43 to 54.29	86.86	62.86 to 90.29	0.04*
Place-and-Hold SG scores- week 1	23.43	18.29 to 33.14	49.71	36.57 to 52.57	0.02*
Active SG scores– week 4	21.71	16.00 to 33.71	26.29	6.86 to 31.43	0.68

Significance $p \leq 0.05$ *
$p \leq 0.01$ **

There was no significant difference in the active SG scores which was assessed from the fourth week. Since the groups were not comparable on the initial assessment the change in scores over 12 weeks were used to compare results for the excursion-based and force-based groups.

Table 4.8 shows the difference in the median SG scores between week 1 and week 6, of the excursion-based, force-based and total groups for passive and place-and-hold ROM. The difference shows an improvement in the passive SG scores from week 1 to week 6 in the total (17.43) and excursion-based (22.85) groups, but a decrease in passive SG scores (-5.72) in the force-based group.

Table 4.8 Median change in Strickland and Glogovac scores from week 1 to week 6 for both groups (n=10)

Difference Week 1-6	Total Group		Excursion Group		Force group		p value	Effect sizes Cohen r	95% Confidence intervals
	Median and lower and upper quartiles								
Difference in passive SG scores	17.43	-1.71 to 27.43	22.85	14.28 to 29.14	-5.72	-10.29 to 17.14	0.06	0.38	-0.6 to 1.36
Difference in place-and-hold SG scores	-2.57	-17.14 to 14.28	5.72	-9.72 to 14.86	-26.28	-26.85 to -17.14	0.02*	0.50	-0.48 to 1.48

Significance p ≤0.05*
Significance p ≤0.01**

Small effect size 0.1
Medium effect size 0.3*
Large effect size 0.5**

The difference for the median place-and-hold SG scores showed an improvement from week 1 to 6 for the excursion-based group (5.72), but a large decrease for the force-based group (-26.28) and minor decrease for the total group (-2.57) (Table 4.8). There was a significant difference and a large effect size between the two groups with regard to the place-and-hold median difference between week 1 and week 6.

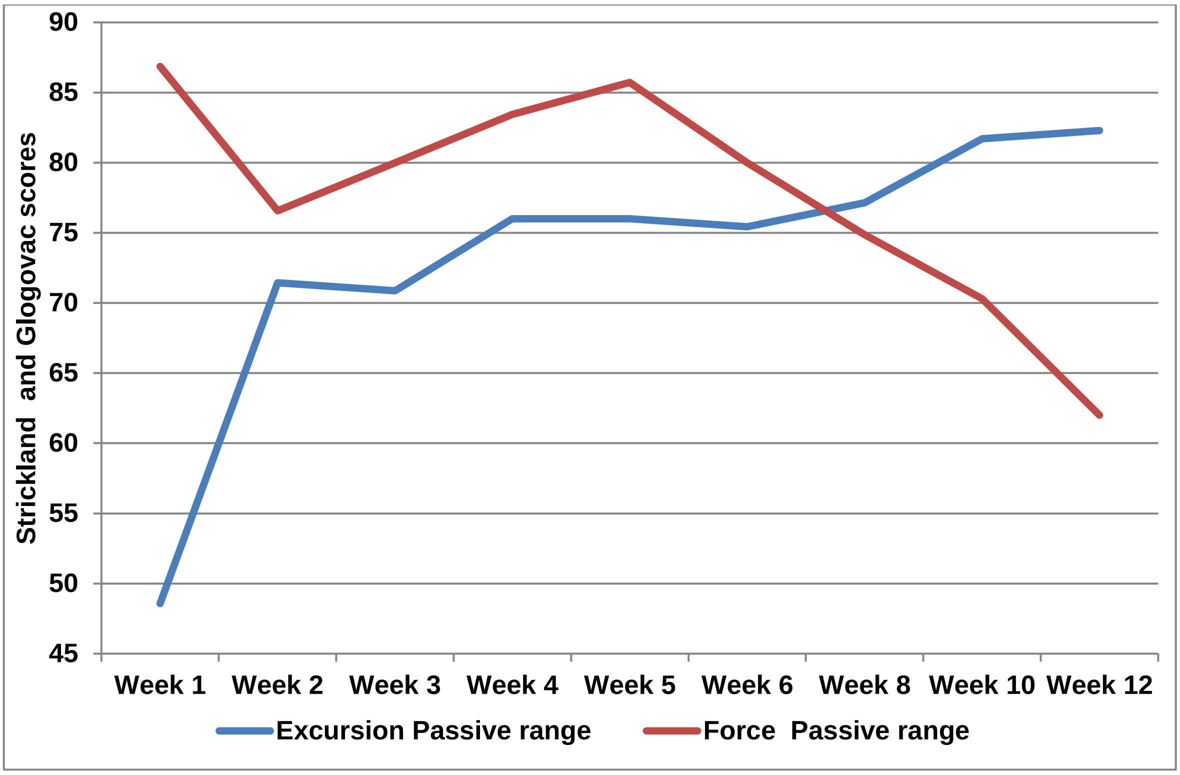

Figure 4.3 Changes in median passive Strickland and Glogovac scores over 12 weeks for both groups

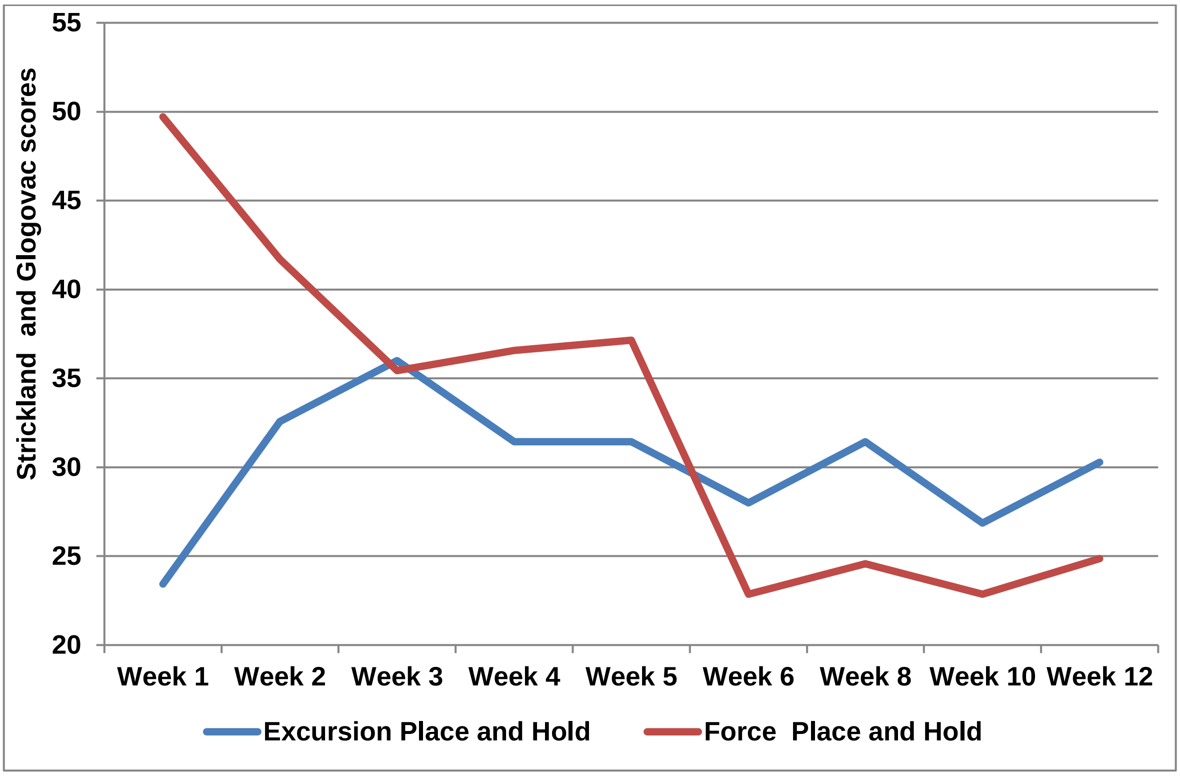

Figure 4.4 Changes in median place-and-hold Strickland and Glogovac scores over 12 weeks for both groups

Table 4.9 indicates that, when the difference in median SG scores were considered for week 6- 12, the only variable that showed a significant difference and medium effect size between the two groups was the passive scores. The median passive SG score of the excursion-based group showed an improvement (9.14) from week 6 to week 12, whereas the median score of the force-based group indicated a decrease of 18.57.

The difference between the median place-and-hold and active SG scores at 6 and 12 weeks for the force-based group was negative (-4.28 and -5.14 respectively).

There were however improvements from week 6 to week 12 in the median place-and-hold and active SG scores for the total and excursion-based groups. However there was no statistically significant difference and a small effect size was noted, which indicated that there was no clinical difference for either the place-and-hold or the active difference in SG scores.

Table 4.9 Median change in Strickland and Glogovac scores from week 6 to week 12 for both groups (n=10)

Difference Week 6-12	**Total Group**		**Excursion Group**		**Force group**		**p value**	**Effect sizes Cohen r**	**95% Confidence intervals**
	Median and lower and upper quartile								
Difference in passive SG scores	6.29	-10.29 to 13.15	9.14	6.28 to 13.72	-18.57	-13.14 to -24.00	0.02**	0.42	-0.56 to 1.4
Difference in place and Hold SG scores	2.29	0.86 to 8.29	2.29	1.71 to 4.57	-4.28	-20.57 to 12.00	0.88	0.03	-0.95 to 1.01
Difference in active SG scores	4.00	-2.86 to 9.15	4.57	-1.71 to 13.14	-5.14	-11.43 to 1.15	0.18	0.29	-0.69 to 1.27

Significance p ≤0.05*
Significance p ≤0.01**

Small effect size 0.1
Medium effect size 0.3*
Large effect size 0.5**

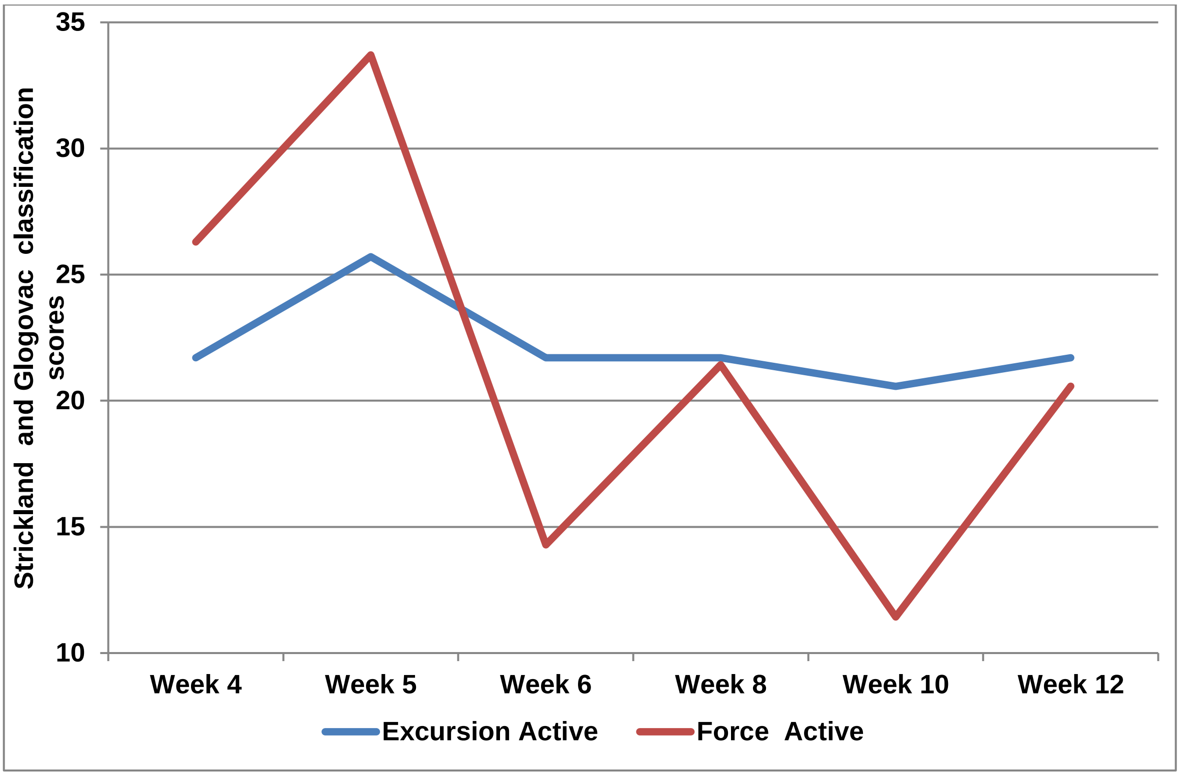

Figure 4.5 Changes in median active Strickland and Glogovac scores over 12 weeks for both groups.

4.3.3 The Disabilities of the Arm, Shoulder and Hand

The DASH results are divided into three sections according to those on the questionnaire. These include varied daily activities, work activities and sport or musical instrument related activities. A higher score on the DASH questionnaire indicates a greater disability (Solway, et al., 2002).

4.3.3.1 Within group changes

Excursion group

The excursion-based group reported a decrease in their median DASH score for the varied ADL section, and thus improvement in their ability to use their upper limb in everyday activities, from the initial assessment to the final assessment. All the participants' final DASH scores for the general ADL section were between 20 and 30 points (Figure 4.6). The DASH manual reports that interpretation of scores has not yet been performed to explain what level of functioning a person has based on their score, or how much improvement has been achieved based on a change in scores (Solway, et al., 2002).

The DASH scores for the work section showed an increase in disability with a final score that was 9.37 higher than the initial score. The participants in the excursion-based group were responsible for operating machines and carrying out piece jobs and their injury affected their ability to work.

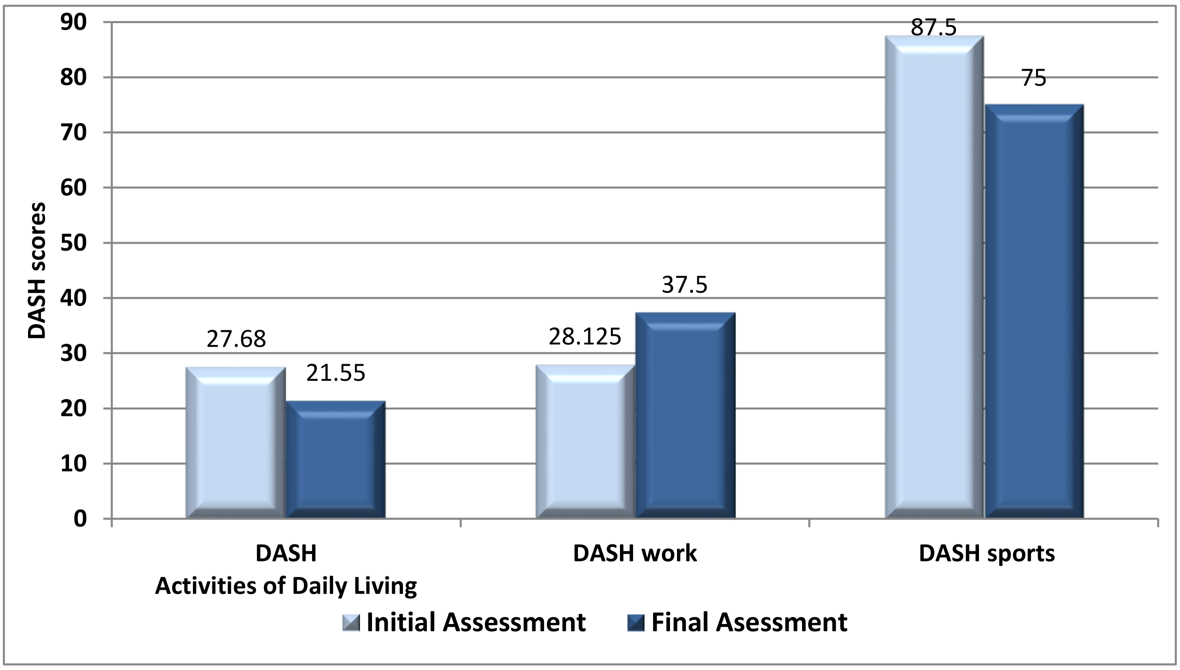

Figure 4.6 Changes in median Disabilities of the Arm, Shoulder and Hand scores for initial and final assessments for the excursion-based group.

The DASH sport scores indicated a high disability score at the initial and final sessions as the sports the participants in this group participated in were weight-lifting at gym, soccer and basketball. The high score indicated the effect the participants’ injuries had on their sport participation, which improved by 11.5 points over the 12 week intervention programme for this group.

Force group

The force group reported a decrease in their median DASH score for the general ADL section, and thus improvement in their ability to use their upper limb in everyday activities, from their initial assessment to their final assessment (Figure 4.7) The one participant who completed the DASH questionnaire in the force-based group indicated an improvement in her ability to work as a laboratory technician.

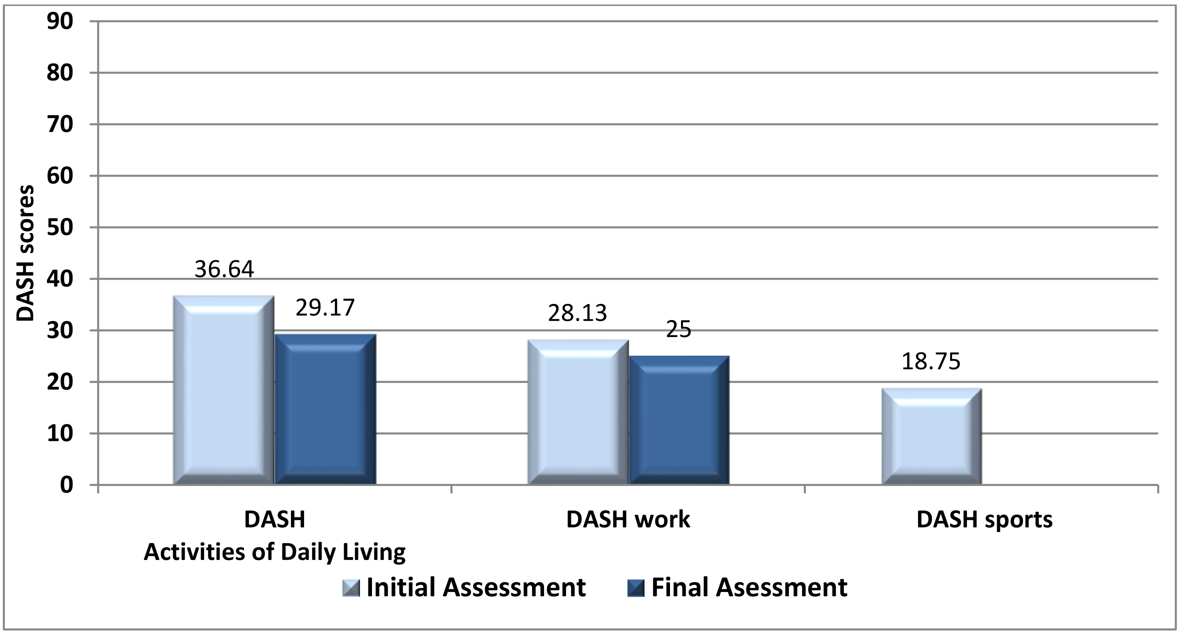

Figure 4.7 Changes in median Disabilities of the Arm, Shoulder and Hand scores for initial and final assessments for the force-based group

It was not possible to compare the initial and final scores for the sport/musical instrument section of the DASH questionnaire as neither of the two participants in this group completed the final questionnaire for this section. One of the participants, who played soccer, was non-adherent to attending the final treatment session and the other one did not participant in any sporting or musical instrument related activities.

4.3.3.1 Between group changes

At the initial treatment session the participants in the excursion-based group had a DASH score of 27.68 for general ADLs. This was 8.96 points lower than the initial median DASH score for the force-based group. Both the excursion-based and the force-based groups indicated a decrease in their median DASH scores, and thus improvement in their functioning for this section, from their initial assessment to their final assessment. The change in the median DASH scores for the general ADLs section at the final session for the excursion-based group showed less improvement than those of the force-based group.

Table 4.10 Median change in Disabilities of the Arm, Shoulder and Hand for both groups (n=4)

Disabilities of the Arm, Shoulder and Hand	Total Group		Excursion Group		Force group		p value	Effect sizes Cohen r	95% Confidence intervals
	Median and lower and upper quartile								
Section 1: Activities of daily living	-7.87	-37.14 to -6.11	-6.13	-64.66 to -6.10	-9.62		0.77	-0.29	-1.26 to 0.69
Section 2: Work	Too few participants for results to be analysed								
Section 3: Sport	Too few participants for results to be analysed								

Significance p ≤0.05*
Significance p ≤0.01**

Small effect size 0.1
Medium effect size 0.3*
Large effect size 0.5**

There was no significant difference in the change in DASH scores for the general ADL section between the excursion-based and force-based groups. The scores showed a small effect size which did not indicate clinical differences between the groups.

It was not beneficial to compare the final scores of the work and sport/musical instrument sections as limited scores were available from the force-based group in order for the change in the median scores to be analysed.

4.3.4 Participant Satisfaction- Within and between group changes

The participant satisfaction questionnaire was completed by four out of the five participants and was done during the final assessment and therapy session.

The median scores were 1 for both the excursion-based and the force-based groups for question one - ‘Are you satisfied with the surgery you received’ and question two - ‘Are you satisfied with the therapy that you received’ However the range between the upper and lower quartiles could only be established for the excursion-based group as only one participant completed the questionnaire in the force based group.

The participant in the force-based group was more satisfied with the appearance of her hand (question three) than the participants in the excursion based group, with median scores of 1.00 and 2.00 respectively. Once again, the participant in the force-based group was slightly more satisfied with the functionality of her hand (question four), than the participants in the excursion-based group, resulting in a significant difference between the two groups for participant satisfaction.

The participants in both groups were equally satisfied (a median score of 2.00) with their ability to continue life as they did before they were injured. However, the satisfaction of the participants in the excursion-based group differed vastly as the lower quartile for this group was 1.00 and the upper quartile 5.00. When reviewing the results of the total group it is evident that, as a whole, the participants were more satisfied with the surgery and therapy that they received than they were with the functionality of their hand and their ability to continue life in a similar manner as they did premorbidly.

Table 4.11 Excursion-based and force-based median scores for participant satisfaction questionnaire (n=4)

	Total Group		**Excursion Group**		**Force group**		**p value**
	Median and lower and upper quartile						
Satisfied with surgery	1.00	1.00-2.50	1.00	1.00-4.00	1.00		0.006**
satisfied with therapy	1.00	1.00-1.50	1.00	1.00 - 2.00	1.00		
satisfied with appearance	1.50	1.00-3.00	2.00	1.00-4.00	1.00		
satisfied with functionality of hand	2.50	2.00-3.00	3.00	2.00-3.00	2.00		
Satisfied that you can continue life	2.00	1.50-3.50	2.00	1.00-5.00	2.00		

Significance p ≤0.05*
Significance p ≤0.01**

Small effect size 0.1
Medium effect size 0.3*
Large effect size 0.5**

4.4 Summary of results

There were no statistically significant differences between the excursion-based and force-based groups with regard to the participants' age, home language and tendency to smoke cigarettes. Once again, there was no significant difference between the highest level of education, employment status and SES of the two groups. This indicates that at baseline, these two groups were considerably comparable in terms of personal demographics.

As far as medical history is concerned there was no significant difference between the two groups in all areas including number of fingers injured, type of fingers injured, dominant hand injured, cause of injury and nature of injury. When comparing the excursion-based and force-based groups for factors relating to surgery and therapy, it was noted that there were no significant differences between the groups for the operating surgeon, the number of days between the injury and surgery and the initial therapy sessions. There was however, a significant difference between the two groups with regard to the tendons repaired. All the tendons in the excursion-based group received only a repair of the FDP while all the tendons in the force-based group received a repair of both the FDP and FDS.

The SG score within the excursion-based group was classified as poor for place-and-hold and active ROM throughout the treatment programme. The passive SG scores however, started in the range of fair and improved to good, over the 12 week treatment programme. The force-based group had similar results for the place-and-hold and active SG scores in that they were also poor throughout the treatment programme. The passive SG scores for the force-based group was different in that it was classified as good at the initial session and decreased over the 12 weeks programme to result in a final classification of poor.

When comparing the SG scores between the two groups at the initial treatment session there was a significant difference for both the passive and the place-and-hold scores. There was a significant difference and a large effect size between the two groups with regard to the median place-and-hold difference between week 1 and week 6. There was a significant difference and medium effect size in the SG score change from week 6 to week 12 for passive ROM, but not for place-and-hold or active ROM.

The median DASH scores within the excursion-based group decreased from the initial to the final sessions, for the ADL and sports sections but not for the work sections. A decrease in DASH score indicates an improvement in upper limb functioning. Within the force-based group an improvement was noticed in all three sections from week one to week 12. There was a small effect size, which did not indicate clinical differences between the groups, and no significant difference between the excursion-based and force-based groups for the general ADL and work sections of the DASH questionnaire.

A review of the results obtained from the participant satisfaction questionnaire showed that the force-based group was significantly more satisfied than the excursion-based groups. The results of the total group showed that as a whole the participants were more satisfied with their surgery and therapy than they were with the functionality of their hand and their ability to continue life in a similar manner as they did premorbidly.

It was thus evident that while these two groups were considerably comparable in terms of personal demographics there was a significant difference between them with regard to the tendons repaired. The results of the three outcomes measured were varied in that the excursion-based group achieved better final passive SG scores, while the force-based group was significantly more satisfied and showed an improvement in their independence in work related activities, when compared to the excursion based group. It is necessary to further discuss these findings and compare them to the findings of previous South African and international research studies to gain a better understanding of the possible reasons for these differences.

CHAPTER 5- DISCUSSION

5.1 Introduction

This chapter will discuss the findings of the study and how they relate to similar studies both internationally and within a South African context. The demographics of the participants will be discussed in detail in this chapter as well as the effect that the participants' injuries, type of surgeries and timing of treatment have on their outcomes. The outcomes achieved, including ROM, upper limb functionality and participant satisfaction, will be compared to outcomes achieved using SWM and other approaches reported in the literature. The findings of these outcomes and the possible effects that a South African context has on the success of these approaches will also be considered. Finally the limitations of the study will be discussed to gain a better understanding of why certain results were obtained.

5.2 Demographics

5.2.1 Personal Demographics and Context

In this study there was no significant difference between the participants in the excursion-based group and the force-based groups with respect to personal demographics and the contexts in which the participants lived.

The gender distribution in this study showed a male to female ratio of 4:1 and all participants were between the ages of 24 and 34 years, with an average age of 30 years. This is in line with much of the literature that states that the majority of patients who injure their flexor tendons are young males (Kitis, et al., 2009; Trumble, et al., 2010). The age range and ratio of male to female participants differed slightly, in that Trumble et al. (2010) had wider age range (15 to 51 years), a male to female ratio of 2:1 and a similar average age of 29 years (Trumble, et al., 2010). Kitis et al (2009) also had a male to female ratio of 2:1 in their study in Pamukkale, Turkey and an average age of 33 years (Kitis, et al., 2009).

Although it has been suggested that age can have an effect on the outcomes of FTIs this was not the case in this study where most participants fell into the younger adulthood group for which the outcome of FTI has been shown to be positive (Rigo & Røkkum, 2016)

The five participants of this study were all of African race, living in an under-resourced community in the Boksburg/Benoni area and were all dependent on the public health care system to address their medical care. The population receiving treatment at public hospitals in South Africa are not necessarily representative of the entire population of South Africa. The reason for this is that public hospitals offer medical care at a lower cost to the South African public and thus the individuals and families utilising these services are often lower income earners (Dhai, 2012).

The home languages of this study's population differed and although all treatment sessions and home programmes were communicated in English, accommodations were made for all participants by having pictures in the home programme to demonstrate the meaning of the instructions, as well as including demonstrations and repetition into the treatment sessions. The topic of treatment language verses home language is one which is rarely discussed in flexor tendon related research, as the majority of studies are carried out in the participants' first language (Boyer, et al., 2005; Tanaka, et al., 2005; Trumble, et al., 2010) This, however, is not often the case in South Africa, where there are 11 official languages and many other African languages spoken throughout the country. The lack of available funds in public hospitals makes it difficult to afford translators (Dhai, 2012), and thus medical professionals are required to treat patients to the best of their ability despite the language barrier. The lack of literature discussing the effect of the treatment language on the patient's outcomes makes it difficult to determine whether the results of this study may have been affected by the fact that treatment was conducted in the participant's second or third language.

Literature indicates that patients from an under-resourced environment are often associated with lower levels of education (Atabuga, et al., 2011). This study found a similar trend where only some participants had completed high school and none had completed any form of tertiary education. The researcher adapted the way in which the condition, treatment and home programme was explained to ensure that it was understandable to participants with varying levels of education and understanding of English. The feedback from the participants was that they adequately understood their condition and what was required of them in terms of their home programme. This was further confirmed by questioning each participant on their splint routine and home programme exercises at the beginning and end of each session.

The participants in this study had a unemployment rate lower than the national average of 47.8% noted in the study by Spark et al. (2015), as only 20% of the population was unemployed at the time of their injuries (Spark, et al., 2015). Of the 80% of employed participants, 20% returned to work as advised by the researcher within the 12 week rehabilitation period, 20% returned prior to being deemed fit for work, due to threats of job loss, and the remaining 40%, who were self-employed in heavy duty positions carrying out ‘piece jobs’ were unable to return to work due to the nature of their job and thus earned no income during this time.

A study by Mncube et al. (2014) found that 86.6% of therapists working in a public hospital in South Africa reported that the location of the participants’ employment had an effect on their adherence to attending frequent visits (Mncube & Puckree, 2014). This was not noticed in this study as there was only one non-adherent participant, and he did not work further away from TMH than the adherent participants. In this study, being employed, despite the location, was found to motivate participants to attend therapy as they were eager to regain function in order to return to work.

The percentage of participants who admitted to smoking throughout their rehabilitation in this study was 40% (20% in the excursion-based group and 20% in the force-based group) compared to the 29% and 50.5% reported by Trumble et al. (2010) and Kitis et al. (2009) respectively. Other studies including that of Trumble et al. (2010) and Rigo and Røkkum (2016) have found that the participants who had a history of smoking throughout their rehabilitation were more likely to have worse results in areas such as ROM, flexion contractures and satisfaction scores, than their non-smoker counterparts (Trumble, et al., 2010; Rigo & Røkkum, 2016). The results yielded by this study differed from those in the literature in that the participants who smoked achieved active ROM scores that were no worse than the participants who did not smoked prior to and during their rehabilitation.

5.3 Medical History

5.3.1 Nature of the injury

There was no significant difference between the two groups for the cause of the injury. Overall, there were more injuries caused by assault or violence than IODs, which may be reflective of the cause of injuries in South Africa (Norman, et al., 2007). The cause of a FTI can have a considerable effect on the overall recovery of the injured fingers, as a FTI caused by a crush or a tearing mechanism is usually more severe than one caused by a clean cut from a knife or glass (Starnes, et al., 2012). Crush FTIs also usually result in decreased overall ROM, increased contractures and a higher rate of secondary surgeries (Starnes, et al., 2012). In this study only one participant had a crush injury but his outcomes were no worse than those with a clean cut.

There was no significant difference between the two groups in terms of injury to the dominant hand versus injury to the non-dominant hand, despite 40% of participants having a FTI of their dominant hand. The findings in this study relating to which hand was injured differ from those of Rosberg, Carlsson, Hojgard, Lindgren, Lundborg and Dahlin (2003) but are similar to those reported by Trumble et al. (2010) (Rosberg, et al., 2003; Trumble, et al., 2010). There was no indication in this study that participants with a dominant FTI required less treatment and/or were able to return to work sooner than participants with injuries of the non-dominant hand, as was found in the literature (Rosberg, et al., 2003) The participants with dominant hand injuries did however present with higher average scores for the DASH, indicating the injury to their dominant hand did have a greater effect on their occupational performance (Trumble, et al., 2010)

The limited surgical notes provided by the treating surgeons at TMH indicated that none of the participants had had any associated digital nerve injuries. When the two groups were compared with regard to the number and type of fingers that were injured, there was no significant difference noted. The MF and RF were the most commonly injured fingers in this study accounting for 60% of the participants, while the IF and LF were only injured in 40% of the participants.

A FTI of the LF was found to be a negative predictor to active ROM (Rigo & Røkkum, 2016), due to this finger being the least frequently used as it is easy to avoid using it when engaging in functional grip activities (Libberecht, et al., 2006). There were the same amount of participants with LF FTIs in the force-based and excursion-based groups, and thus the injured finger was not a compounding factor in this study. The literature states that participants who have multiple finger FTIs are more likely to experience poorer outcomes and increased complications, than those with a single finger injury (Trumble, et al., 2010). This was not evident in this study as the excursion-based group, which was made up of participants with two and three finger FTIs, scored better overall active SG and DASH scores, than the force-based group that was made up of participants with one and two finger FTIs.

Although the inclusion criteria indicated that patients with either zone II or zone III FTIs could participate, there were no participants with FTIs in zone III that were appropriate for this study. It is well known that FTIs in zone II are the most difficult to treat both surgically and therapeutically and result in poorer outcomes than similar injuries in other zones (Rigo & Røkkum, 2016). The fact that all injuries were in the same zone eliminated the effects that injuries in varying zones might have had on the outcomes and thus the overall conclusion of the study. Of the 10 injured fingers, nine (90%) had both FDS and FDP injuries and only one (10%) had an isolated FDP injury, with an intact FDS. Despite expecting a full recovery in active PIP ROM of the finger with an isolated FDP injury, by week 12 this finger had developed a PIP flexion contracture and had a maximum active flexion ROM of only 63°. This active flexion ROM score was within the range of active PIP ROM scores of the remaining participants, who experienced combined FDS and FDP tendon injuries.

5.3.2 Surgical and Therapeutic Treatment History

There were three orthopaedic surgeons at TMH who performed the FTRs on the participants of this study, all of whom would be categorized as a grade two: 'Specialist- less experienced' surgeons according to the table recommended by Tang (2013) (Tang, 2013). The medical information provided by these surgeons, both verbally and in the hospital file, indicated that various unspecified surgical procedures were performed by these three treating orthopaedic surgeons. The commonalities between the repairs performed by the three surgeons were that all used a Brunner incision to expose the tendon, 3/0 nylon and a four or more strand suture repair technique, with a running epitendonous suture to repair the ruptured tendon.

The type of suture and exact number of strands used to repair each participant's FTI differed greatly between the surgeons, as did their knowledge and experience levels. There was no significant difference between the surgeons in terms of the number of tendons repaired by each. Coincidentally Surgeon B operated on all the participants in the force-based group, while surgeon A and C both operated on the participants in the excursion-based group. Surgeon B performed a combined FTR of both the FDS and the FDP on all participants in the force-based group. Surgeons A and C both performed isolated repairs of the FDP tendons on all the excursion-based participants. Unlike that recommended by Moriya et al (2015) the FDS tendon was not partially excised during the repair of the force-based participants (Moriya, et al., 2015). The surgeons who performed the surgery and the tendons that were repaired were the only surgical variables that had a significant difference ($p \leq 0.008$) between the two groups and according to the discussion below may have had an effect on the outcomes of this research.

Over the past 30 years a substantial amount of literature has been written in developed countries about the benefits and challenges of using an isolated FDP tendon repair versus a combined FDP and FDS tendon repair to repair a FTI. Amadio, Hunter, Jaeger, Wehbe and Schneider (1985) support Lister, Kleinert, Kutz and Atasoy (1977) who recommended that the FDP and both slips of the FDS should always be repaired to preserve the vinacular blood supply to the FDP tendon, which ultimately results in an increased active ROM (Lister, et al., 1977; Amadio, et al., 1985). More recent research by Moyira, Yoshizu, Maki, Tsubokawa, Narisawa and Endo (2015) and Rigo and Røkkum (2016) also reported significantly better active ROM results and overall outcomes in participants who had received a combined FDP and FDS tendon repair (Moriya, et al., 2015; Rigo & Røkkum, 2016).

In contrast, Tang (1994) found better active ROM results with less secondary surgeries and lower adhesion and re-ruptures rates in participants that had received an isolated FDP repair of a FTI in zone 2C (Tang, 1994). His finding supported those of Brunelli, Vigasio and Brunelli (1983) which stated that the success of the isolated FDP repair can be attributed to the simplicity of the surgical procedure, the elimination of possible adhesions between the two tendons and the decreased number of sutures, and thus resistance, at the repair site (Brunelli, et al., 1983; Tang, 1994).

While there is no literature that states at exactly which post-injury day or post-operative day the patient should receive surgery or begin therapy to gain optimal outcomes, there are certain time ranges which result in better outcomes than others. The inclusion criteria limited the maximum lengths of these periods based on recommendation in literature (Tang, 2007a; Evans, 2012; Clancy & Mass, 2013) and several potential participants were excluded as they did not received surgery and therapy within the allocated time periods. There were no significant differences noted in this study between the excursion-based and the force-based groups for either the number of days between the participants' injury and surgery or the number of days between the participants' surgery and the initiation of therapy.

Some participants in this study waited up to 10 days for their FTR which was longer than the maximal delay of seven days, which was reported by Tang (2007a) as being the maximum number of days that surgery could be delayed before the patients' outcomes would begin to be compromised (Tang, 2007a). A slight delay of surgery after a FTI can be beneficial in some cases as it allows time for any infection to be addressed and for the oedema to be managed, prior to the surgery (Tang, 2007a). However a delay of more than seven days has been found to result in negative effects, such as rounding of the edges of the tendon ends, the initiation of adhesion formation and increased rigidity in the tendon sheath (Tang, 1994; Tang, 2007a).

There was little variation in the number of days between participants' surgery and the initiation of therapy, as all participants started occupational therapy between three and five days post operatively. This is the recommended amount of time, as it allows time for the pain and oedema to subside, thus lowers the chance of tendon ruptures occurring (Zhao, et al., 2005; Tang, 2007a; Evans, 2012; Clancy & Mass, 2013). There is no need to begin mobilisation of the injured finger before three days postoperatively as it is unlikely that adhesions will start forming so soon after surgery (Tang, 2007a). Zhao, Amadio, Tanaka, Yang, Ettema, Zobitz and An (2005) found the group that started mobilization one day after their FTR to have a 33% higher rupture rate than the group that started mobilisation five days postoperatively (Zhao, et al., 2005).

5.4. The effect that the Excursion-based Approach and the Force-based Approach have on the Participants' Outcomes

The outcomes provided a comprehensive overview of the effectiveness of the force-based and excursion-based approaches used in this study. These included active, passive and place-and-hold finger ROM, the DASH questionnaire as well as the participant satisfaction questionnaire. These outcomes provided objective and subjective assessments of the participants' recovery throughout their 12 week rehabilitation period. They were specifically chosen as they are affordable to use in a public hospital and relatively easy for second or third language English speaking participants from an under-resourced community to understand and follow, with guidance.

The excursion-based and force-based approaches were very similar in that the same splint was used for both, follow up visits were scheduled for the same postoperative periods, mobilization was started on the same postoperative day with the same exercises and all participants followed the same wound, oedema and scar management programmes. The only areas that differed between the two approaches was the type of exercises and the way in which they were presented to the participants, during treatment sessions and home programmes.

The first group followed excursion-based exercises which were introduced to the participants at specific postoperative dates, while the second group followed force-based exercises which were introduced to the participants based on the amount of improvement that they achieved from the previous session to the current session. It was necessary to measure the outcomes of these participants before, throughout and after their 12 week rehabilitation period to determine if both or either of these approaches achieved good or excellent results in treating repaired FTIs in a public hospital in South Africa. The results of these outcomes were also used to make a comparison between the excursion-based approach and the force-based approach to determine whether there were any significant differences in the outcomes of these two groups when utilised in this context.

5.4.1. Range of Motion

The first objective of the study was to determine the difference in passive, place-and-hold and active ROM from one week to the next in the excursion-based and force-based groups, by inserting the raw ROM scores into the SG formula.

While the outcomes featuring in flexor tendon studies differ vastly, one that appears in the majority of studies is ROM measurements (Kitis, et al., 2009; Justan, et al., 2011; Moriya, et al., 2015; Spark, et al., 2015; Rigo & Røkkum, 2016). Active ROM is the best way to determine if a patient with an FTI has recovered successfully (Strickland & Glogovac, 1980) or if they have developed complications, such as adhesions, ruptures or contractures. Raw ROM scores are confusing and do not clearly indicate improvements within or between groups. It is thus necessary to make sense of the flexion and extension ROM scores of the joints of the injured fingers by inserting them into a formula to gain one single meaningful score for each finger.

The SG formula was used to calculate the ROM scores of the participants in this study and these scores were then classified according to Strickland’s Original Classification system. This was recommended over Strickland’s Modified Classification as it provides a stricter and more realistic indication of the severity of the participants’ ROM deficits (Baktir, et al., 1996; Tang, 2007a).

The SG scores were analysed within each of the groups as well as between the excursion-based and force-based groups. Throughout the rehabilitation period both groups were similar in that the median passive SG scores were the highest and the active SG scores the lowest with the place-and-hold scores between. The median place-and-hold and active scores for both groups were classified as poor, below 50, throughout the 12 week rehabilitation period, thus indicating that the participants developed complications. While it is not unusual for participants to achieve poor results in the initial weeks of therapy, the majority of the place-and-hold and active SG scores should have improved to a good or excellent classification by the 12th week of a successful rehabilitation programme (Rigo & Røkkum, 2016).

While there was limited ROM in the MP joints initially due to pain, oedema and disuse of the hand, over the 12 week rehabilitation period all participants regained full active flexion and extension of the MP joints. This was in line with literature, which states that there is no reason for the participants to have longstanding MP ROM limitations or complications after a FTR. The reason for this is that the intrinsic muscles, which are primarily responsible for MP joint flexion and stability, are usually not injured at the time of the FTI (Cannon, 2011). The MP joint ROM measurements were not relevant to this study as they had no effect on the outcomes obtained.

Range of motion measurements are a useful tool in confirming the diagnosis of complications in repaired FTIs. None of the participants were diagnosed with tendon re-rupture as they all had some degree of active flexion at the final session. However, all participants developed adhesions at the tendon repair site, which was diagnosed by the fact that they had fair/good median passive SG scores, but poor active SG scores (Pettengill & Van Strien, 2011). After diagnosing the participants with adhesions the treating surgeons at TMH referred them to a plastic surgeon specialising in hand surgery at a tertiary hospital for tenolysis surgery.

A comparison of the SG scores of the two groups at the initial session, illustrated that the passive and place-and-hold median SG scores of the force-based group were significantly higher than those of the excursion-based group. These initial measurements were taken prior to the introduction of any specific excursion-based or force-based exercised programmes. It is thus suspected that the significant difference in initial SG scores could be attributed to the fact that an isolated FDP repair was performed on the excursion-based group whereas a combined FDP and FDS repair was performed in the force-based group. These findings are in agreement with the majority of the literature mentioned previously (Lister, et al., 1977; Amadio, et al., 1985; Moriya, et al., 2015; Rigo & Røkkum, 2016).

From week one to week six the median passive and place-and-hold SG scores of the excursion-based group increased, while the same scores in the force-based group decreased. The difference in scores between the two groups was only significant for place-and-hold. The median change in SG scores between week six and week 12 showed the same pattern as the change in scores from week one to week six, for passive, place-and-hold and active ROM. After the initial six weeks the excursion-based group continued to improve and the force-based group continued to decline. For this period only the difference in median passive SG scores showed a significant difference between the two groups.

Unlike the initial difference in SG scores, the change in scores from week one to week six and week six to 12 may have been influenced by the differing approaches used to treat the two groups of participants. The excursion-based approach introduced exercises to the participants at specific time intervals and in a specific order, starting with the exercise that gained the least amount of excursion and grading up weekly to the exercise that achieved the most amount of excursion. The force-based approach, which introduced new exercises, from the one requiring the least amount of force to the one requiring the most amount of force, based on the participant’s improvement between sessions.

While many of the exercises included in the two treatment approaches were similar, the excursion-based approach included several additional exercises. These included tendon gliding exercises and active flexion and extension of the wrist with relaxed fingers at week four and simultaneous extension of the wrist and fingers at week five (Cannon, 1993). The excursion-based approach also incorporated buddy strapping of the injured fingers at week six, after the splint was discontinued and a strengthening programme from week eight onwards (Cannon, 1993), while the force-based approach only advised that a strengthening programme should be included if the participant is returning to a labour type job (von der Heyde, 2008). It appears that the additional exercises, strapping and strengthening programme included in the excursion-based approach were more beneficial in improving the participants passive, place-and-hold and active ROM.

All participants were adherent to attending their therapy sessions between week one and week eight, and thus the change in SG scores from week one to week six could not be attributed to fluctuations in the participants’ adherence. One of the participants in the force-based group was not adherent to attending his therapy sessions at week eight and week 12, however the change in SG scores from week six to week 12 followed a similar pattern- of improved excursion-based and worsening force-based scores, to that of the week one to week six change. When the weekly SG scores for the force-based group were reviewed, a slight increase in the place-and-hold and active SG scores was noted at week eight and week 12. This indicated that it is likely that the one injured finger of the non-adherent participant had worse place-and-hold and active SG scores than the remaining two fingers in the force-based group.

Over the course of the 12 week rehabilitation period the median passive SG scores for the excursion-based group improved by 33.72 points from a poor to a good final classification. However the same scores for the force-based group followed an opposite pattern, by decreasing 24.86 points from an initial classification of excellent to a final classification of fair at week 12. While the passive SG scores of one group improved and the other worsened, neither groups achieved excellent passive SG scores as expected.

Literature advises that regular protected passive stretching exercises should be included in all flexor tendon rehabilitation approaches as they are essential in preventing joint stiffness (Pettengill, 2005). Both exercise programmes contained a significant amount of therapy-based and home-based passive stretching exercises from the initial session to the final session. The most likely reason that the groups only achieved fair and good passive SG scores is because the participants of both groups were not fully adherent to following their home exercise programmes in the intended manner. It is possible that they were not exercising as often as advised or that they did not fully understand how much pressure to apply to the finger during stretching exercises. The only way in which the participants' adherence to home programmes could be monitored was through subjective feedback from the participant and this may not have been accurate.

A slight improvement of less than 7 points was noted for both the median place-and-hold and the active SG scores in the excursion-based group over the 12 week period. The force-based group's median place-and-hold and active SG scores were once again opposite, as they decreased by 24.85 and 5.71 points respectively from the initial to the final session. This resulted in the final active SG scores of the excursion-based group (who received an isolated FDP repair) being better than those of the force-based group (who received a combined FDS and FDP repair). Unlike the initial SG scores, these results were not in agreement with the majority of the literature. Literature supporting these findings, states that an isolated FDP tendon repair will result in better TAM scores (Tang, 1994), significantly decreased gliding resistance (Zhao, et al., 2002c) and significantly lower work of flexion than in fingers where both the FDS and FDP were repaired (Hwang, et al., 2009)

It is suspected that the initial advantage for repairing both tendons was lost as the repair of both the FDS and FDP tendons resulted in there being double the amount of friction, bulk and stiffness at the repair site, which hampered the gliding of the tendon in the tendon sheath (Zhao, et al., 2002c). This limited ability to glide resulted in the quicker and more severe formation of adhesions and thus the rapid decrease in place-and-hold and active SG scores in the force-based group.

Amadio (2005) reported that an approach should be considered successful if the participants regain 80% or more of their injured finger’s premorbid active ROM within the first 12 weeks postoperatively (Amadio, 2005). Many other studies consider an approach to be successful if the participants achieve active SG scores or TAM scores which fall into the good or excellent category (Baktir, et al., 1996; Trumble, et al., 2010; Moriya, et al., 2015). Tang (2013) reported that although the majority of the studies carried out in specialised hand units scored good and excellent results in 80% or more of participants, the results obtained in public hospitals, were much more disappointing (Tang, 2013). He accounts these limited outcomes in the public hospitals to aspects such as a less than ideal ‘surgical team and rehabilitation set up’ as well as the fact that ‘practice guideline or knowledge may not have been updated’ (Tang, 2013, p. 254).

Although the excursion-based group showed slightly better final SG scores than the force-based group it is important to note that the active SG scores for both groups were classified as poor at week 12 and all participants developed adhesions. While there are many factors that may have contributed to the lack of success of both SWM approaches used in this study, including non-adherence to attending therapy and following home programmes, the differing surgical repairs received by participants and the varying group sizes, literature states that the rehabilitation approach has the biggest effect on the participants' recovery (Amadio, 2005). It can thus be assumed that neither the excursion-based nor the force-based SWM approaches are appropriate to restore participants' active ROM after a FTR in an under-resourced public hospital in South Africa.

5.4.2. DASH questionnaire

The second objective of the study was to explore the upper limb functioning of patients with repaired FTIs who are being treated using either the excursion-based approach or the force-based approach, according to DASH scores.

Restoring a patient's independence in functional activities is the ultimate goal of rehabilitation; however these same activities are also used as an assessment tool and a treatment technique in occupational therapy sessions. Using functional activities as an outcome measure also allows the therapist to gain a better understanding of the patient's ability to cope in their workplace and thus their return to work can be planned optimally. The DASH questionnaire is one of many functional assessments available, and as a result of its simplicity, was chosen as an outcome measure for this study.

While many research studies base the success of an approach on the final active ROM results, there is literature which states that a treatment approach should not be deemed unsuccessful if it does not achieve good, or excellent active ROM results (Hume, et al., 1990). The reasoning behind this is that it has been proven that a patient can carry out their ADLs independently with as little as 39% of their premorbid active finger ROM (Hume, et al., 1990). It is thus essential to include a functional assessment in flexor tendon related research to determine how much difficulty patients experience while carrying out their ADLs, irrespective of their ROM measurements.

In the excursion-based group, the DASH scores for general ADLs and sport decreased by a median score of 6.13 and 12.5 respectively from the initial session to the final session, thus indicating an improvement in function (Beaton, et al., 2001; Libberecht, et al., 2006). In the force-based group the median DASH scores for general ADLs and work activities indicated a decrease in scores of 9.62 and 3.13 respectively. Although an improvement in functioning was noticed for all the above -mentioned sections, the final DASH scores for all participants were above 20, indicating that both groups had residual functional difficulties at the end of the 12 week rehabilitation programme. These findings are in line with the final SG scores for both groups, as the development of adhesions and limited ROM at 12 weeks were severe enough to prevent participants from being able to flex their fingers enough to independently engage in functional activities, as they did premorbidly.

An exception to the pattern of improved functioning was noticed in the work scores for the excursion-based group, as the median score increased from the initial to the final sessions. This indicated that the participants felt that they had less independence in carrying out work activities at their final session, than they did at their initial session. A constant or increased ability to use the injured hand in functional activities was expected for all sections as the participants were unable to use any fingers of their injured hand in activities at the initial session, due to the hand being splinted. However, at the final session participants had no splint restrictions and were able to use the limited active ROM of the injured finger/s as well as the active movement of all uninjured fingers to engage in ADLs.

A possible reason that the excursion-based participants could have rated their ability to function at work as being worse at the final session than at the initial session could be due to a change in their circumstances. At the initial session the participants rated their ability to perform their work tasks based on their perception of the tasks as they had not returned to work and were unable to use their hand actively. By the 12th week all participants had returned to work and thus their final score was based on their actual attempts to perform their work activities, which may have been more difficult than they had initially imagined.

Beaton et al. (2001) reported that a DASH score that decreased by 15 or more points indicated that a noticeable improvement had been made in the participant's functioning (Beaton, et al., 2001). When the difference in DASH scores were viewed individually, none of the participants in either of the groups experienced a difference of 15 or more points between the initial and final scores for any sections of the DASH. It is thus evident that, although improvement was noticed in the majority of the DASH scores, the change in scores was not enough to be clinically relevant. Furthermore, when comparing the median change in DASH scores for the excursion-based group and the force-based group for the general ADL and work sections, it was noted that all the scores had a small effect size, and none showed a significant difference.

The limited functional recovery of the participants could be attributed to similar reasons discussed throughout this chapter relating to the under-resourced context. One of these was the inconsistent surgical repairs performed by surgeons with varying amounts of specialised training and experience. Another was that it appears that the SWM approaches were not suitable for this population as they didn't fully understand what was required of them, which lead to non-adherence to following their home exercise programmes and essentially limited improvement in functioning.

At the initial session the excursion-based group perceived themselves as being more independent in functioning in general ADLs, whereas the force-based group was more independent in carrying out sport related activities. The participants of the two groups rated themselves as having similar functional abilities in carrying out work activities at the initial session. The excursion-based group remained more independent in general ADLs at the final session, but the participants in the force-based group perceived their ability to function in work related activities as being better than that of the excursion-based group. There was no final sport score for the force-based group, as the only participant who engaged in sport activities in the force-based group was non-adherent to attending his final treatment session.

These scores do not show a specific pattern, nor do they support the higher SG scores of the force-based group at the initial session, and the excursion-based group at the final session. The suspected reason for this is that there were a limited number of participants in this study, in that the final median DASH scores were based on three participants in the excursion-based group and one in the force-based group. It is believed that the results would have been more consistent and reliable and would possible have showed a bigger effect size if there were the intended number of people in this study.

Another aspect that may have limited the overall DASH results of the participants is the fact that the final DASH questionnaire was completed at 12 weeks post-operatively. Research has shown that much of the participants' improvement in functioning occurs between the 12th week and the 12th month postoperatively (May & Silfverskiöld, 1993; Moriya, et al., 2015). Thus results of a DASH questionnaire carried out six or 12 months postoperatively would have given a better representation of the participants' functional abilities in general, work and sport related activities. The active place-and-hold group in the study by Trumble et al. (2010) obtained a final DASH score of 2.0, with a standard deviation of 3.7 at one year post-operatively (Trumble, et al., 2010). This lower score indicated less functional disability than the mean final DASH score of 23.24 in this study, at three months post-operatively.

One of the benefits of the DASH is that it is region specific and thus can be used on a variety of conditions that affect the upper limb (Solway, et al., 2002). This, however can also be seen as a disadvantage as generalised functional measurement tools, such as the DASH, do not always give condition- specific results. This is a concern in conditions such as FTIs as the injury is not always very disabling, but still severe, which is not always adequately represented by the DASH results (Libberecht, et al., 2006). This may also be the reason that minimal change in scores were noticed from the initial to final session as neither groups illustrated a change in scores of more than 12.5.

Beaton et al (2001) report that their study found the DASH to be responsive to change before and after treatment, have a good construct validity and a high test-retest reliability and internal consistency in a variety of proximal and distal conditions, including those with small changes in the acute phase (Beaton, et al., 2001; Solway, et al., 2002). Kitis et al. (2009) found the DASH to be beneficial in their study and recommended the use of the DASH to monitor the patient's functional improvement or decline after a FTR (Kitis, et al., 2009). Another positive aspect of using the DASH as an outcome measurement tool is that, while some research indicates that it is difficult to compare the results of participants with differing injuries (Libberecht, et al., 2006), the DASH was seen to have no significant difference between participant with single finger injuries and those with multiple finger injuries (Trumble, et al., 2010).

5.4.3. Participant Satisfaction Questionnaire

'Patient satisfaction is at the very heart of healthcare; even the most technically competent care is meaningless if it does not satisfy the users' (Lochoro, 2004, p. 248). Many studies relating to FTIs, surgery and rehabilitation have been published over the past 40 years, but very few of these include an outcome measure that assesses the participants' satisfaction (Chesney, et al., 2011). The majority of the studies measure the ROM, strength and some measure quality of life, but it is rare to find a study that discusses how satisfied the participant was with their surgery, therapy and their overall outcome. More recently, researchers have started emphasising the importance of including a measure of participant satisfaction in FTI research (Trumble, et al., 2010; Chesney, et al., 2011). The ultimate goal of rehabilitating any patient with a hand injury is to equip them to return to their ADLs in a way in which they are satisfied. Therefore the third objective of the study was to determine the satisfaction with the outcomes of patients with FTI, who are being treated using either the excursion-based approach or the force-based approach.

Three of the five items mentioned in the participant satisfaction questionnaire showed no difference in median satisfaction scores between the two groups. The force group scored significantly lower, and was thus more satisfied in the remaining two items, which included the participants' 'satisfaction with appearance of the hand' and 'satisfaction with functionality of the hand' items. Overall the force-based group was classified as being 'very satisfied', while the excursion based group was classified as being 'a bit satisfied' with their results. These scores do not support the fact that the excursion-based group gained better active SG scores and perceived themselves as having better functioning in general ADL activities than the force-based group.

The participant satisfaction levels of both groups were higher than expected as it was thought that the participants' limited active ROM and inability to function independently in ADLs would have decreased their satisfaction levels. Our findings contradicted those of Trumble et al. (2010) who found that satisfaction was high in participants who had regained their active ROM and their ability to carry out functional activities independently (Trumble, et al., 2010).

There are several possible reasons for the difference in findings between this study and the study by Trumble et al. (2010), as well as the fact that these findings don't support the ROM and DASH outcomes found in this study. Reasons could include the participants having a lack of insight into their condition or treatment, low expectations for their recovery and answering the satisfaction questionnaire in a biased manner so as not to offend the researcher or jeopardize their future treatment (Sitzia & Wood, 1997; Bouaiti, et al., 2016). It is likely that the results obtained are not an accurate representation of an under-resourced population as the force-based scores are based on one participant's ratings and the excursion-based scores on the ratings of three participants. In order to confirm that these findings are representative of a larger under-resourced population, a similar study with a larger population should be carried out.

One participant in particular was 'a bit dissatisfied' and 'very dissatisfied' in the majority of the items on the questionnaire. This could be a result of the fact that this participant injured his dominant hand and was a student, machine operator and weight lifter, and was thus severely incapacitated by his injury. It could also be due to the fact that this participant was the youngest, the most highly educated and perhaps had the highest expectations and understanding of the implications of his injury and lack of recovery (Bouaiti, et al., 2016). This participant's satisfaction scores were the worst in the group despite having only one injured finger, while the remaining participants had two - three injured fingers. These findings contradicted those of Trumble et al. (2010), who found that participants with multiple finger injuries were significantly less satisfied than participants who had experienced a single finger FTI, regardless of the treatment approach used (Trumble, et al., 2010).

The inclusion of the participant satisfaction questionnaire was beneficial in this study as it gave the researcher insight into how the participants felt about the treatment they received and their outcomes. Only one other FTI related study, by Trumble et al (2010), included a participant satisfaction questionnaire and the study was performed in a well-resourced community in a developed country (Trumble, et al., 2010). Although the questionnaire in this study differed from the one used in the study by Trumble et al. (2010) they both analysed similar items (Trumble, et al., 2010). There was no evidence of any FTI related studies carried out in South Africa that included the use of a participant satisfaction questionnaire. It was therefore not possible to compare the results obtained to those expected from other under-resourced community receiving treatment at a public hospital in South Africa.

5.5 Factors in the South African context which affected the outcomes

The last objective of the study was to explore the outcomes of patients with FTI in relation to being treated in a South African public hospital context. The researcher identified a number of contextual factors that could be considered as having an effect on the outcomes achieved in this study.

5.5.1 Adherence to the Treatment Programme

The data collection took place over a period of 12 months, with each participant's treatment programme running for 12 weeks during this 12 month period. A power analysis of a similar study by Trumble et al. (2010) indicated that in order to have a power of 80% then there should be at least 13 fingers in each group (Trumble, et al., 2010). The introduction of new participants into the trial was ended at the end of the 12 month period, despite not obtaining the optimal number of fingers.

Overall five participants, with a total of 10 injured fingers were introduced to the study during the allocated 12 month period. Several other potential participants with repaired FTIs at TMH were excluded from this study due to them not fitting the inclusion criteria. The most common reasons for exclusion were that they had tendon injuries in zones other than II and III, they did not receive surgery within the first 10 days after their injury or they had comorbid or pre-existing injuries affecting their upper limb function. The five participants were divided into the two groups randomly and this resulted in there being two participants, with three injured fingers (30%) in the force-based group and 3 participants with seven injured fingers (70%) in the excursion-based group.

Of these five participants, one was not adherent to following a home programme or attending follow up treatment sessions. He arrived for his treatment session several times without his splint on and did not arrive for his eight week and 12 week treatment sessions. This resulted in the end number of adherent participants being four with nine injured fingers. Mncube and Puckree (2014) reported that expecting participants to come for treatment sessions twice a week or more would result in non-adherence (Mncube & Puckree, 2014). Despite asking participants to come for therapy only once a week for the initial six weeks and once every two weeks for the final six weeks, a non-adherence rate of 20% was still noted in this study.

The non-adherent participant was one of the two participants in the force-based group. This resulted in the comparisons of the outcomes of the two groups at 12 weeks being less reliable as there was only one participant with two injured fingers in the force-based group and three participants with seven injured fingers in the excursion-based group. As mentioned previously, it is suspected that the remaining participants were not fully adherent to following their home exercise programmes as advised, which was evident in the poor passive ROM results, but this could not be confirmed.

The most common factors that cause participants from an under-resourced community in South Africa to be non-adherent to attending therapy sessions is an inability to take time off work to attend their treatment session, living or working far from the hospital, forgetting the date of their session, a lack of insight into their condition and treatment programme and a lack of funds to pay for the public transport to get to the hospital. Several of these elements were eliminated from this study by thoroughly explaining the severity of the participant's injury and the importance of attending follow up sessions. The researcher also contacted each participant one day prior to their session to remind them of the date and time of their session and they were given money at each session to cover the cost of their transport to the hospital for their following session.

5.5.2 Demographic factors

The majority of published flexor tendon studies in the literature are carried out in well-resourced communities in developed countries. The demographic factors of participants in those studies differ greatly from those of the participants in this study. One participant in particular, from the excursion-based group, came from a very under-resourced environment, where he did not have access to running water and electricity in his home. These circumstances are commonly experienced by many South Africans living in under-resourced communities in both urban and rural areas (Atabuga, et al., 2011). It is difficult to compare the results of this study with those carried out in well-resourced communities, due to the differing contexts in which treatment is taking place. Therapists and researchers should consider these aspects when treating patients in under-resourced environments by adapting the patients' home programmes and supplying patients with the materials required to clean and dress their wounds.

The participants in this study and the majority of patients receiving treatment in public hospitals are from under-resourced communities who are unable to afford medical aid or to pay for the costs of private medical treatment. As a result, they are obliged to seek treatment at public hospitals where the access to specialised care is limited and the level of services received is often poor due to over-crowding and under staffing (Atabuga, et al., 2011). The problem of under-resourced public hospitals is further exacerbated by the fact that there is an increase in the number of violent/crime related injuries amongst member of under-resourced communities (Atabuga, et al., 2011). It is thus evident that members of under-resourced communities are high risk for acquiring a FTI and those who do injure their flexor tendons are disadvantaged in terms of the quality of healthcare that they receive due to limited resources in public hospitals in South Africa. Limited resources and unfavourable circumstances affect participants' outcomes in various ways including increasing their risk of developing an infection due to a lack of running water, increasing their risk of tendon ruptures as participants often return to work before they are ready as they are at risk of losing their jobs and increasing the likelihood of them being non-adherent as they cannot afford the transport costs to return to the hospital for follow up visits.

5.5.3 Surgery and Therapeutic Treatment

Rehabilitating a patient with very little knowledge about the severity of the FTI and the nature of the surgical procedure performed is a reality with which many therapists in South African public hospitals are faced. High patient loads and the limited number of doctors often result in doctors having less time to write detailed hospital notes and consult with the therapist on the postoperative rehabilitation plan. Due to the nature of the intern and community service employment contracts in public hospitals in South Africa, there is a frequent turnover of therapists and doctors (Mncube & Puckree, 2014), resulting in a large number of inexperienced health workers and a lack of consistency in the surgical and rehabilitation programmes (Mncube & Puckree, 2014). Detailed data discussing each surgeon's training and experience in treating FTIs was not collected, and thus the effects of these aspects on the participants' outcomes could not be comprehensively discussed.

The lack of detailed surgical records indicating the reasons for repairing only the FDP in some cases and both the FDS and the FDP in others made it difficult to judge to what extent the surgeons used research evidence-based literature to guide their treatment. Due to the many challenges faced in public hospitals, it appears that the surgeons chose techniques based on their clinical judgement and the context of the participants, rather than evidence-based literature from developed countries. These techniques could differ from day to day and patient to patient. While research has proven that using an isolated FDP repair versus a combined FDP and FDS repair does have an effect on the outcomes of FTI research, the results obtained in this study differed from those seen in literature. In this study the excursion-based group, where only the FDP was repaired, obtained better final results than the force-based group, which consisted of participants who had received a combined FDS and FDP repair. These findings possibly support the fact that the surgeons are successfully using clinical reasoning to guide their treatment rather than the evidence-based literature from developed countries.

Ideally, patients suffering from FTIs should be brought to the hospital soon after their injury and taken into surgery the same day for a FTR by an experienced doctor (Tang, 2007a; Rigo & Røkkum, 2016). This however is not always possible in public hospitals in South Africa as patients are known to delay seeking medical care for several days after their injury and when they do arrive at the hospital waiting lists for surgical procedures are often long, due to high patient loads and limited resources. In this study 20% of the participants received surgery one week after their injury and a further 20% of participants received surgery more than a week after their injury. Literature states that a delay of FTR by more than a week has been found to be a negative predictor in the patient's functional results in zone I, II and III FTIs (Rigo & Røkkum, 2016).

5.5.4 Range of Motion

As previously discussed, a lack of experienced and specially trained therapists, surgeons and nurses is a very common problem experienced in the majority of public hospitals in South Africa. This study found that the inexperience/lack of specialised training of the medical professionals at TMH affected both the assessment of ROM, as seen in the inconsistent blinded ROM measurements, as well as the ROM outcomes, in that all participants in this study developed adhesions and achieved poor active SG scores.

The surgeons operating at TMH were further pressured by working in an under-resourced public hospital with high patient loads and limited human resources, which lead to their surgical notes being very brief. This lack of information on the nature of the surgical repair made it difficult for the researcher to accurately interpret the ROM results achieved by participants. The researcher as well as other therapists working in similar settings, are thus being forced to become less dependent on the surgical background of the patient as provided by the doctors and base their decisions and reasoning more on the clinical picture of the patient in front of them. While this is not what literature recommends, it has become a reality for many therapists when treating patients with a repaired FTI in public hospitals in South Africa.

The ROM results of this study indicate that using evidence-based research from developed countries is not necessarily best practice for patients from under-resourced public hospitals. It is therefore evident that both surgeons and therapists working in public hospitals in South Africa need to use their experience and clinical judgement to adjust the recommendations from literature to suit the specific needs and context of their patients. While this was attempted during this study, the ROM results showed that more structured and more aggressive active motion treatment approaches are required to gain optimal outcomes with these patients.

5.5.5 Disability of the Shoulder, Arm and Hand Questionnaire

While the results from the DASH questionnaire are useful in gaining a better understanding of the participants functioning, it would not be fair to assume that the way in which the questionnaire is structured will be equally as effective for participants of a variety of SESs, culture, education levels and home languages

(Solway, et al., 2002). For example, it might be difficult for a participant who does not have electricity to comment on their ability to change a light bulb or blow-dry their hair, as they may never have been exposed to these tasks before. Other leisure activities such as Frisbee, badminton, knitting, golf and tennis may also be unfamiliar to participants with a lower SES.

Despite the questionnaire being phrased in South African English it was suspected that participants with lower education levels did not fully comprehend terms such as ‘tingling’ and ‘moderate difficulty’, or concepts such as ‘feeling capable and confident in their abilities’. The participants also had difficulty understanding the various Likert scales throughout the three sections of the questionnaire. To ensure that all participants understood the questionnaire equally, the researcher went through the questionnaire with the participants and gave them the opportunity to ask questions or clarify items. While it is believed that this may have improved participant understanding, it also could have had a negative impact on the results of the questionnaire as the participants may have been biased because they knew the researcher would see their answers.

It is suspected that the participants SES, education levels and home language may have negatively affected the DASH scores obtained, as they were rating certain activities that they may not have fully understood. A cross cultural adaptation would have been useful in this study, as it would have allowed the therapists to simplify unfamiliar phrases and terms (Solway, et al., 2002), thus enabling participants of varying cultures, education levels and SES to be on the same level when answering the questions independently which would have resulted in more realistic and reliable outcomes.

5.5.6 Participant Satisfaction Questionnaire

The participant satisfaction results obtained in this study are relatively high, despite the participants not regaining their active ROM and independence in ADLs. It is suspected that there are several reasons for this, all of which stem from the fact that the participants came from an under-resourced community and received treatment at a public hospital. Possible reasons would include the participants having a lack of insight into their condition (Bouaiti, et al., 2016) and low expectations of recovery due to previous negative experiences at public hospitals (Sitzia & Wood, 1997). Furthermore ‘social desirability response bias argues that patients may report greater satisfaction than they actually feel because they believe positive comments are more acceptable to survey administrators’ (Sitzia & Wood, 1997, p. 1836) which could also have caused higher satisfaction scores despite minimal improvements in ROM and function from the initial session to the final session.

5.6 Limitations of the Study

The most influential limitation noted in this study is the small sample size. There were several aspects that resulted in difficulty finding suitable and sufficient participants to participate in this study. These included potential participants declining the invite to participate in this study as they were unable to commit to coming back for weekly treatment sessions and patients being excluded for having concurrent hand injuries and not receiving surgery within the recommended time period. As a result, this study had a low statistical power in comparing the outcomes of a force-based and an excursion-based approach in the treatment of FTIs in an under resourced environment in South Africa.

Another relevant limitation was the lack of knowledge transfer from the doctors to the therapists regarding the nature of the injury and type of surgical repair performed. After reading the participants’ hospital files and interviewing the treating surgeons the researcher still did not have a very good understanding of the number of strands of the FTR or the type of repair performed. This made it difficult for the therapist to know how strong the repair was and how much force should be applied to the repair to initiate movement of the tendon without causing it to re-rupture.

The fact that all participants spoke a different first language and were of a different culture to the researcher acted as a limitation in some aspects of this study. The researcher explained all aspects of the assessment, treatment and home programme in English with demonstrations, but it was possible that some participants did not get a comprehensive understanding of their condition and what was required of them.

A measurement tool related limitation, evident in this study was that the DASH questionnaire was a generic measure of functionality. The purpose of using this measure in the study was to gain an understanding of the amount of functional improvement the participants experienced from the initial session to the final session. The DASH questionnaire did not give a realistic representation of this, due to the items on the questionnaire being too generalised for such a small but serious injury.

The 20% non-adherence rate of the participants was also a limitation in this study. The lack of participants in the force-based group had a large impact on the validity of the comparisons of results made between the two groups at the final sessions. It is likely that the adherence rate of participants would have been worse had the researcher not given the participants money to cover the cost of their transport to the hospital for their treatment sessions.

The timing of the study and treatment sessions was also a limitation noted in this study. Some FTI studies conducted in developed countries kept the participants in hospital for the first several weeks of their rehabilitation programme (Moriya, et al., 2015) while others advised participants to come for treatment two to three times a week initially (Groth, 2005; Kitis, et al., 2009). It is possible that better results would have been obtained if participants were coming to the hospital for treatment twice a week for the initial six weeks and once a week from six weeks onwards. This would have allowed the researcher to monitor their ROM closer and adjust their treatment programme more often to prevent adhesions.

Another time related limitation in this study was that the study was only carried out for 12 weeks. Research has shown that FTIs continue to show improvement for up to 12 months after the FTR (May & Silfverskiöld, 1993) and it is therefore necessary to track the participant's outcomes for up to one year to gain a good understanding of their recovery. It is important to remember that the limited financial resources of both the hospital and the participants might make attending therapy more frequently and for a longer period unrealistic. Although measuring the participants' outcomes for a longer period of time might have given the researcher a better understanding of the participants overall improvement or decline, research has found that their ROM results, measured at three weeks and eight weeks postoperatively, showed a significant correlation to the long term outcomes of the participants (Silfverskiöld & Andersson, 1993; Rigo & Røkkum, 2016)

5.7 Summary

The sample size in this study was smaller than initially planned due to there being a lack of appropriate patients who fitted the inclusion criteria during the one year data collection period. All outcomes represented in this study are based on the results of seven injured fingers in the excursion-based group and three injured fingers in the force-based group, of which one was not adherent to attending the final session. The sample size was thus very small, which resulted in the individual differences of each participant having a much greater impact on the overall outcomes of the study. It was therefore difficult to say whether the results obtained were attributed to the treatment approaches used, or the participants' individual medical, personal and social differences.

There were no significant differences noted in the personal demographics of the two treatment groups. The only medical factor that appears to be significantly different between the two groups was the fact that all the fingers in the force-based group received a combined FTR of the FDS and FDP, while all the fingers in the excursion-based group received an isolated FTR of the FDP tendon. There is much debate in the literature around which of these repairs is more effective in the treatment of FTIs. This study found participants who had received an isolated FDP repair to have better active ROM results at their 12 week session.

The median SG scores for the force-based group were higher than those of the excursion-based group at the initial session. Over the 12 week rehabilitation period the force-based group's scores decreased and the excursion based group's scores increased resulting in the final passive, place-and-hold and active SG scores of the excursion-based group to be higher than those of the force-based group. It is believed that both the isolated FDP repair and the excursion-based approach were responsible for these scores being higher than the force-based group. However, both groups did have poor place-and-hold and active scores throughout the rehabilitation period, rendering neither of the approaches as successful in restoring ROM in this setting.

The median DASH scores improved for all three sections in both groups except for the work section of the excursion-based group where the participants felt that they had a decline in function from week one to week 12. However, all the improvements in functioning were less than the minimum clinically important difference. The excursion-based group perceived themselves as having better functionality in general ADLs at the final session while the force-based DASH scores indicated that this group was more independent in work related activities at the final session.

The participant satisfaction questionnaire which was completed by the participants at the final treatment session, indicated that overall the force-based group was significantly more satisfied with their treatment and outcomes than the excursion-based group. More specifically, the force-based group was slightly more satisfied with the appearance and functionality of their hand at their final session. These findings were unexpected as, at the final treatment session, the force-based group had poorer active ROM results and independence in general ADL activities than the excursion-based group.

The outcomes of this study were affected by many factors specific to living in an under-resourced community and receiving surgery and rehabilitation in a public hospital in South Africa. These outcomes include, but are not limited to, having no access to running water and electricity, difficulty returning to hospital for follow up treatment sessions, low education levels of participants, difficulty communicating with participants, staff members with little experience in the field of flexor tendon surgery and rehabilitation and a lack of information on the nature of the FTR performed. These factors had a very apparent effect on the outcomes of the participants, which was not noticed in any FTI related literature carried out in developed countries.

CHAPTER 6- CONCLUSION

The aim of this study was to compare and determine the effectiveness of an excursion-based and a force-based SWM approach in the treatment of participants with a repaired FTI in Zone II or III, over a 12 week rehabilitation period. The participants were from under-resourced communities in Johannesburg, South Africa and they received surgery and rehabilitation at a public hospital. These participants varied in age, gender, home language, education level and SES, and were an adequate representation of the population attending public hospitals in South Africa.

The personal and social context of the patients, experience of health professionals and resources available in public hospitals in South Africa differ vastly to those available in better developed first world countries (Singer & Maloon, 1988; Mncube & Puckree, 2014). It was thus necessary to determine if the rehabilitation approaches, which had been successfully used in developed countries, were effective in treating patients in public hospitals in South Africa. This was done by measuring the passive, place-and-hold and active ROM of the participants at each treatment session. The participants were also required to complete the DASH questionnaire at their initial and final treatment session and a participant satisfaction questionnaire at their final session.

The excursion-based group showed an improvement in all SG scores over the rehabilitation period, while the force-based group showed a decline. At the 12 week session all the SG scores for the force-based group were lower than those of the excursion-based group. The DASH scores improved from the initial to the final session for all sections of both groups, except the work section of the excursion-based group. The excursion-based group's DASH scores showed that they had fewer difficulties participating in general ADLs than the force-based group. Despite developing adhesions and having difficulty performing many activities, the participants in the force-based group were classified as being 'very satisfied', while the excursion-based group was classified as being 'a bit satisfied' at their final session.

Based on these results it is likely that the excursion-based approach would achieve better outcomes, in an under-resourced community, than the force-based approach. However, when the outcomes were reviewed at the final treatment session it was noted that place-and-hold and active SG scores for both groups were rated as poor, both groups continued to experience difficulties carrying out general, work and sport activities and neither of the groups was fully satisfied with the treatment they had received or their outcomes. The information gained from this research study demonstrates that treating patients in under-resourced public hospitals in South Africa has many challenges that would be unfamiliar to surgeons and therapists treating in developed countries.

It is thus clear that neither of these approaches, or SWM in general, should be used to rehabilitate repaired FTIs of patients who are living in under-resourced communities and received surgery and therapy at public hospitals in South Africa. Therapists rehabilitating patients with repaired FTIs need to continue to search for a treatment approach that is safe enough to use on a variety of patients, where very little information is known about the surgical repair procedure and the knowledge and experience of the surgeons differs greatly. This approach should not only be safe enough to use on FTRs with a variety of strengths, but also simple enough for therapists with very little experience in flexor tendon rehabilitation to understand and apply practically. The simplicity of the approach should extend to the way in which it is presented to the patients, who differ greatly in their cultures, education levels, home languages and socioeconomic status.

6.1 Recommendations for Future Research

The outcomes gained in this study are relevant for the development of flexor tendon rehabilitation in public hospitals in South Africa. Due to the many limitations noted in this study, it would be difficult to assert that the outcomes represent the entire under-resourced population of South Africa who receive treatment for FTIs at public hospitals. It is therefore recommended that a similar study be carried out with a larger sample size. This could be achieved by extending the length of the study from one year to three years and/or by doing the same study at various different public hospitals throughout South Africa and combining the results. The results obtained in such a study would be more representative of the entire under-resourced population of South Africa.

It is recommended that there is a better exchange of information between the surgeons and the researcher in any future FTI research studies carried out in public hospitals in South Africa. The researcher should provide the surgeon with a list of detailed questions which he should answer, regarding the nature of the surgery. These questions should enquire about the type of suture material used, the number of strands used, the suture technique used, which tendons were repaired and which other structures were repaired i.e. the sheath or digital nerves. This information will guide the researcher in deciding on the best course of action for each patient as well as be a useful source of information when reviewing and discussing the outcomes of the patients.

It is recommended that blinded ROM measurements are included in future studies to eliminate any chance of researcher bias in the participants' results. Although it was intended to include these results in this study, this was not feasible as the researcher and therapists' ROM scores differed greatly, due to the blinded therapists having very little experience in measuring ROM. It is thus recommended that, in the future, the blinded measurements be performed by therapists with three or more years of experience in the field of hand therapy. Alternatively, the therapists could undergo a comprehensive practical training session, where they are required to practice measuring passive, place-and-hold and active ROM on several patients with several different injuries prior to the initiation of the study.

Many authors have stated that the participants' outcomes continue to show improvements up to one year postoperatively (May & Silfverskiöld, 1993; Baktir, et al., 1996; Libberecht, et al., 2006; Moriya, et al., 2015). Future studies should increase the data collection period for each participant to 12 months. The frequency of follow-up visits could have been decreased to monthly visits from six months to one year postoperatively. It would be beneficial for the ROM to be measured at every session, the DASH questionnaire to be completed at week one, week 12, six months and 12 months postoperatively and the participant satisfaction questionnaire to be completed at week 12 and one year postoperatively. Researchers should take into consideration that it might be difficult to ensure adherence of participants over such a long period of time.

While the DASH questionnaire did provide useful information on the participants' ability to function in ADLs, it was a generalised questionnaire and the results obtained were not specific and it thus did not provide detailed enough information on the functioning of patients with repaired FTIs. Researchers have recommended that a functional assessment is developed which specifically focuses on the ability of patients with repaired FTIs to regain independence in ADLs (Libberecht, et al., 2006).

A cross cultural adaptation should be carried out on both the DASH questionnaire (or the questionnaire used to replace it) and the participant satisfaction questionnaire before they are used in future studies in public hospitals in South Africa, to ensure that the items included are relevant and comprehensible to the participants who will be completing them. This would result in the quality of the participant ratings being improved and the outcomes being more accurate and essentially more useful in the study.

It would also be recommended in the future, that the assessment and treatment sessions be conducted in the participants' home language. If this is not possible, then it would be ideal to get a translator to translate the sessions and home programmes to ensure that every participant has a good understanding of their condition and the treatment requirements. Providing participants with DASH and participant satisfaction questionnaires in their home language would not only make it easier for them to answer the questions accurately but it would also enable the participants to complete the questionnaire independently. This would eliminate the aspect of the participants' ratings being influenced by the researcher's involvement.

The current findings of this study indicate that the SWM approaches introduced, may not be appropriate for patients from under-resourced communities who are receiving treatment at a public hospital in South Africa. It is however recommended that a similar study be carried out in the future, using the same methodology and the above-mentioned recommendations to determine whether these treatment approaches would be more successful in treating patients with a FTI from well-resourced communities, who received treatment in a private hospital in South Africa.

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APPENDIX A- Ethical Clearance Certificate

R14/49 Ms Michelle Hellyar

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130941

NAME:
(Principal Investigator) Ms Michelle Hellyar

DEPARTMENT: Occupational Therapy
Tambo Memorial Hospital

PROJECT TITLE: Comparison of Excursion-Based Approach with Force-Based Approach in Rehabilitation of Repaired Flexor Tendons in Zone II and III

DATE CONSIDERED: 27/09/2013

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Denise Franzsen

APPROVED BY:
Professor PE Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 11/10/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**.

Principal Investigator Signature Date 20/10/2013

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B- Letter of Permission to Conduct Research

Letter of Permission from TMH

Dear Dr. Christoforou

I have registered to do my masters in occupational therapy at The University of Witwatersrand via dissertation. I will be required to complete a dissertation based on research that I have conducted in the area of hand therapy at Tambo Memorial Hospital (TMH). As flexor tendon injuries are a common problem experienced by clients at Tambo Memorial Hospital, I have chosen to do a study comparing the excursion-based approach with the force-based approach in the rehabilitation of repaired flexor tendons in zone II and III.

This study will consist of using either an excursion-based approach (the active place-and-hold mobilization approach) or a force-based approach (the modified pyramid approach) to rehabilitate clients who have had a flexor tendon repair in zones II or III at TMH. A splint will be made for each client at their initial session, after which they will be given an exercise program. This exercise program will be adjusted over a period of 12 weeks. I will also be required to access the client's medical records to gain information on the nature of their injury as well as the exact procedure used to repair their tendon in surgery.

The data collection part of the research will start in January 2014 and continue until April 2015, at the latest. After this time the results will be analysed and written up as a research dissertation. After completion of the dissertation the results of this study will be made available to the management of TMH, the occupational therapy department at TMH as well as any clients who request to find out more about the results of the study.

Kind Regards

Michelle Hellyar

BSc OT (Wits), DHT (Pret)

4/1/2014

APPENDIX C- Client Information Sheet

Client Information Sheet

Title: Comparison of Excursion-Based Approach with Force-Based Approach in Rehabilitation of Repaired Flexor Tendons in Zone II and III

Good day,

I, Michelle Hellyar am an occupational therapist registered for a Masters in Occupational Therapy, at The University of Witwatersrand. As part of my dissertation I will be doing research at Tambo Memorial Hospital (TMH) on the effectiveness of two newly introduced approaches which will be used to treat repaired flexor tendon injuries.

Research in leading countries, including America, has shown that the two flexor tendon repair approaches that I am studying both have had very good results. I would like to see if introducing these approaches to the hand therapy program in the OT department at Tambo Memorial Hospital will result in similar outcomes for clients with repaired flexor tendon injuries, as the context differs from that in the USA.

I am inviting you to take part in the study and I would be most grateful if you would consider participating in this research project.

What do we expect from clients in the study?

You have been considered to be a part of this research study as you have a repaired flexor tendon injury that fits the criteria for my research study. If you do chose to be a part of this research you will be randomly allocated to one of two treatment groups and receive treatment according to either an excursion-based approach or a force-based approach. Neither of these treatments has been proved to be better or worse than the other.

The research process will take place over a period of 12 weeks, but some clients may need continued treatment after 12 weeks. If you choose to participate in the research you will be required to come to an OT session once a week (for the first 6 weeks) and once every second week (for the next 6 weeks). At the first session I will make a splint for you and teach you the exercises you should do at home. You will also be asked to assist the therapist to complete a form with your personal details and medical information.

You will be expected to do the exercises and wear the splint continuously for 24 hours a day at home. At each therapy session a therapist will measure your movement and I will give you more exercises to do. After several weeks (approximately 6) I will remove the splint and give you more exercises. I will tell you what activities you can and cannot do with your injured hand. It is very important that you follow the programme as closely as possible to ensure that your treatment is successful.

After you have attended OT for 12 weeks you will be given two questionnaires to complete. The first one allows you to comment on how satisfied you are with the treatment that you received and the second one asks you which daily activities are you able to do yourself and which ones you still need help with.

Are there risks or benefits to participation?

The benefits to being a part of this study are that newly developed, internationally approved approaches will be used to treat your injury. These approaches are highly recommended by therapists working in America, as they have had good results when using them to treat clients. You will be provided with feedback on the results of the study once it is finished on request.

With all approaches used to rehabilitate flexor tendon injuries there maybe risk of complications. There are no specific risks, discomforts or side effects that will be experienced by you if you follow the newly introduced approaches. If you do develop a complication, as with all flexor tendon injuries, you will be referred to the orthopaedic surgeon at TMH who will assess your hand and decide, with the therapist on the best course of treatment.

May I withdraw from the study?

Yes, you are allowed to leave the study at any time during the research process without giving a reason, if you feel that you no longer wish to be a part of the research. Remember that choosing to participate in this study is completely voluntary and there will be no negative effects on you or your future treatment if you decide to leave the study. If you do leave the study, you will be encouraged to continue attending occupational therapy as a client unrelated to the research, so that we can continue to rehabilitate your hand until it is working effectively.

What about confidentiality?

Any information that you provide during the research, such as your personal information, measurements of your movement and answers to your questionnaires will be kept confidential at all times during and after the study. All information gained from you will be recorded under codes, and not under your name. The list with your name on will be kept separate by me at a secure separate location. When writing up the research report the clients will remain anonymous, by ensuring that no names are used.

I am adequately skilled and able to carry out this research as I have completed a post-graduate diploma in hand therapy and I have attended several workshops both in

South Africa and internationally that focus on the rehabilitation of repaired flexor tendon injuries. If you have any queries, more information can be obtained from myself on my number

Work: 011 898 8299

E-mail: michellehellyar@gmail.com

Contact details of HREC administrator and chair at the University of the Witwatersrand- for reporting of complaints / problems. Should there be any ethical queries about the research please feel free to contact the Human Research Ethics Committee (HREC) Chairman Prof P Cleaton-Jones at 011 7171234 or anisa.keshav@wits.ac.za for reporting of complaints / problems

If you are willing to participate please read and sign the consent form that follows.

Thank you for your co-operation

Michelle Hellyar

BSc OT (Wits), DTH (Pret)

APPENDIX D- Informed Consent Form

Informed Consent

I, ______________________________ (name of client) have read the client information sheet for the study: **Comparison of Excursion-Based Approach with Force-Based Approach in Rehabilitation of Repaired flexor tendons in Zone II and III.**

I understand what the treatment program and research process entails. I am choosing from my own free will to participate in this research and follow the treatment approach that is advised by the therapist for a minimum period of 12 weeks.

I accept the potential risks and benefits relating to treatment of all repaired tendon injuries. I understand my rights and that I am able to resign as a research participant at any given time throughout the research process, although I will be required to continue therapy for my own benefit.

Signature of Client **Date**

______________________ ______________________

Signature of Researcher **Date**

______________________ ______________________

APPENDIX E- Personal and Medical Information Form

Client Code: ________

PERSONAL DEMOGRAPHICS AND

MEDICAL INFORMATION

To be kept separate

Client's Name: ______________________________

Hospital Number: ______________________________

Phone Number: ______________________________

____

Date of Injury: ______________________________

Client Code: _______

Personal Details

Gender: Male ☐ Female ☐

Date of birth/age: ______________________________

Highest level of education: ______________________________

Occupation: ______________________________

Home language: ______________________________

Hand dominance: Right ☐ Left ☐ Ambidextrous ☐

Does client smoke cigarettes: Yes ☐ No ☐ Occasionally ☐

Level of understanding English: Full ☐ No ☐ Some ☐

Resources at home: Electricity Yes ☐ No ☐

Running water Yes ☐ No ☐

Details of Injury

Cause of injury: ______________________________

Date of Injury: ______________________________

Nature of the Injury

- Hand injured: Right ☐ Left ☐
- Zone of injury: II ☐ III ☐
- Complete or partial (> 50%) injury: Complete ☐ Partial ☐
- Fingers and tendons (FDS and/or FDP) injured:______________________________

____

____

____

____

Client Code: ________

Other structures injured: ____

____

____

Work related injury: Yes ☐ No ☐

Pre-existing injuries or medical conditions: ______________________________

____

____

Surgical Details

Date of repair: ______________________________

Time between injury and repair: ____________________

Surgery performed by: __________________________

Procedure (FDP and/or FDS repaired): ______________________________

____

____

Repair of digital nerve: Yes ☐ No ☐

If yes, which one: ____

Sheath repaired: Yes ☐ No ☐

Other surgery performed on current injury: Yes ☐ No ☐

Type of suture repair and number of strands used: ______________________

____

____

Client Code: ________

Therapy Details

Therapy approach being used: ______________________________

Date of initial therapy session: ______________________________

Time between repair and initial therapy session: ______________________________

Adherence to attending therapy: Yes (>70%) ☐ No (<30%) ☐

Partial (30-70%) ☐

Adherence to home programs: Yes ☐ No ☐ Sometimes ☐

Complications noted? ______________________________

____

____

Date complication was noticed: ______________________________

Does client require follow up surgery: Yes ☐ No ☐

If yes, what surgery is recommended? ______________________________

____

APPENDIX F- Range of Motion Record Sheet

Client Code: _______

ROM RECORD SHEET

Finger being assessed:_______________

RESEARCHER	Date of Ax:	Session: 1 (Initial Session)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

BLINDED THERAPIST	Date of Ax:	Session: 1 (Initial Session)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

RESEARCHER	Date of Ax:	Session: 2 (10-14 days)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

RESEARCHER	Date of Ax:	Session: 3 (3 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

Client Code: _______

Finger being assessed:_______________

RESEARCHER	Date of Ax:	Session: 4 (4 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

RESEARCHER	Date of Ax:	Session: 5 (5 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

RESEARCHER	Date of Ax:	Session: 6 (6 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

BLINDED THERAPIST	Date of Ax:	Session: 6 (6 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

RESEARCHER	Date of Ax:	Session: 7 (8 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

Client Code: ________

Finger being assessed:_______________

RESEARCHER	Date of Ax:	Session: 8 (10 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

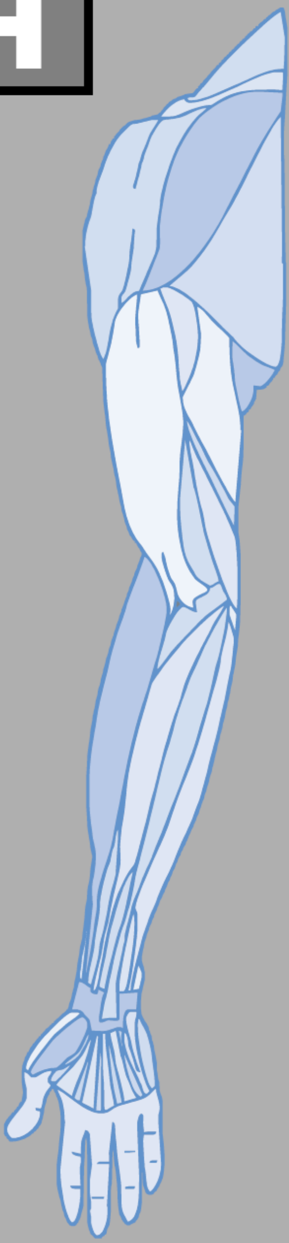
RESEARCHER	Date of Ax:	Session: 9 (12 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

BLINDED THERAPIST	Date of Ax:	Session: 9 (12 Weeks)	
	Passive	Place and Hold	Active
MP			
PIP			
DIP			

APPENDIX G- The DASH Questionnaire

DISABILITIES OF THE ARM, SHOULDER AND HAND

THE DASH



INSTRUCTIONS

This questionnaire asks about your symptoms as well as your ability to perform certain activities.

Please answer *every question*, based on your condition in the last week, by circling the appropriate number.

If you did not have the opportunity to perform an activity in the past week, please make your *best estimate* on which response would be the most accurate.

It doesn't matter which hand or arm you use to perform the activity; please answer based on your ability regardless of how you perform the task.

South African English translation developed by Oxford Outcomes Ltd, Oxford, UK under contract by GlaxoSmithKline, UK

DISABILITIES OF THE ARM, SHOULDER AND HAND

Please rate your ability to perform the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new bottle.	1	2	3	4	5
2. Write.	1	2	3	4	5
3. Turn a key.	1	2	3	4	5
4. Prepare a meal.	1	2	3	4	5
5. Push open a heavy door.	1	2	3	4	5
6. Place an object on a shelf above your head.	1	2	3	4	5
7. Do heavy household chores (e.g. wash walls, wash floors).	1	2	3	4	5
8. Garden or do yard work.	1	2	3	4	5
9. Make a bed.	1	2	3	4	5
10. Carry a shopping bag or briefcase.	1	2	3	4	5
11. Carry a heavy object (over 5 kg).	1	2	3	4	5
12. Change a light bulb overhead.	1	2	3	4	5
13. Wash or blow-dry your hair.	1	2	3	4	5
14. Wash your back.	1	2	3	4	5
15. Put on a pullover jersey.	1	2	3	4	5
16. Use a knife to cut food.	1	2	3	4	5
17. Recreational activities which require little effort (e.g. card playing, knitting, etc.).	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g. golf, hammering, tennis, etc.).	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g. playing frisbee, badminton, etc.).	1	2	3	4	5
20. Manage transportation needs (getting from one place to another).	1	2	3	4	5
21. Sexual activities.	1	2	3	4	5

DISABILITIES OF THE ARM, SHOULDER AND HAND

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A LOT	EXTREMELY
22. During the past week, *to what extent* has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups? *(Circle number.)*	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem? *(Circle number.)*	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. *(Circle number.)*

	NONE	MILD	MODERATE	SEVERE	EXTREME
24. Arm, shoulder or hand pain.	1	2	3	4	5
25. Arm, shoulder or hand pain when you performed any specific activity.	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5
27. Weakness in your arm, shoulder or hand.	1	2	3	4	5
28. Stiffness in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? *(Circle number.)*	1	2	3	4	5

	STRONGLY AGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	AGREE	STRONGLY AGREE
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem. *(Circle number.)*	1	2	3	4	5

DASH DISABILITY/SYMPTOM SCORE = $\left[\frac{\text{(sum of n responses)}}{n} - 1\right] \times 25$, where n is equal to the number of completed responses.

A DASH score may not be calculated if there are more than 3 missing items.

DISABILITIES OF THE ARM, SHOULDER AND HAND

WORK MODULE (OPTIONAL)

The following questions ask about the impact of your arm, shoulder or hand problem on your ability to work (including homemaking if that is your main work role).

Please indicate what your job/work is: ____________________

❑ I do not work. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty…

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. …using your usual technique for your work?	1	2	3	4	5
2. …doing your usual work because of arm, shoulder or hand pain?	1	2	3	4	5
3. ….doing your work as well as you would like?	1	2	3	4	5
4. …spending your usual amount of time doing your work?	1	2	3	4	5

SPORTS/PERFORMING ARTS MODULE (OPTIONAL)

The following questions relate to the impact of your arm, shoulder or hand problem on playing *your musical instrument or sport or both.*
If you play more than one sport or instrument (or play both), please answer with respect to that activity which is most important to you.

Please indicate the sport or instrument which is most important to you: ____________________

❑ I do not play a sport or an instrument. (You may skip this section.)

Please circle the number that best describes your physical ability in the past week. Did you have any difficulty…

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. …using your usual technique for playing your instrument or sport?	1	2	3	4	5
2. …playing your musical instrument or sport because of arm, shoulder or hand pain?	1	2	3	4	5
3. …playing your musical instrument or sport as well as you would like?	1	2	3	4	5
4. …spending your usual amount of time practising or playing your instrument or sport?	1	2	3	4	5

SCORING THE OPTIONAL MODULES: Add up assigned values for each response; divide by 4 (number of items); subtract 1; multiply by 25.
An optional module score may <u>not</u> be calculated if there are any missing items.

APPENDIX H- Client Satisfaction Questionnaire

Client Code: ___________

Client Satisfaction Questionnaire

The reason for this questionnaire is to find out how satisfied you are with your hand after the surgery and therapy that you had.

Please read the questions below and answer them putting a circle around the number that shows how satisfied you are in each area below.

Circle only 1 number for each question.

	Very Satisfied	A bit Satisfied	Undecided	A bit Dissatisfied	Very Dissatisfied
1. How satisfied are you with the surgery/operation that the doctor did?	1	2	3	4	5
2. How satisfied are you with the therapy that you received after the operation?	1	2	3	4	5
3. How satisfied are you with how your hand looks?	1	2	3	4	5
4. How satisfied are you with how well your hand works?	1	2	3	4	5
5. How satisfied are you that you can carry on with your life, even if it is different to before?	1	2	3	4	5

Other Comments: ____

____

____

APPENDIX I- Excursion-Based Approach Protocol

Excursion-Based Approach (Active Place-and-Hold Mobilization Approach)

Rehabilitating repaired FTIs in Zone I- III

By Nancy M Cannon

Precautions and Important Points to Remember

- Below is a guideline to using the active place-and-hold mobilization approach to treat repaired flexor tendon injuries. This is an excursion-based protocol which is based entirely on time (it is not improvement-based) and therefore all clients will start the same exercises at the same time post operatively.
- It is **very important** that the therapist knows what type of repair was done in surgery, and how many strands were used, so that they have a good understanding of the strength of the repair and what exercises can be done safely. This approach can only be used with clients who have had a four, or more, strand flexor tendon repair.
- If any sign of tendon gapping or triggering is noted during therapy, put the therapy process on hold and send the client back to the surgeon to address your concern.
- If the client's oedema is significantly increased it is recommended to delay the early active flexion, as the oedema may add significant resistance to the flexor tendons and risk rupture.
- The client should return for therapy once a week for the first 6 weeks and once every second week from weeks 6 -12.
- Educating the client is very important:
  - Explain the nature and severity of a flexor tendon injury to the client, and emphasise that they must be extremely careful when using/moving their hand as it takes approximately 12 weeks for a tendon injury to heal, but there is still a possibility that it can rupture after that.
  - Explain why the client has to wear the splint, what exercises they must do at home and how to remove and replace the splint on their arm. Before the client leaves their OT session ask them to repeat the information that they learnt.

    - Advise the client not to engage in active or passive combined wrist and digit extension until instructed by their therapist to do so.

Assessment

- Avoid measuring muscle strength of a flexor tendon repair with a dynamometer (even after 12 weeks) as it places too much stress on the healing tendon.
- The therapist should measure the range of motion (ROM) of the MP, PIP and DIP joints of the injured finger/s at every session, using a goniometer.
    - During the initial phase, these measurements can be taken in the splint to avoid composite digit extension.
    - Measure passive ROM in flexion and extension (don't measure passive composite extension of MP, PIP and DIP).
    - Also measure place and hold ROM in flexion and active finger extension.

Rehabilitation Program

<u>3-6 Days Post Operatively</u>- Initial appointment

- The client will begin therapy at 3-6 days postoperatively, after being referred by the surgeon.
- Remove the Plaster of paris back-slab and bulky compressive bandage.
- Clean and dress the wound at each session. Use light compressive dressing, as dressing adds resistance to active movement.
- Manage the oedema by encouraging the client to keep the injured hand elevated, and by using finger socks or coban on a periodic basis during the day and/or night.
    - Ensure that the finger socks or coban are removed before the client performs place and hold or active flexion (in order to decrease the resistance).
    - The best rehabilitation results are obtained when oedema is brought under control during the initial 5-7 days following surgery.
- Education (as mentioned above)
- Make a dynamic, 2-piece, dorsal, forearm based MP extension blocking splint is made for injured hand.
    - Wrist:
        - The splint allows 20-30º of flexion (when the foam block is in place)

        - The splint should limit wrist extension to 15- 30º extension
        - Between exercises the client should insert a foam block into the dorsal surface of the splint to maintain the wrist in a flexed position
    - MP joints of all fingers should be in 60- 70º flexion
    - IP joints should be in full extension
- Exercise
    - Teach the client the passive ROM exercises outlined in the Modified Duran Program
        - 10 repetitions per hour.
    - After the passive ROM exercises they should active place and hold synergistic flexion with wrist extension.
        - These are done by passively flexing the fingers into composite flexion, while simultaneously extending the wrist. Once the hand is in this position the client must actively attempt to maintain a fist with gentle muscle contraction for 5 seconds. This is followed by relaxing the fingers and wrist.
        - They will be advised to do these exercises 10 times, every waking hour

<u>10-14 Days Post Operatively</u>

- Continue wound and oedema management, and client education, as necessary.
- Remove sutures, once the wound has healed and start scar management
    - Remove excess dry skin
    - Massage the scar with aqueous cream for 10 minutes, 3 times a day.
    - Pressure garments and silicone gel can also be used to manage the scar after the wound has fully healed. Remove these if the client is performing active or place and hold exercises.
- Check the splint and adjust it if necessary.
- Exercises
    - Continue doing The Modified Duran passive exercises in the splint, as well as the active, place and hold synergistic motion exercises within the confines of the splint
- It is very important that the client achieves excellent passive flexion within the initial 10-14 days postoperatively.

4 Weeks Post Operatively

- The client should continue wearing their splint, but they can remove it when doing exercises.
- Continue oedema and scar management, as well as client education as necessary.
- Check the splint and adjust it if necessary.
- Exercises
    - Continue The Modified Duran Exercise Program within the splint.
    - The following active ROM exercises are performed without a splint. Do these 25 repetitions every 2 hours.
        - Place and hold synergistic flexion exercises
        - Active composite finger flexion and extension with wrist in neutral- Never tell the client to "make a fist", rather tell them to "place their fingers in their hand and hold them there gently". Tell them they should just bend their fingers enough so that they can slip a finger from their opposite hand in and out. Encourage the client to practice gentle finger flexion with the unaffected hand and then try the same movement with the affected hand
        - Tendon gliding exercises (active finger movement with wrist in neutral)-
            - Straight hand- MP, PIP and DIP joints in extension
            - Shelf/table top fist- MP flexion, IP extension
            - Straight fist- MP and PIP flexion with DIP extension
            - Composite fist- flexion on MP, PIP and DIPs
            - Hook fist- MP extension, with PIP and DIP flexion
            - Straight hand
        - Active flexion and extension of the wrist, with the fingers relaxed.

5 Weeks Post Operatively

- Continue oedema and scar management, as well as client education as necessary.
- Check the splint and adjust it if necessary.
- Exercise
    - Continue Modified Duran Exercises and active ROM exercises (outlined above).
    - Add another active ROM exercise- The client should make a composite fist, followed by extending the wrist and digits simultaneously.

6 Weeks Post Operatively

- Continue oedema and scar management as necessary.
- Educate the client well, explain that at 6 weeks the tendon is only 50% healed and they must still be very cautious. Explain to the client what activities they can do and which they shouldn't, ie. They can wipe a table but not scrub, they can wash their face but not brush their teeth.
- Discontinue the use of the splint.
    - Allow the client to continue wearing it when sleeping or when visiting crowded places.
- If active extension is limited a resting splint can be made for the client to wear when sleeping.
    - This is made in the maximum amount of extension that the client can achieve actively achieve. Do not maximise full passive extension.
- Initiate Budding strapping of the PIP and DIP joints of the involved digit to its adjacent digit.
    - This is done to remind the client not to use the hand for heavy lifting activities.
- Blocking (isolated joint) exercises may be introduced to the DIP and PIP joints as needed.
    - NB- If excellent ROM has been achieved (80-85% of normal motion) then blocking exercises are not recommended. In addition blocking is not permitted to the small finger as it may risk rupture.
- From 6 weeks the client can start engaging in light activities of daily living and these activities can be slowly upgrade over the weeks to heavier tasks.

8 Weeks Post Operatively

- Continue oedema and scar management, as well as client education.
- Gentle, progressive strengthening may be initiated beginning with a stress ball, theraputty and a hand exerciser.

10-12 Weeks Post Operatively

- Continue oedema and scar management, as well as client education.
- The client is encouraged to resume normal use of his hand in all activities of daily living and to refrain from heavy lifting and tight sustained grip for up to 14-16 weeks.

APPENDIX J- Force-Based Approach Protocol

Force-Based Approach (Modified Pyramid Approach)

Rehabilitating repaired FTIs in zone II-IV

By Rebecca von der Heyde

Precautions and Important Points to Remember

- Below is a guideline to using the Modified Pyramid Approach to treat repaired flexor tendon injuries. This approach is based entirely on the client's improvement (it is not time-based) and therefore the amount of time that each client spends doing certain exercises may differ between the various clients.
- It is **very important** that the therapist knows what type of repair was done in surgery, and how many strands were used, so that the therapist has a good understanding of the strength of the repair and what exercises can be done safely.
- If any sign of tendon gapping or triggering is noted during therapy, put the therapy process on hold and send the client back to the surgeon to address your concern.
- Educating the client is very important:
  - Explain the nature and severity of a flexor tendon injury to the client, and emphasise that they must be extremely careful when using/moving their hand as it takes approximately 12 weeks for a tendon injury to heal, but there is still a possibility that it can rupture after that.
  - Explain why the client has to wear the splint, what exercises they must do at home and how to remove and replace the splint on their arm. Before the client leaves their OT session ask them to repeat the information that they learnt.
  - Advise the client NOT to engage in active or passive combined wrist and digit extension until instructed by their therapist to do so.
  - Explain to the client that the longer they wear their splint and the less their exercises change the better their rehabilitation is going.

Wound, Oedema and Scar Management

- Clean and dress the wound at each session. Use minimal bandage, as bandage adds resistance to active movement.
- Remove sutures at approximately 2-3 weeks, once the wound has healed.
- Manage the oedema as soon as possible by encouraging the client to keep the injured hand elevated and by using a pressure garment or coban. Ensure that the PG or coban is removed for place and hold exercises or active motion to avoid resistance.
- Once the wound has healed and sutures have been removed, remove excess dry skin and begin scar massage. Massage the scar with aqueous cream for 10 minutes, 3 times a day.
- Pressure garments and silicone gel can also be used to manage the scar after the wound has fully healed, remove these when doing place and hold or active movement.

Assessment

- Avoid measuring muscle strength of a flexor tendon repair with a dynamometer (even after 12 weeks) as it places too much stress on the healing tendon.
- The therapist should measure the range of motion (ROM) of the MP, PIP and DIP joints of the injured finger/s at every session, using a goniometer.
    - During the initial phase, these measurements can be taken in the splint to avoid composite digit extension.
    - Measure passive ROM in flexion and extension (don’t measure passive composite extension of MP, PIP and DIP).
    - Also measure place and hold ROM in flexion and active finger extension.
- In order to determine if the client should continue doing the same exercises as previously or whether they should start a new exercises the ROM measurements should be inserted into the below calculation:
    - Groth’s Adhesion Grading System

$$\frac{\text{Current DIP flexion- Previous DIP flexion}}{\text{Previous DIP flexion}} \quad \text{X } 100$$

- If the answer is less than 10% it means that there is no resolution of active lag between therapy sessions, and the next exercise in the sequence (explained below) should be introduced to the therapy program.

    - If the answer is more than 10% the client can continue with the exercises that they have been doing as they are achieving an improvement.

Splinting

Remove the Plaster of paris back-slab and make a splint for the client at their first hand therapy session (3- 6 days post operatively). A dynamic, 2-piece, dorsal, forearm based MP extension blocking splint is made for injured hand.

- Wrist:
    - The splint allows 20-30º flexion (when the foam block is in place)
    - The splint should allow 15-30º wrist extension
    - Between exercises the client should insert a foam block into the dorsal surface of the splint to maintain the wrist in a flexed position
- MP joints of all fingers should be positioned in 60-70º flexion
- IP joints in full extension

Exercises

The order in which the exercises should be introduced to the client (based on the force required to perform them):

1. Passive, protected digital extension
2. Place and hold synergistic flexion, with active wrist extension
   (Place fingers passively in full flexion, actively extend wrist while still passively holding fingers. Then try to actively maintain a position of wrist extension and finger flexion for 5 seconds, and relax.)
3. Active straight fist
4. Active hook fist
5. Active composite fist
   (Never tell the client to "make a fist", rather tell them to "place their fingers in their hand and hold them there gently". Tell them they should just bend their fingers enough so that they can slip a finger from their opposite hand in and out.)
6. Active, isolated PIP flexion
7. Active, isolated DIP flexion

Initial Session

- The client will begin therapy at 3-6 days postoperatively, after being referred by the orthopaedic surgeon.
- Wound and oedema management
- Education (as mentioned above)
- Make a custom made splint (as mentioned above) for the client.
- The client will be taught passive protected digital extension and place and hold synergistic flexion, and they will be advised to do these exercises 10 times, every waking hour.
- Measure passive and place and hold ROM of injured finger/s.
- If the client has marked oedema, decrease the frequency of exercises and allow them to perform place and hold exercises to mid-range. If these changes are made, document them for research purposes.

Follow Up Sessions

- The client should return for therapy once a week for the first 6 weeks and once every second week from week 6-12.
- Continue wound, oedema and scar management as necessary, as well as client education.
- Check the splint and adjust it if necessary.
- At every therapy session the therapist will measure and record the client's active/place and hold ROM in flexion. If the client has an improvement of 10% or more in their ROM from the previous week, they will continue doing the same exercises that they were doing. If they have less than 10% improvement the next exercise in the sequence will be added to their home exercise program. Only add one exercise at a time.
- Discontinue permanent use of the splint at 6 weeks post operatively. Allow the client to continue wearing it when sleeping or when visiting crowded places.
    - A whole session should be spent on discharging the splint- educate the client well, explain that at 6 weeks the tendon is only 50% healed and they must still be very cautious. Explain to the client what activities they can do and which they shouldn't, ie. They can wipe a table but not scrub, they can wash their face but not brush their teeth.
- After 6 weeks continue to move the client up the pyramid and only add a strengthening program after that if they are returning to a labor-type job.

ADLs

- From 6 weeks the client can start engaging in light activities of daily living and the activities can be slowly upgrade over the weeks to heavier tasks.

APPENDIX K- Outcome Measure Summary Sheet

Client Code: _______

OUTCOME MEASURE SUMMARY SHEET

Range of Motion -Strickland & Glogovac Formula (Strickland's Modified Classification)

Finger being Ax:		
Time post-op	**Place and Hold**	**Active**
Week 1- Researcher		
Week 1- Therapist		
Week 6- Researcher		
Week 6- Therapist		
Week 12- Researcher		
Week 12- Therapist		

Finger being Ax:		
Time post-operatively	**Place and Hold**	**Active**
Week 1- Researcher		
Week 1- Therapist		
Week 6- Researcher		
Week 6- Therapist		
Week 12- Researcher		
Week 12- Therapist		

Finger being Ax:		
Time post-operatively	**Place and Hold**	**Active**
Week 1- Researcher		
Week 1- Therapist		
Week 6- Researcher		
Week 6- Therapist		
Week 12- Researcher		
Week 12- Therapist		

Finger being Ax:		
Time post-operatively	**Place and Hold**	**Active**
Week 1- Researcher		
Week 1- Therapist		
Week 6- Researcher		
Week 6- Therapist		
Week 12- Researcher		
Week 12- Therapist		

DASH Questionnaire

Initial Assessment

- DASH Score-
- Optional Work Module Score-
- Optional Sport/Performing arts Module Score-

Final Assessment

- DASH Score-
- Optional Work Module Score-
- Optional Sport/Performing arts Module Score-

Client Satisfaction Questionnaire

1. How satisfied are you with the surgery/operation that the doctor did?

   ____

2. How satisfied are you with the therapy that you received after the operation?

   ____

3. How satisfied are you with how your hand looks?

   ____

4. How satisfied are you with how well your hand works?

   ____

5. How satisfied are you that you can carry on with your life, even if it is different to before?

   ____

Refer to Comments Yes ☐ No ☐

APPENDIX L- Excursion-Based Home Exercise Programme

Home Exercises Program

(Excursion-Based Approach)

Important Information

- You must be **VERY** careful when using/moving your injured hand as your muscle tendon grows about 1% per day, so it will only be 100% strong after about 12 weeks. There is even a chance that the tendon can break after 12 weeks.
- **DON'T** grab or pick up any objects with your injured hand as this could cause your tendon to break, and then you will have to have another operation.
- Keep your injured hand lifted up as much as possible during the day and night, so that your fingers point to the sky/ceiling, to help with the swelling in your hand.
- You must **NOT** ever bend your wrist backwards and open your fingers straight at the same time.

Wound Care

- Clean your wound every 3 days using Dettol **or** Savlon **or** Salt water (1 table spoon of salt mixed with warm water).
- Dry it well with gauze before putting the finger sock/bandage on.
- Cover the wound with an Adaptic Digit (finger sock) or Vaseline gauze and a bandage.

Splint Use

- Your splint stops you from using your hand or hurting your hand, and it must be worn permanently for 6 weeks after your operation.
- It is VERY important to wear your splint the **WHOLE** day and the night. You are only allowed to take your splint off when you are washing your wound once every 3 days.
- Never try to fix or adjust your splint, rather call Michelle on 011 898 8299 and she will make an appointment to fix or change it for you.
- You must keep the foam block in your splint at all times and only take it out when you do your exercises.

-- **SESSION 1** --

Exercises

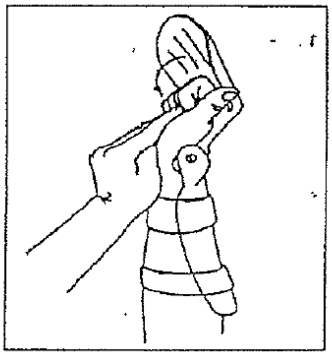
- Remove the Velcro strap that goes over your fingers, when doing all exercises
- Do each of the exercises 10 times every hour that you are awake

Do stretching exercises, using your uninjured (strong) hand (with foam block in place)

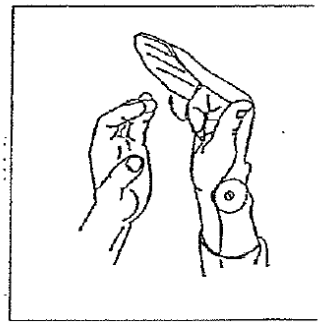
1. Stretch the top finger joint bent & straight, while other 2 joints are bent
2. Stretch the middle finger joint bent & straight, while other 2 joints are bent
3. Stretch all 3 joints bent at the same time
4. Straighten your fingers as much as possible in your splint, using your own muscles.

Do active place and hold exercises (keep your splint on but take out the foam block)

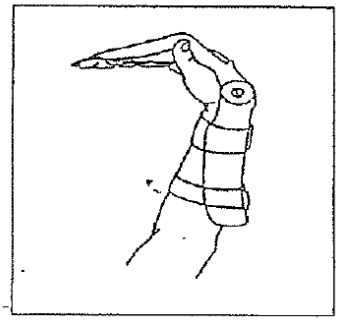
1. Use your uninjured (strong) hand to push your injured fingers into a fist, while moving your wrist backwards at the same time.



2. Using the muscles of your injured hand try to hold your fingers closed for 5 seconds, without help from your uninjured (strong) hand.



3. Relax your muscles and allow your wrist to bend forward and try to open your fingers straight to the top of your splint using your own muscles.



Scar Management

It's important to massage your scar and wear your pressure sock/glove, to stop your scar from getting raised, hard and growing onto your muscles under your skin. If this happens you will need a second operation.

You need to do scar management for at least 6 months after your operation.

- Wear your pressure sock/glove during the day and night. Only take it off when cleaning the wound and when doing exercises.
- Always wear the pressure sock/glove the opposite way to your clothes, with the seam facing away from the skin.
- If your pressure sock/glove gets dirty, you can hand wash it with washing powder/soap and leave it inside the house to dry. Never leave it in the sun to dry
- Massage your scar with aqueous cream, 3 times a day for 5-10 minutes.
    - Massage the scar hard enough to move the skin from side to side.

SESSION 4

Splint

- Keep wearing your splint during the day and night and only take it off when washing your hand, putting the pressure garment on/off to massage the scar and when doing certain exercises.

Scar management

- Keep doing scar management that was taught to you before.

Exercises

- Remove the Velcro strap that goes over your fingers, when doing all exercises.
- Do each of the exercises below 25 times every 2 hours that you are awake

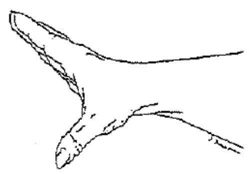
Keep doing the stretching exercises taught to you before. (With the splint **ON** and the foam block in place)

Keep doing the active place and hold exercises taught to you before (But now take your splint **OFF** for these exercises)

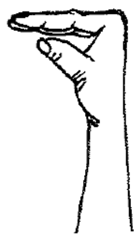
Slowly bend your wrist backwards and forwards, using the muscles of your injured hand while relaxing your fingers (Take your splint **OFF** for these exercises)

Do the finger exercises below, using the muscle of your injured hand (Take your splint **OFF** for these exercises)

1. Fingers straight



2.Bottom joint bent & fingers straight

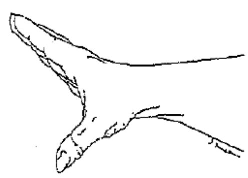


3.Bottom & middle joints Bent, top joints straight

4.Bend all joints

5.Bottom joint straight & fingers bent

6. Fingers straight



SESSION 5

Splint

- Keep wearing your splint during the day and night and only take it off when washing your hand, putting the pressure garment on/off to massage the scar and when doing certain exercises.

Scar management

- Keep doing scar management that was taught to you before.

Exercises

- Remove the Velcro strap that goes over your fingers, when doing all exercises.
- Do each of the exercises below 25 times every 2 hours that you are awake

Keep doing the stretching exercises taught to you before. (With splint **ON** and foam block in place)

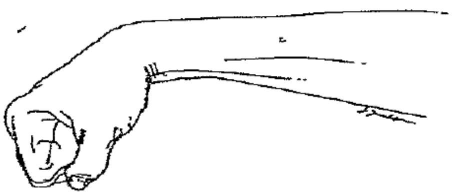
Keep doing the active place and hold exercises taught to you before (With splint **OFF**)

Keep doing your wrist backwards and forwards exercises taught to you before (With splint **OFF**)

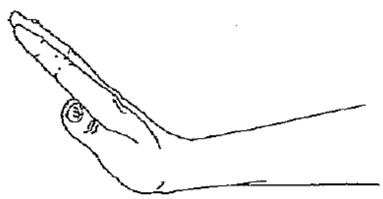
Keep doing the finger exercises taught to your before (With splint **OFF**)

Start doing exercise below (With splint **OFF**)

- The fingers are closed and the wrist is bent forward



- Then bend the wrist back and open the fingers straight



-- **SESSION 6** --

Splint and strapping

- Don't wear your splint during the day. Only wear it at night when sleeping and when in crowded places.
- Strap your injured finger to the uninjured finger next to it during the day, to give your finger support and remind you not to use it for heavy activities.

Scar management

- Keep doing scar management that was taught to you before.

Exercises

- Do each of the exercises below 25 times every 2 hours that you are awake

Keep doing the stretching exercises taught to you before. (With splint **OFF**)

Keep doing the active place and hold exercises taught to you before (With splint **OFF**)

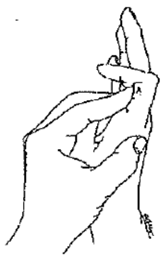
Keep doing your wrist backwards and forwards exercises taught to you before (With splint **OFF**)

Keep doing the finger exercises taught to your before (With splint **OFF**)

Keep doing wrist and finger combined movement taught to your before (With splint **OFF**)

Start doing Blocking exercises below of your injured finger (With splint **OFF**)

- Hold the bottom joint still and use your own muscles to move the middle joint bent and straight



- Then hold your middle joint still and use your own muscles to move the top joint bent and straight.

Activities

NB- At 6 weeks your tendon is only 50% healed, and you must still be very careful as it can snap very easily. You can use your injured hand for easy and light activities like wiping a table or washing your face, but nothing hard, tiring or heavy like scrubbing or brushing your teeth.

APPENDIX M- Force-Based Home Exercise Programme

Home Exercises Program

(Force-Based Approach)

Important Information

- You must be **VERY** careful when using/moving your injured hand as your muscle tendon grows about 1% per day, so it will only be 100% strong after about 12 weeks. There is even a chance that the tendon can break after 12 weeks.
- **DON'T** grab or pick up any objects with your injured hand as this could cause your tendon to break, and then you will have to have another operation.
- Keep your injured hand lifted up as much as possible during the day and night, so that your fingers point to the sky/ceiling, to help with the swelling in your hand.
- You must **NOT** ever bend your wrist backwards and open your fingers straight at the same time.

Wound Care

- Clean your wound every 3 days using Dettol **or** Savlon **or** Salt water (1 table spoon of salt mixed with warm water).
- Dry it well with gauze before putting the finger sock/bandage on.
- Cover the wound with an Adaptic Digit (finger sock) or Vaseline gauze and a bandage.

Splint Use

- Your splint stops you from using your hand or hurting your hand, and it must be worn permanently for 6 weeks after your operation.
- It is VERY important to wear your splint the **WHOLE** day and the night. You are only allowed to take your splint off when you are washing your wound once every 3 days.
- Never try to fix or adjust your splint, rather call Michelle on 011 898 8299 and she will make an appointment to fix or change it for you.
- You must keep the foam block in your splint at all times and only take it out when you do your exercises.

-- SESSION 1 --

<u>Exercises</u>

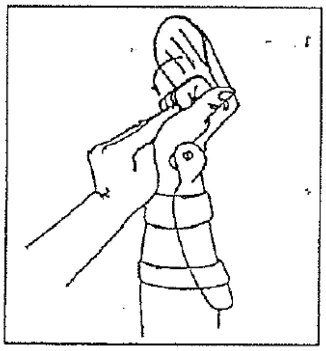
- Remove the Velcro strap that goes over your fingers, when doing all exercises
- Do each of the exercises 10 times every hour that you are awake

Do stretching exercises, using your uninjured (strong) hand (with the splint **ON** and the foam block in place)

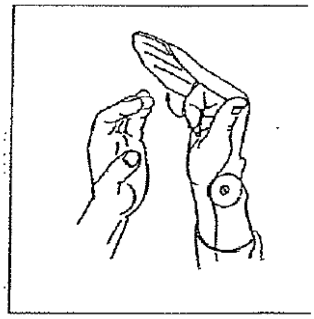
1. Stretch the top finger joint bent & straight, while other 2 joints are bent
2. Stretch the middle finger joint bent & straight, while other 2 joints are bent
3. Stretch all 3 joints bent at the same time
4. Straighten your fingers as much as possible in your splint, using your own muscles.

Do active place and hold exercises (keep your splint **ON** but take out the foam block)

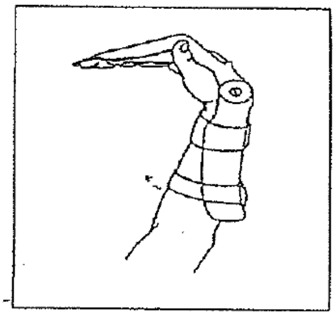
1. Use your uninjured (strong) hand to push your <u>injured fingers into a fist</u>, while moving your <u>wrist backwards</u> at the same time.



2. Using the muscles of your injured hand try to <u>hold your fingers closed for 5 seconds</u>, without help from your uninjured (strong) hand.



3. Relax your muscles and allow your <u>wrist to bend forward</u> and try to <u>open your fingers straight</u> to the top of your splint using your own muscles.



Scar Management

It's important to massage your scar and wear your pressure sock/glove, to stop your scar from getting raised, hard and growing onto your muscles under your skin. If this happens you will need a second operation.

You need to do scar management for at least 6 months after your operation.

- Wear your pressure sock/glove during the day and night. Only take it off when cleaning the wound and when doing exercises.
- Always wear the pressure sock/glove the opposite way to your clothes, with the seam facing away from the skin.
- If your pressure sock/glove gets dirty, you can hand wash it with washing powder/soap and leave it inside the house to dry. Never leave it in the sun to dry
- Massage your scar with aqueous cream, 3 times a day for 5-10 minutes.
    - Massage the scar hard enough to move the skin from side to side.

--Session 6--

Splint

- You must not wear your splint during the day anymore.
  Only wear it at night when you are sleeping and when in crowded places.

Activities

Very Important- At 6 weeks your tendon is only 50% healed, and you must still be very careful as it can snap very easily.

- You are allowed to use your injured hand for easy and light activities like wiping a table or washing your face
- You are not allowed to use your injured hand for anything that is hard, tiring or heavy like scrubbing or brushing your teeth.

Scar management

- Keep doing scar management that was taught to you before.

Exercises

- Remove the Velcro strap that goes over your fingers, when doing all exercises
- Do the exercises below 10 times every hour that you are awake

Keep doing the stretching exercises taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the active place and hold exercises taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Start doing the straight fist finger exercise below, using the muscle of your injured hand

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Bend the bottom and middle joints of your fingers, while keeping the end joints straight, hold it in that position for 5 seconds and then relax your hand. (See Picture below)

Scar management

- Keep doing scar management that was taught to you before.

Exercises

- Do the exercises below 10 times every hour that you are awake

Keep doing the stretching exercises taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the active place and hold exercises taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the straight fist finger exercise taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Start doing the hook fist finger exercise below, using the muscle of your injured hand

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Bend the end and middle joints of your finger, while keeping the bottom joint straight, hold it like that for 5 seconds and then relax your hand. (See picture below)

Scar management

- Keep doing scar management that was taught to you before.

Exercises

- Do the exercises below 10 times every hour that you are awake

Keep doing the stretching exercises taught to you before.

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the active place and hold exercises taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the straight fist finger exercise taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the hook fist finger exercise taught to your before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Start doing the closed hand exercise below, using the muscle of your injured hand

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Bend all the joints of your injured fingers to make a closed fist, hold it like that for 5 seconds and then relax your hand. (See picture below)

Scar management

- Keep doing scar management that was taught to you before.

Exercises

- Do the exercises below 10 times every hour that you are awake

Keep doing the stretching exercises taught to you before.

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the active place and hold exercises taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the straight fist finger exercise taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the hook fist finger exercise taught to your before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

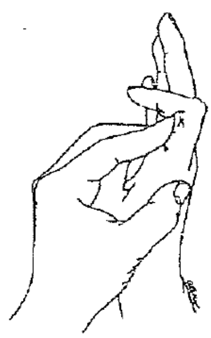
Keep doing the closed hand exercise taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Start doing the middle joint blocking exercises below, of your injured finger

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Hold the bottom joint of your finger straight and use your own muscles to bend the middle joint, keep it there for 5 seconds and then straighten it. (See picture below)



Scar management

- Keep doing scar management that was taught to you before.

Exercises

- Do the exercises below 10 times every hour that you are awake

Keep doing the stretching exercises taught to you before.

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the active place and hold exercises taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the straight fist finger exercise taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the hook fist finger exercise taught to your before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the closed hand exercise taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Keep doing the middle joint blocking exercises taught to you before

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Start doing the end joint blocking exercises below, of your injured finger

- Splint- On/ Off
- Foam Block- In Splint/ Out of splint

Hold the middle joint of your finger straight and use your own muscles to bend the end joint, keep it like that for 5 seconds and then straighten it. (See picture below)