Thumb Carpometacarpal Osteoarthritis

Prediction, rehabilitation and contextual effects

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Dedicated to my parents

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LIST OF ABBREVIATIONS

ADL – Activities of Daily Life

ANOVA – Analysis of variance

APL – Abductor Pollicis Longus

CI – Confidence interval

CMC – First Carpometacarpal joint

CTS – Carpal tunnel syndrome

ECRL – Extensor carpi radialis longus

EPB – Extensor pollicis brevis

EPHPP – Effective Public Health Practice Project quality assessment tool

FCR – flexor carpi radialis

HR – Hazard ratio's

LRTI – Ligament Reconstruction and Tendon Interposition

MCID – Minimum Clinical Important Difference

MCP – Metacarpophalangeal joint

MHQ – Michigan hand questionnaire

OA – Osteoarthritis

PEDro – Physiotherapy Evidence Database

PROM – Patient-reported outcome measure

PSM – Propensity score matching

RCT – Randomized controlled trial

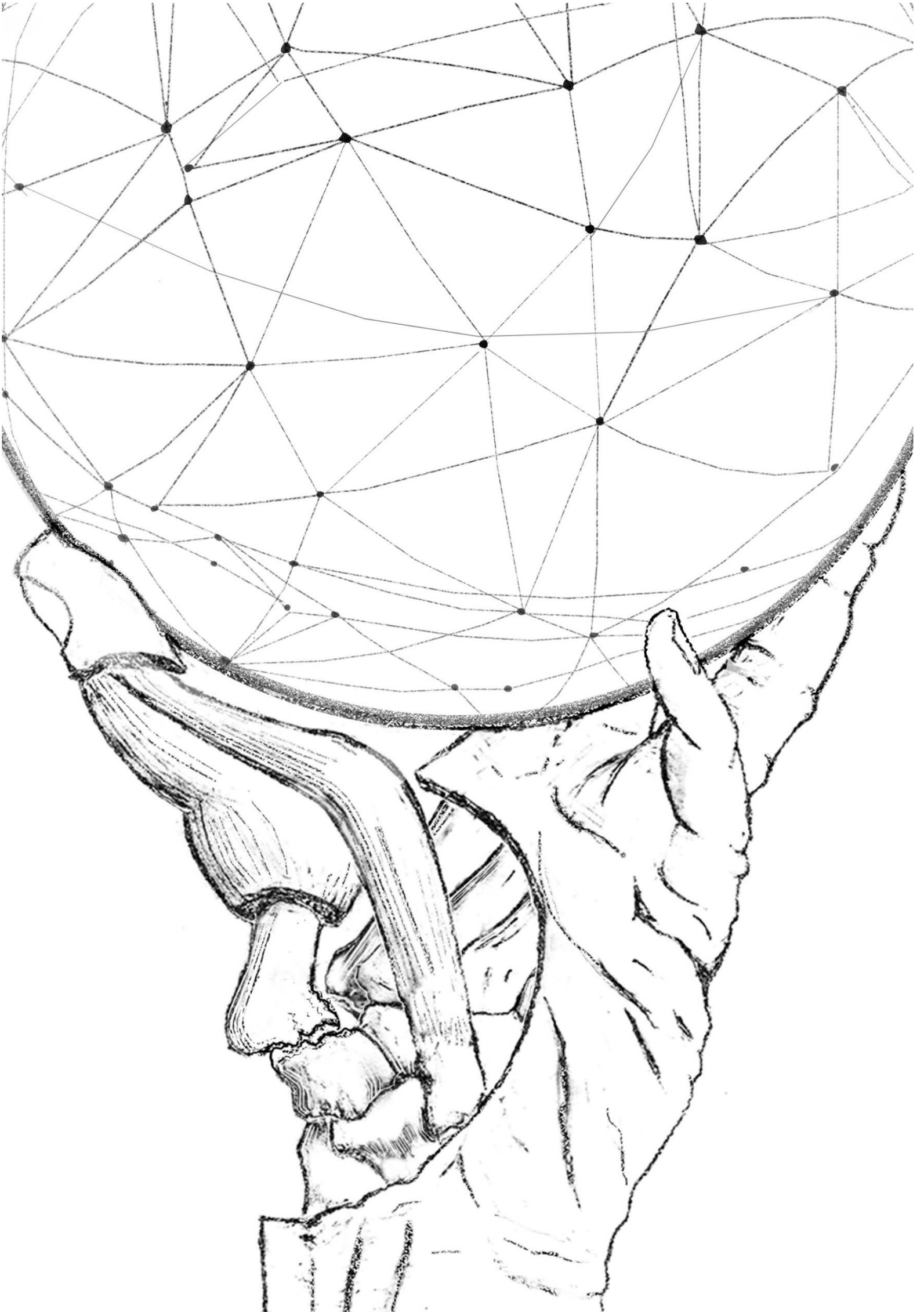
ROM – Range of Motion

SD – Standard Deviation

SE – Standard error

STT – Scapho-trapezio-trapezoidal

VAS – Visual Analogue Scale



GENERAL INTRODUCTION

1

Thumb carpometacarpal (CMC) osteoarthritis is commonly observed in elderly patients.[1] Osteoarthritis is pathologically characterized by subchondral bone change, loss of articular cartilage, osteophyte formation, and synovitis.[2] This can cause weakness, pain and instability that severely impairs hand function.[1] It typically affects postmenopausal women in their fifth to sixth decade of life[3] and the costs of lost productivity ranges between €3500,- and €5500,-.[4] Treatment of CMC osteoarthritis remains challenging. Patients can benefit from non-operative treatment, i.e. orthosis, exercise therapy, steroid injections, education or can request operative treatment, i.e. complete or partial trapiezectomy, arthrodesis, ligament reconstruction etc.[5,6]

Epidemiology

Thumb CMC osteoarthritis is commonly observed in elderly patients. Dahaghin et al.[7] reported in a large cohort study of almost four thousand people older than 55 years that the prevalence of thumb CMC osteoarthritis was 36%. Furthermore, only a moderate association between patient-reported pain with the hand and radiographic osteoarthritis was found, and a weak association between patient-reported disability with the hand and radiographic osteoarthritis. Moreover, Lawrence et al.[8] found similar results: In a Northern England cohort of nearly 3000 people, 62% of the people aged 55 or older had radiographic hand arthrosis and nearly 100% of the people aged 65 years or older. Another study reported an incidence rate of 100 per 100,000 person-years seeking treatment for symptomatic osteoarthritis of the hand.[9] Sodha et al. described an overall radiographic prevalence of thumb CMC osteoarthritis of nearly 91% in patients 80 years or older, and that it increased more rapidly over the years in women than in men.[10] Lastly, a study of Becker et al. found that the prevalence of radiographic thumb CMC osteoarthritis increased gradually with age, reaching a prevalence of 93% in men aged 81 years or older and 100% in women aged 90 years or older.[11] They concluded that more awareness should be created by health professionals that thumb CMC osteoarthritis is a normal part of human aging to which most people adapt, and for which only a minority of people seek help. This is in contrast with many hand surgeons regarding thumb CMC osteoarthritis as a condition that requires surgical treatment in order for patients to have a dependable hand.[11]

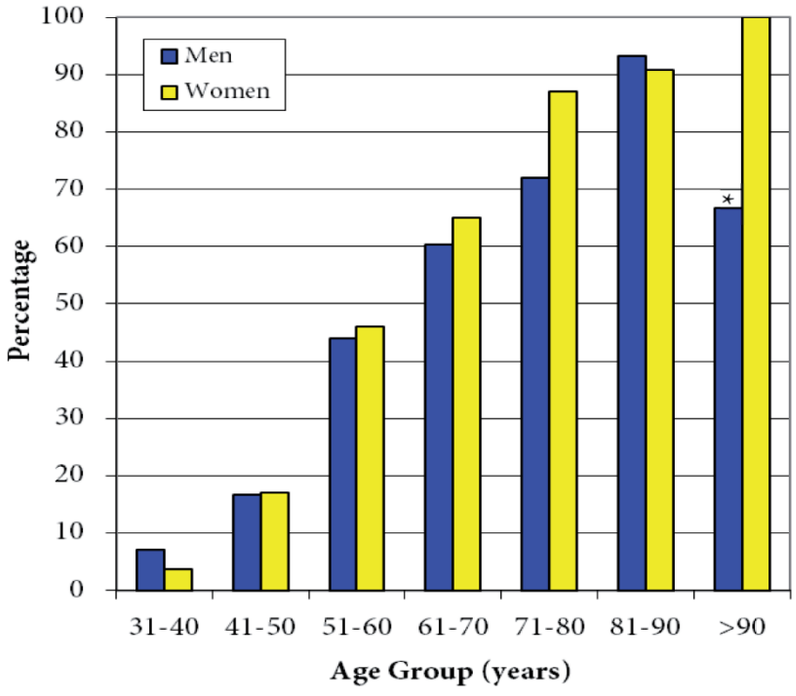


Figure 1. *The prevalence of thumb carpometacarpal arthrosis increases with age in both men and women. *Note that there were only six men older than 90 years in our cohort; therefore, the prevalence among men in this age group is not reliable.*

(Reprinted with permission of Springer, from: Becker SJE, Briet JP, Hageman MGJS, Ring D. Death, taxes, and trapeziometacarpal arthrosis hand. Clin Orthop Relat Res. 2013. doi:10.1007/s11999-013-3243-9.)

Anatomy and Pathophysiology

The thumb carpometacarpal joint is usually described as a biconcave-convex saddle joint. The CMC joint is convex in lateral view and concave in anteroposterior view.[12] The thumb is capable of opposing because the CMC joint is lax, loose and subluxable in resting position (Figure 2).[13] The thumb remains stable and is capable of heavy pinch and grip strength during opposition due to volar and dorsal ligaments and the beak of the thumb metacarpal.[14]

Osteoarthritis is caused by a multifactorial etiology and is described as a loss of cartilage in synovial joints, development of osteophytes, synovitis and subchondral bone deformations.[2] Damage of the joint is triggered by a combination of systemic factors that predisposes the disease and mechanical factors that dictate its severity. Systemic factors that may be associated with osteoarthritis are obesity, diabetes and hypertension.[15] In addition, one study found that female gender, higher age, positive family history and obesity were risk factors for developing hand osteoarthritis.[16] Mechanical factors that have been reported to cause thumb CMC osteoarthritis are 1)

weakening of the palmar beak ligament allowing increased metacarpal movement on the trapezium and subluxation of the CMC-joint and 2) shear stress forces caused by an abnormal abductor pollicis longus insertion damaging the articular cartilage resulting in degenerative osteoarthritis (Figure 3).[17,18] Other mechanical factors that are suggested to be associated with thumb CMC osteoarthritis are fractures or dislocation of the CMC joint.[19] Lastly, a cohort study of Jones et al. surprisingly found that heavy occupational work was associated with less hand osteoarthritis.[20]

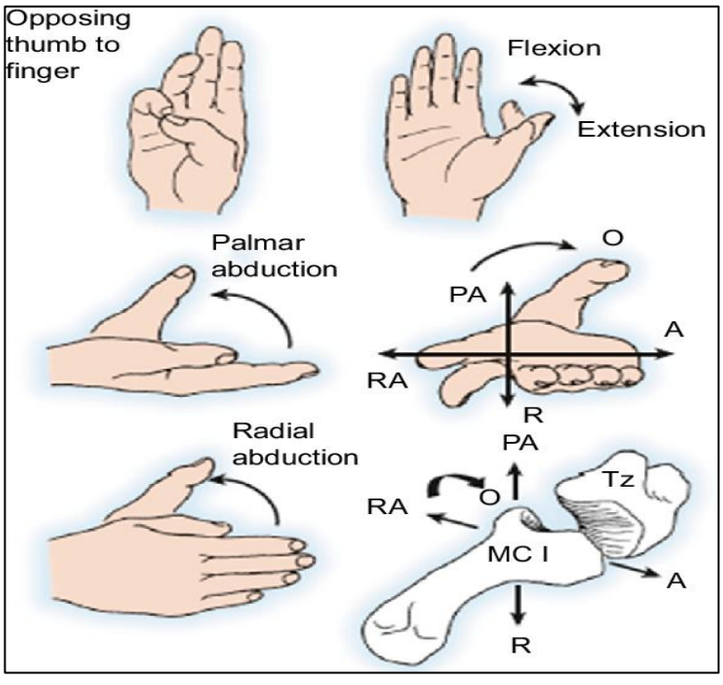


Figure 2. *Range of motion of the thumb Carpometacarpal joint*

Diagnosis and Radiographic staging

The diagnosis of thumb CMC osteoarthritis is based on clinical presentation, physical exam and radiographical imaging.[21] Patients usually have pain at the base of the thumb during pinch movements (e.g., pulling zippers, turning keys) and grip movements (e.g., grasping a bottle, opening a jar).[1] The pain occurs in episodes, usually reoccurring during certain activities.[22] On physical examination, the base of the first metacarpal can be prominent, typically referred as "shoulder sign".[3] This is caused by osteophytes, dorsoradial subluxation and inflammation.[23] Due to subluxation, the thumb remains in an adducted posture, resulting in a first web space contracture over time. To remain able to perform pinch movements, the MCP-1 joint may hyperextend, resulting in a zigzag deformity.[23] Furthermore, the dorsal area of the carpometacarpal joint can be painful during palpation. The "grind test" is positive when circumduction of the carpometacarpal joint while simultaneously applying axial compression results in crepitation or pain.[24]

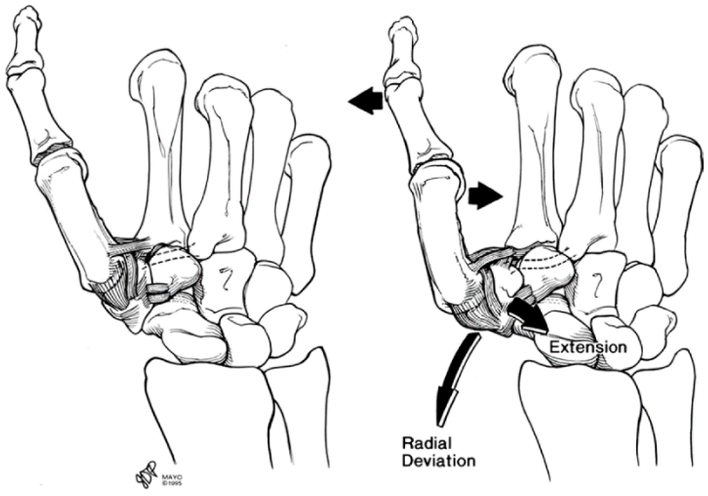


Figure 3. *Cantilever forces on the basal joint can lead to progressive ligamentous incompetence of the anterior oblique and dorsal radial ligaments. Over time, the thumb metacarpal tends to migrate dorsally and proximally, and the distal portion of the metacarpal is held in an adducted position. This can result in compensatory hyperextension of the thumb metacarpophalangeal joint and potential flexion of the thumb interphalangeal joint, resulting in the zigzag deformity. Progressive arthritis at the scaphotrapeziotrapezoid joint can result in compensatory extension of the scaphoid.*

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In order to have a good radiographical view of the first carpometacarpal joint, Robert's view or a Bett's view can be made. This allows projection of all four articular surfaces of the trapezium bone without overlap of other carpal bones.[25] The classification developed by Eaton and Glickel is widely used to stage the severity of thumb carpometacarpal osteoarthritis, ranging from stage 1 (normal) to stage 4 (complete deterioration of the CMC joint with complete loss of cartilage in the STT-joint as well) (Table 1).[26] However, the added value of radiographic imaging in the diagnosis and management of carpometacarpal osteoarthritis is questionable, given the weak association between the prevalence of radiographically diagnosed carpometacarpal osteoarthritis on the one hand and functional complaints and symptoms on the other hand.[27]

Table 1. *Radiographic staging of thumb CMC osteoarthritis according to Eaton and Glickel*[28]

Stage 1	The articular contours are normal. There may be a slight widening of the joint space due to effusion or laxity of the ligamentous support of the CMC joint.
Stage 2	The CMC joint is slightly narrowed with minimal subchondral sclerosis. There may be joint debris < 2 mm in diameter in the form of osteophytes or loose bodies. The ST joint should appear normal.
Stage 3	The CMC joint space is markedly narrowed or obliterated with cystic changes, sclerotic bone, varying degrees of dorsal subluxation, and joint debris exceeding 2 mm in diameter. The ST joint is normal.
Stage 4	There is complete deterioration of the CMC joint as in stage 3 and, in addition, the ST joint is narrowed with apparent sclerotic and cystic changes.

Management

Currently, there are no disease-altering treatments for thumb carpometacarpal osteoarthritis. Treatment can be divided in either non-operative or operative treatment. Table 2 lists the most common therapies used in treating thumb carpometacarpal osteoarthritis, although other therapies are possible. There is a large variation in treatment recommendations prescribed and used by surgeons, partly because none of the outcomes of these treatment options are superior to each other.[28,29] The Dutch guideline on the treatment of thumb CMC osteoarthritis recommends starting with splinting and hand therapy for three to six months, before surgery is considered.[30]

Table 2. *Non-operative and operative treatments for thumb carpometacarpal osteoarthritis*

Non-operative treatment	Operative treatment
Education	Arthroscopy and debridement of the CMC joint
Nonsteroidal anti-inflammatory drugs	Volar ligament reconstruction
Exercise therapy	Metacarpal osteotomy
Orthosis/orthotics	Trapeziectomy
Corticosteroid injection	Trapeziectomy with ligament reconstruction
Hyaluronic acid injection	Trapeziectomy with tendon interposition
Leech therapy	Trapeziectomy with suspension and interposition arthroplasty
	Trapeziectomy with ligament reconstruction and tendon interposition (LRTI)
	CMC arthrodesis
	Implant arthroplasty
	Total CMC joint replacement

Non-operative treatment

As described above, there is a wide array in non-operative treatment options. The most used non-operative treatments are orthotics, exercise therapy and intra-articular injections.[5,31-33]

In general, a hand-based thumb spica orthosis is used to provide support for the CMC joint and to reduce subluxation and inflammation (Figure 4). Orthotics that immobilize the CMC joint reduce pain, but usually do not result in improved hand function and hand strength.[34] Literature suggests that short flexible orthotics are preferred by patients, and are just as effective a longer, more rigid orthotics.[5,35] However, large RCTs comparing both types of orthotics are limited.

Exercise therapy generally focuses on optimizing the position of the thumb to prevent hyperextension of the thumb during pinch and grip movements and on practicing a full range of motion of the thumb.[30] In addition, therapy aims to improve thenar muscle strength in order to retain the correct thumb position.[5] Moreover, exercises are performed in order to maintain the first web space and to improve pinch strength. However, because of the limited evidence available, it is unknown which patients respond favorably, and which patients who initially received a hand orthosis and exercise therapy are eventually converted to surgical treatment. Therefore, larger studies are needed in order to assess the outcome of exercise therapy and hand orthosis over a longer period of time and to study how effective exercise therapy is in avoiding a conversion to surgery. In addition, predictive factors for outcome after exercise therapy as well as conversion to surgery need to be identified, in order to better understand which patients benefit from exercise therapy. Subsequently, the first aim of this thesis is to study treatment outcome after exercise therapy and hand orthosis and its relationship with conversion to surgery (Part 1)

Operative treatment

There are numerous surgical options to treat thumb carpometacarpal osteoarthritis. Most commonly-used techniques described in literature are arthroscopic debridement, joint replacement, volar ligament reconstruction, CMC arthrodesis, metacarpal osteotomy, and trapeziectomy with or without tendon interposition and ligament reconstruction (Table 2). A Cochrane review and a systematic review of Vermeulen et al. comparing multiple surgical techniques concluded that no technique was superior in terms of pain, function, range of motion or strength, and that a simple trapeziectomy is preferable in isolated thumb carpometacarpal osteoarthritis, and that all the other techniques increase risk of complications and may delay recovery.[6,36]

Postoperative rehabilitation

When a surgical intervention has been performed, postoperative treatment usually consists of cast immobilization for a certain number of weeks, after which the cast is removed and replaced by an orthotic device. Afterwards, rehabilitation starts where patients receive exercise therapy exercises, focusing on MCP-1 flexion and palmar abduction and extension of the CMC joint.[30] A systematic review regarding postoperative rehabilitation after surgery for thumb carpometacarpal osteoarthritis reported large variation in types of immobilizations as well as the duration of postoperative immobilization and concluded that no recommendations could be made based on the included studies.[37]

At present, patients are immobilized for an arbitrary number of weeks, without knowing what the optimal time is to start rehabilitation. Therefore, studies are needed to assess if long immobilization is necessary and if shorter immobilization will lead to similar outcomes and complication rates. The second aim of this thesis is therefore to study different components and phases of postoperative rehabilitation for patients who underwent CMC arthroplasty, and to study if different immobilization protocols result in different outcomes (Part 2).

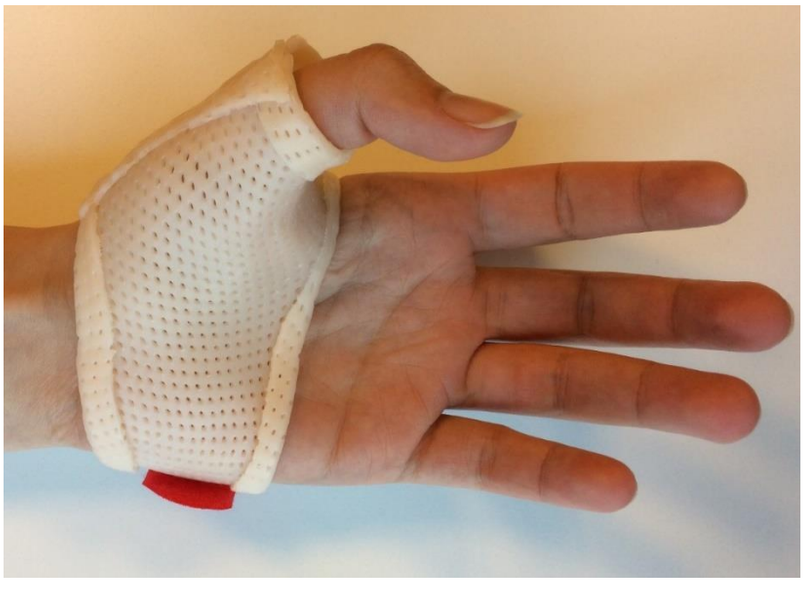


Figure 4. *Thermoplastic butterfly orthosis to immobilize the Carpometacarpal joint.*

Psychological factors and contextual effects

Since thumb CMC osteoarthritis is highly prevalent with advanced age, and only for a small minority of patients seeking care, it is important to gain insight how much of the perceived complaints are caused by actual pathology, and how much by other factors. A study of Becker et al.[38] showed that patients seeking care for their thumb CMC osteoarthritis had, on average, more depressive symptoms and higher catastrophic thinking compared to non-symptomatic thumb CMC osteoarthritis

patients. Another study found that catastrophic thinking and anxiety was moderately correlated with the Quick DASH in patients seeking treatment for their thumb carpometacarpal osteoarthritis.[39] Moreover, Frouzakis et al.[40] found an association between expectations of the patients regarding treatment outcome and the actual patient-reported outcome after surgery for their thumb CMC osteoarthritis. However, the above-mentioned studies had usually low sample sizes, substantial missing data and were of retrospective nature, making it difficult to draw conclusions based on the found results. As a result, it is currently unclear to which extent psychological factors influences perceived pain and functional disability caused by thumb CMC osteoarthritis.

In addition, other factors that may play a role in the variation in outcome are the so-called contextual effects. Contextual effects are defined as all aspects of the healthcare environment (e.g., hygiene, quality of facilities) and therapeutic context (e.g., treatment rationale, response to treatment) that may affect patient perceptions during the delivery of care.[41-43] Contextual effects are an important part of a treatment since this experience with the delivered healthcare contributes to treatment outcomes.[44] A systematic review showed that influencing treatment context can improve patient-reported treatment outcomes.[45] For example in hip prosthetic replacement surgery, better experience with the healthcare process was associated with better treatment outcomes measured with the Oxford Hip score.[46] Another study found that empathy of the physician was the strongest determinant of patient satisfaction after hand surgery, explaining 66% of the variation in patient satisfaction.[47]

In order to better understand why some patients have residual pain and impaired function after treatment, it is important to study the effect of treatment context on treatment outcome in patients with thumb CMC osteoarthritis. Consequently, the last aim of this thesis is to study to what extent psychological factors play a role in the experienced pain and disability in patients with thumb CMC osteoarthritis, and to study if patients' experience with healthcare delivery is associated with treatment outcome in patients being surgically treated for their thumb CMC osteoarthritis (Part 3)

Aims and outline of this thesis

As mentioned above, this thesis has three main aims. The first aim is to study treatment outcome after exercise therapy and hand orthosis and its relationship with surgery (Part 1). The second aim is to study different components and phases of postoperative rehabilitation for patients who underwent CMC arthroplasty, and to study if different immobilization protocols result in different outcomes (Part 2). The last aim is to study to what extent psychological factors play a role in the experienced pain and disability in patients with thumb CMC osteoarthritis, and to study if patients' experience with healthcare delivery is associated with treatment outcome in patients being surgically treated for their thumb CMC osteoarthritis (Part 3). This thesis is structured accordingly as seen bellow.

Part 1: Treatment outcome, prediction and conversion to surgery

In **Chapter 2**, the effect of a combination therapy consisting of exercise therapy and the use of hand orthosis was compared with the effect of only a hand orthosis. In **Chapter 3**, patient-reported outcome after exercise therapy and hand orthosis until one year was described, as well as the proportion that needed additional surgical treatment. **Chapter 4** aimed to identify predictive factors for outcome after exercise therapy and hand orthosis, and to find predictive factors for conversion to surgery. In **Chapter 5**, the aim of the study was to investigate the relationship between pain and hand function at the start, during and at the end of conservative treatment, and the hazard of converting to surgery.

Part 2: Postoperative rehabilitation after CMC arthroplasty

In **Chapter 6**, a systematic review was performed to describe and to create an overview on the different components and phases of postoperative rehabilitation protocols for patients who underwent CMC arthroplasty and to quantify how often these are used. Furthermore, we investigated several specific components or variations in postoperative rehabilitation protocols that are presently discussed. **Chapter 7** aimed to investigate if shorter immobilization (3-5 days plaster cast followed by a thermoplastic thumb spica orthosis until 4 weeks) is non-inferior to longer immobilization (10-14 days plaster cast followed by a thermoplastic thumb spica orthosis until 6 weeks) after surgery in terms of hand function, pain intensity and complications postoperatively.

Part 3: Psychological factors and contextual effects in thumb CMC osteoarthritis

In **Chapter 8**, we aimed to study to what extent psychological distress, pain catastrophizing and illness perception relate to pain levels in patients with thumb CMC osteoarthritis. In **Chapter 9**, the aim was to investigate which aspects of the

experienced healthcare delivery are associated with better treatment outcome after surgery of thumb CMC osteoarthritis in terms of both patient-reported outcomes as well as therapist-reported outcomes.
The thesis ends with a general discussion and future perspectives based on the presented findings.

References

1. Berger AJ, Meals RA. Management of osteoarthrosis of the thumb joints. *J Hand Surg Am*. 2015. doi:10.1016/j.jhsa.2014.11.026.
2. Dieppe PA, Lohmander LS. Pathogenesis and management of pain in osteoarthritis. In: *Lancet*. ; 2005. doi:10.1016/S0140-6736(05)71086-2.
3. Gillis J, Calder K, Williams J. Review of thumb carpometacarpal arthritis classification, treatment and outcomes. *Can J Plast Surg*. 2011. doi:10.1177/229255031101900409.
4. Marks M, Vliet Vlieland TPM, Audige L, Herren DB, Nelissen RGHH, van den Hout WB. Healthcare costs and loss of productivity in patients with trapeziometacarpal osteoarthritis. *J Hand Surg (European Vol*. 2015;40(9):927-934. doi:10.1177/1753193414568293.
5. Spaans AJ, Van Minnen LP, Kon M, Schuurman AH, Schreuders AR, Vermeulen GM. Conservative treatment of thumb base osteoarthritis: A systematic review. *J Hand Surg Am*. 2015;40(1):16-21.e5. doi:10.1016/j.jhsa.2014.08.047.
6. Vermeulen GM, Slijper H, Feitz R, Hovius SER, Moojen TM, Selles RW. Surgical management of primary thumb carpometacarpal osteoarthritis: A systematic review. *J Hand Surg Am*. 2011;36(1):157-169. doi:10.1016/j.jhsa.2010.10.028.
7. Dahaghin S, Bierma-Zeinstra SMA, Ginai AZ, Pols HAP, Hazes JMW, Koes BW. Prevalence and pattern of radiographic hand osteoarthritis and association with pain and disability (the Rotterdam study). *Ann Rheum Dis*. 2005. doi:10.1136/ard.2004.023564.
8. Lawrence JS, Bremner JM, Bier F. Osteo-arthrosis. Prevalence in the population and relationship between symptoms and x-ray changes. *Ann Rheum Dis*. 1966;25(1):1-24. doi:10.1136/annrheumd00506-0006.
9. Oliveria SA, Felson DT, Reed JI, Cirillo PA, Walker AM. Incidence of symptomatic hand, hip, and knee osteoarthritis among patients in a health maintenance organization. *Arthritis Rheum*. 1995. doi:10.1002/art.1780380817.
10. Sodha S, Ring D, Zurakowski D, Jupiter JB. Prevalence of osteoarthrosis of the trapeziometacarpal joint. *J Bone Jt Surg - Ser A*. 2005. doi:10.2106/JBJS.E.00104.
11. Becker SJE, Briet JP, Hageman MGJS, Ring D. Death, taxes, and trapeziometacarpal arthrosis hand. *Clin Orthop Relat Res*. 2013. doi:10.1007/s11999-013-3243-9.
12. Edmunds JO. Current concepts of the anatomy of the thumb trapeziometacarpal joint. *J Hand Surg Am*. 2011. doi:10.1016/j.jhsa.2010.10.029.
13. Crisco JJ, Halilaj E, Moore DC, Patel T, Weiss APC, Ladd AL. In vivo kinematics of the trapeziometacarpal joint during thumb extension-flexion and abduction-adduction. *J Hand Surg Am*. 2015. doi:10.1016/j.jhsa.2014.10.062.

14. Cooney WP, Lucca MJ, Chao EYS, Linscheid RL. The kinesiology of the thumb trapeziometacarpal joint. *J Bone Jt Surg - Ser A*. 1981. doi:10.2106/00004623-198163090-00002.

15. Sowers M. Epidemiology of risk factors for osteoarthritis: systemic factors. *Curr Opin Rheumatol*. 2001. doi:10.1097/00002281-200109000-00018.

16. Kriegs-Au G, Petje G, Fojtl E, Ganger R, Zachs I. Ligament reconstruction with or without tendon interposition to treat primary thumb carpometacarpal osteoarthritis. A prospective randomized study. *J Bone Joint Surg Am*. 2004;86-A(2):209-218.

17. Pellegrini VD. Osteoarthritis of the trapeziometacarpal joint: The pathophysiology of articular cartilage degeneration. I. Anatomy and pathology of the aging joint. *J Hand Surg Am*. 1991. doi:10.1016/S0363-5023(10)80054-1.

18. Jónsson H, Valtýsdóttir ST, Kjartansson Ó, Brekkan Á. Hypermobility associated with osteoarthritis of the thumb base: A clinical and radiological subset of hand osteoarthritis. *Ann Rheum Dis*. 1996. doi:10.1136/ard.55.8.540.

19. Haara MM, Heliövaara M, Kröger H, et al. Osteoarthritis in the carpometacarpal joint of the thumb: Prevalence and associations with disability and mortality. *J Bone Jt Surg - Ser A*. 2004. doi:10.2106/00004623-200407000-00013.

20. Jones G, Cooley HM, Stankovich JM. A cross sectional study of the association between sex, smoking, and other lifestyle factors and osteoarthritis of the hand. *J Rheumatol*. 2002.

21. Tsai P, Beredjiklian PK. Physical Diagnosis and Radiographic Examination of the Thumb. *Hand Clin*. 2008. doi:10.1016/j.hcl.2008.03.004.

22. Barron OA, Glickel SZ, Eaton RG. Basal joint arthritis of the thumb. *J Am Acad Orthop Surg*. 2000. doi:10.5435/00124635-200009000-00005.

23. Eaton RG, Littler JW. Ligament reconstruction for the painful thumb carpometacarpal joint. *J Bone Joint Surg Am*. 1973. doi:10.1016/S0969-4765(04)00066-9.

24. Merritt MM, Roddey TS, Costello C, Olson S. Diagnostic value of clinical grind test for carpometacarpal osteoarthritis of the thumb. *J Hand Ther*. 2010. doi:10.1016/j.jht.2010.02.001.

25. Dela Rosa TL, Vance MC, Stern PJ. Radiographic optimization of the eaton classification. *J Hand Surg Am*. 2004. doi:10.1016/j.jhsb.2003.09.003.

26. Eaton RG, Glickel SZ. Trapeziometacarpal osteoarthritis. Staging as a rationale for treatment. *Hand Clin*. 1987.

27. Zhang Y, Niu J, Kelly-Hayes M, Chaisson CE, Aliabadi P, Felson DT. Prevalence of symptomatic hand osteoarthritis and its impact on functional status among the elderly: The framingham study. *Am J Epidemiol*. 2002. doi:10.1093/aje/kwf141.

28. Becker SJE, Teunis T, Blauth J, Kortlever JTP, Dyer GSM, Ring D. Medical Services and Associated Costs Vary Widely Among Surgeons Treating Patients With Hand Osteoarthritis. *Clin Orthop Relat Res*. 2014. doi:10.1007/s11999-014-3912-3.

29. Appleby J, Raleigh V, Frosini F, Bevan G, Gao H, Lyscom T. Variations in Health Care. The good, the bad and the inexplicable. *Var Heal*. 2011. doi:10.1377/hlthaff.var.63.

30. Van Uchelen, J, Beumer A, Brink SM, Hoogvliet P, Moojen TM, Spaans AJ VG. Dutch guideline for conservative and surgical treatment for primary thumb base osteoarhtritis. *Amsterdam, Netherlands NVPC, NVVH, NOV, VRA, VvBN*. 2014.

31. Stamm TA, Machold KP, Smolen JS, et al. Joint protection and home hand exercises improve hand function in patients with hand osteoarthritis: a randomized controlled trial. *Arthritis Rheum*. 2002;47(1):44-49.

32. Colditz JC. The biomechanics of a thumb carpometacarpal immobilization splint: design and fitting. *J Hand Ther*. 2000;13(3):228-235.

33. Joshi R. Intraarticular corticosteroid injection for first carpometacarpal osteoarthritis. *J Rheumatol*. 2005;32(7):1305-1306.

34. Carreira ACG, Jones A, Natour J. Assessment of the effectiveness of a functional splint for osteoarthritis of the trapeziometacarpal joint of the dominant hand: A randomized controlled study. *J Rehabil Med*. 2010. doi:10.2340/16501977-0542.

35. Becker SJE, Bot AGJ, Curley SE, Jupiter JB, Ring D. A prospective randomized comparison of neoprene vs thermoplast hand-based thumb spica splinting for trapeziometacarpal arthrosis. *Osteoarthr Cartil*. 2013. doi:10.1016/j.joca.2013.02.006.

36. Wajon A, Vinycomb T, Carr E, Edmunds I, Ada L. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. *Cochrane database Syst Rev*. 2015;(2):CD004631. doi:10.1002/14651858.CD004631.pub4.

37. Wolfe T, Chu JY, Woods T, Lubahn JD. A systematic review of postoperative exercise therapy management of basal joint arthritis. *Clin Orthop Relat Res*. 2014;472(4):1190-1197. doi:10.1007/s11999-013-3285-z.

38. Becker SJE, Makarawung DJS, Spit SA, King JD, Ring D. Disability in patients with trapeziometacarpal joint arthrosis: incidental versus presenting diagnosis. J Hand Surg Am. United States; 2014 Oct;39(10):2009–2015.e8.

39. Lozano-Calderon SA, Souer JS, Jupiter JB, Ring D. Psychological differences between patients that elect operative or nonoperative treatment for trapeziometacarpal joint arthrosis. Hand. 2008. doi:10.1007/s11552-008-9098-y.

40. Frouzakis R, Herren DB, Marks M. Evaluation of expectations and expectation fulfillment in patients treated for trapeziometacarpal osteoarthritis. *J Hand Surg*

Am. 2015;40(3):483-490. doi:10.1016/j.jhsa.2014.10.066.

41. Arnold MH, Finniss DG, Kerridge I. Medicine's inconvenient truth: The placebo and nocebo effect. *Intern Med J*. 2014;44(4):398-405. doi:10.1111/imj.12380.

42. Connor-Greene PA. The therapeutic context: Preconditions for change in psychotherapy. *Psychotherapy*. 1993;30(3):375-382. doi:10.1037/0033-3204.30.3.375.

43. Wolf J a, Niederhauser V, Marshburn D, Lavela SL. Defining patient experience. *Patient Exp J*. 2014;1(1):7-19.

44. Curran J. The Doctor, his Patient and the Illness. *BMJ*. 2007;335(7626):941. doi:10.1136/bmj.39384.467928.94.

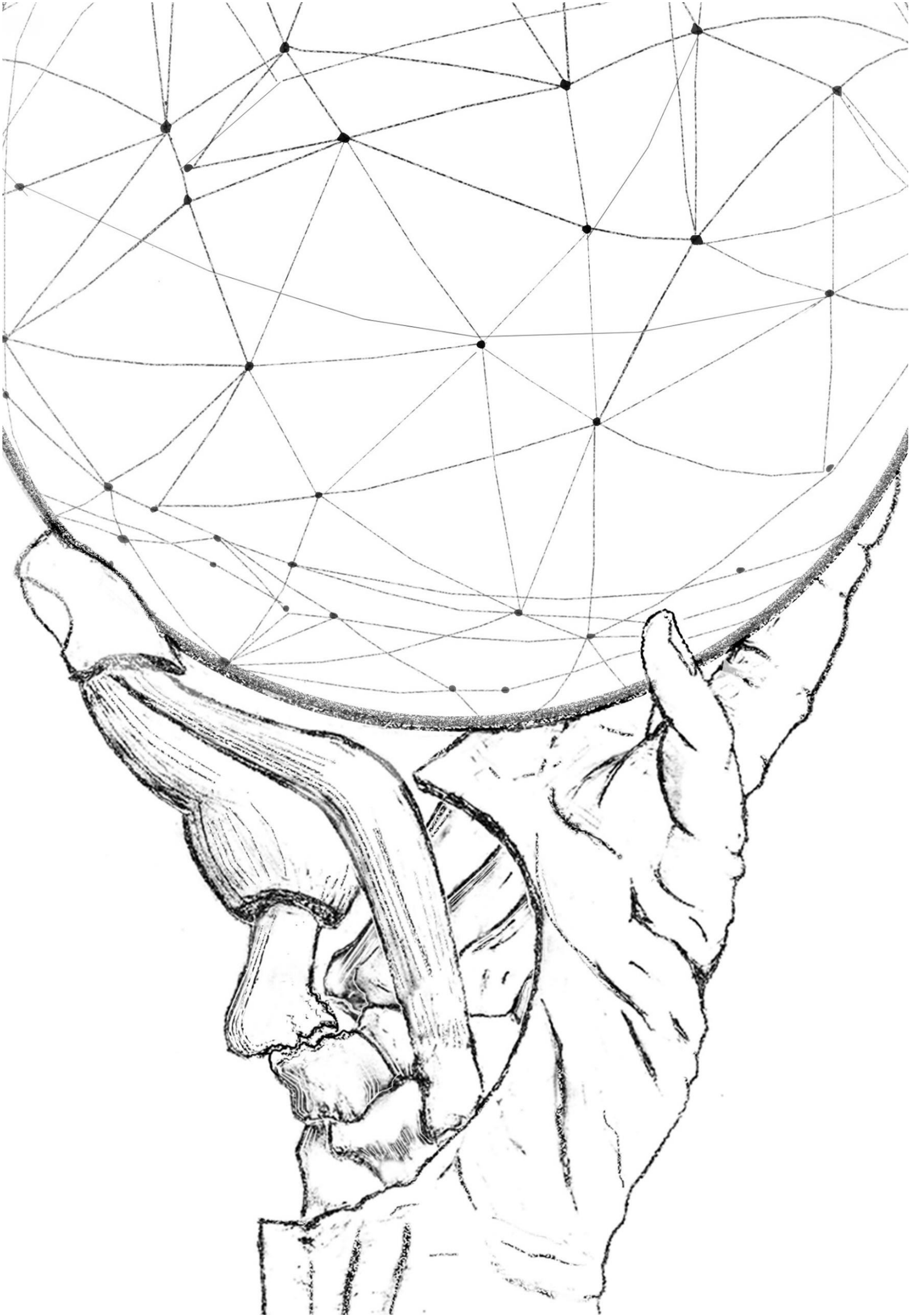
45. Di Blasi Z, Harkness E, Ernst E, Georgiou A, Kleijnen J. Influence of context effects on health outcomes: a systematic review. *Lancet*. 2001;357(9258):757-762. doi:10.1016/S0140-6736(00)04169-6.

46. Black N, Varaganum M, Hutchings A. Relationship between patient reported experience (PREMs) and patient reported outcomes (PROMs) in elective surgery. *BMJ Qual Saf*. 2014;23(7):534-543. doi:10.1136/bmjqs-2013-002707.

47. Menendez ME, Chen NC, Mudgal CS, Jupiter JB, Ring D. Physician Empathy as a Driver of Hand Surgery Patient Satisfaction. *J Hand Surg Am*. 2015;40(9):1860-1865. doi:10.1016/j.jhsa.2015.06.105.

PART 1

TREATMENT OUTCOME, PREDICTION AND CONVERSION TO SURGERY



EXERCISE THERAPY IN ADDITION TO AN ORTHOSIS REDUCES PAIN MORE THAN AN ORTHOSIS ALONE IN PATIENTS WITH THUMB BASE OSTEOARTHRITIS: A PROPENSITY SCORE MATCHING STUDY

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2

Abstract

Objectives: To compare the effect of exercises and orthotics with orthotics alone on pain and hand function in patients with thumb carpometacarpal (CMC) osteoarthritis (OA).

Methods: In this prospective cohort study, a sample of 173 patients with CMC OA was included in this study of which 84 were matched on baseline demographics and baseline primary outcomes using propensity score matching. Data collection took place in thirteen outpatient clinics for hand surgery and hand therapy in the Netherlands. Patients were divided in either exercise and orthotics group versus orthotics alone group. Primary outcomes included pain and hand function at three months, measured using Visual Analogue Scales (0-100, VAS) and the Michigan Hand outcomes Questionnaire (0-100, MHQ).

Results: A larger decrease in VAS pain at rest (11.1 points difference, 95% Confidence interval (CI): 1.9, 20.3, p=0.002) and during physical load (22.7 points difference, 95% CI: 13.6, 31.0, p<0.001,) was found in the exercise + orthotic group compared to the orthotic group. Additionally, larger improvement was found for the MHQ subscales pain, work performance, aesthetics and satisfaction in the exercise + orthotic group. No differences were found on other outcomes.

Conclusions: Conservative treatment for patients with CMC OA should include exercises, since there is a relatively large treatment effect compared to using an orthosis alone. Future research should study exercises in a more standardized setting to confirm this finding.

Introduction

Osteoarthritis (OA) of the thumb carpometacarpal joint (CMC) is a common disorder, with a radiologically diagnosed prevalence amongst females aged ≥50 years of 33-40%.[1-3] Patients with CMC OA often experience thumb pain, limitations in activities of daily life (ADL) and present clinical features such as thenar muscle wasting or thumb deformity.[1,4]

Guidelines and reviews advise to start with non-surgical treatment, including analgesics, intra-articular injections, orthotics and exercise programs.[5-7] While these interventions are widely used, evidence that supports these non-surgical treatments, especially exercise programs is limited.[5-13] Nonetheless, while analgesics, intra-articular injections or orthotics may provide short-term results, exercise programs may provide a long-term solution by improving joint mechanics and function.[12]

Most exercise programs intend to improve active stability and positioning of the CMC joint into a more stable position of extension/abduction, since the CMC joint becomes less stable during flexion/adduction.[9,12-17] Additionally, exercises focus on maintaining the first web space and pinch strength.[10-14] Orthotics often complements exercises, to reduce subluxation and inflammation, but are also prescribed as a stand-alone treatment.[11,14]

If non-surgical treatment fails to alleviate symptoms, conversion to surgical treatment may be considered. However, disadvantages of surgical treatment are its long recovery, prolonged patient discomfort & limitations and high costs.[6,18,19] Furthermore, it has been reported that for a trapeziectomy with/without ligament reconstruction and tendon interposition, 11-33% of the patients would not consider the same treatment again under the same circumstances.[19-23] Hence, because of the potential advantages compared to surgical treatment, more research on the added value of exercises in addition to orthotics is needed, since few studies are conducted and those available are of low methodological quality.[5,7,8,11]

This prospective cohort study compares the effect of a combination therapy consisting of range of motion, coordination and strengthening exercises and orthotics versus orthotics alone on pain and hand function in patients with CMC OA.

Methods

Study design

This was a prospective cohort study with propensity score matching (PSM) using a consecutive, population-based sample, reported following the STROBE statement.[25]

Setting

This study was performed at thirteen outpatient clinics for hand therapy and hand surgery in The Netherlands. Data collection took place between October 2015 and February 2017 and the local Medical Research Ethical Committee approved this study.

Data collection was part of routine outcome measurement using GemsTracker electronic data capture tools.[26] GemsTracker (Generic Medical Survey Tracker) is a secure web-based application for distribution of questionnaires and forms during clinical research and quality registrations.[27,28] A certified hand surgeon diagnosed patients with CMC OA by physical examination and radiographic evaluation to determine Eaton stage.[6,24] Subsequently, patients were referred for hand therapy and follow-up with the hand surgeon took place after three months to decide if further treatment was needed.

Participants

Participants were eligible for inclusion when they were adult and diagnosed with stage I-IV[24] CMC OA. Exclusion criteria were: 1) secondary CMC OA (i.e. due Bennett's fracture); 2) comorbidity interfering with treatment/outcome (i.e. Quervain's tenosynovitis); 3) patient history includes surgery interfering with treatment/outcome; or 4) steroid injection <6 weeks in hand/wrist.

Treatment

Due the observational design, treatment was not completely standardized as in randomized controlled trials. However, the hand therapists were trained to use and carry out treatment following a strict guideline.[29] The guideline prescribes the use of both orthotics and exercises. However, the exercises were not applied for every patient, depending on considerations made by the hand therapist and patient (i.e. influenced by therapy costs/traveling distance). Therefore, the hand therapists completed surveys at baseline, six weeks and three months on the treatment content and potential deviations to ensure guideline usage.[29]

Participants with more than two hand therapy sessions were classified into the exercise + orthotic group, received exercises and a static orthosis to reduce synovitis and instability.[11,30] The orthosis was thermoplastic, custom-made and immobilized the CMC in extension/abduction and the first metacarpophalangeal joint (MCP-1) in flexion. The exercise program included hand therapy sessions and exercises performed at home by the patient, aiming to improve active stability of the CMC during pinch in extension/abduction as instability and degeneration occurs in flexion/adduction.[10,12,14-17] In the first treatment phase (week 0-6), coordination of the intrinsic thenar muscles (except the adductor pollicis), extensor pollicis brevis and the first dorsal interosseous was exercised.[10,12,14] Participants were instructed to use the orthosis 24h/day in this phase, except during exercises. In the second phase (week 6-3 months), orthosis usage was reduced, guided by the hand therapist and strengthening exercises for the thenar muscles (except adductor pollicis) were initiated (details in Appendix 1).[10,12] Participants in the orthotic group were provided with the same orthosis, usage instructions and wearing time, but only two or less hand therapy sessions were

scheduled in which general advice and information on CMC OA was provided and no structured exercises were performed.

Primary & secondary outcomes

Primary outcomes were pain and hand function. Pain at rest and during physical load (i.e. activities needing pinch force, such as opening a jar or turning a key) was measured at baseline, six weeks and three months using a Visual Analogue Scale (VAS, 0-100, higher scores indicate more pain). The VAS is a reliable and valid instrument to measure pain intensity in patients with rheumatic diseases and has a minimal clinical important difference (MCID) of eleven.[31] Hand function was measured at baseline and three months using the Michigan Hand Outcomes Questionnaire (MHQ).[32] The MHQ total score was used as primary outcome while the subscales were secondary outcomes (0-100, higher scores indicate better performance except for the subscale pain).[32] The MHQ has a high internal consistency, high internal validity, acceptable reliability and is particularly applicable for patients with hand OA.[32] The Minimal Clinically Important Difference ranges between 9 and 13 points for total MHQ and between 11 and 14 points for the subscales.[33,34] Additionally, patient satisfaction was assessed at three months using a self-designed questionnaire on treatment effect and willingness to undergo treatment again.

Additional measurements

Stage of CMC OA[6,24], age, gender, type of work, therapy frequency, symptom duration and dominant side treated was derived from patient charts and surveys completed by the hand therapists. The hand therapists performed and registered measurements using standardized forms and were trained to conduct standardized measurements.[35] Additional baseline characteristics included MCP-1 flexion/hyperextension and inter metacarpal distance (IMD). MCP-1 flexion/hyperextension was measured using the American Society of Hand Therapists recommendations.[35] Presence of hyperextension at MCP-1 was dichotomized while MCP-1 flexion was used as continuous variable. IMD was measured using a caliper, because its reliability is superior to goniometric measurements of abduction.[36,37] Measurements of IMD were dichotomized, where 3.3mm difference between the unaffected and affected side was defined as limited IMD, since 3.3mm is the smallest detectable difference for IMD.[37] In bilateral involvement, the hand with the worst baseline MHQ score was used.

Study size

No recommendations on power analysis for PSM were found in literature. A study on Dupuytren's disease by Zhou et al.[28] used PSM, where 60% of the total sample was matched. Therefore, we estimated that at least 60% of the total sample would be matched, resulting in an estimated sample of 124 before PSM and 74 after PSM for a F-test, a conventional medium effect size of .15 (defined by Cohen[38]) and a power of

0.80. Since group ratio between the orthotic and exercise + orthotic group was unclear prior to analysis, we enlarged the sample to >200.

Statistical methods

At baseline, 91.7% of the demographic characteristics and primary outcomes were available. When data was missing, we checked whether it could be retrieved from patient charts. Missing value analysis on demographics and outcomes at three months showed a non-significant Little's test (p=0.495 and p=0.341 respectively), which confirmed that missing values were missing at random (MAR).[39-41] To further evaluate missing data at three months, significant testing was performed on demographic characteristics and baseline primary outcomes to compare participants with the presence of a primary outcome at three months with participants without the presence of a primary outcome at three months. No significant differences between were found (Supplementary Table 1). Since data were MAR and no differences were found between participants with and without the presence of a primary outcome at three months, multiple imputation was used to obtain missing data for continuous variables with <75% missing.[39,42,43]

Since comparing groups in observational studies is usually difficult due to differences between groups in covariates, we used PSM.[44] PSM involves a propensity score, which is the probability for an individual to be assigned to a particular treatment given observed covariates.[45,46] PSM allows comparing matched individuals, the only difference being whether they are treated with the intervention of interest or not.[45]

Propensity scores were estimated using logistic regression, where treatment status was regressed on baseline characteristics[45-47] using: VAS pain at rest and during physical load, MHQ total score, MCP-1 hyperextension, MCP-1 flexion, limited IMD, presence of STT OA (Eaton >III[24]), age, gender, type of work, symptom duration and dominant side treated. The propensity scores were subsequently used to match participants on a one-to-one basis using a nearest-neighbor algorithm with a matching tolerance width of 0.2 SD of the logit of the propensity score.[45,47] Between-group differences in demographic characteristics were analyzed before and after matching using standardized mean differences.[47-49]

Continuous outcomes were analyzed using univariate linear mixed model analysis and paired sample t-tests. The threshold for significance is lowered to 0.0125 from a conventional 0.05 to correct for multiple testing. The patient satisfaction questionnaire was analyzed on item level using Wilcoxon signed rank and McNemar tests.

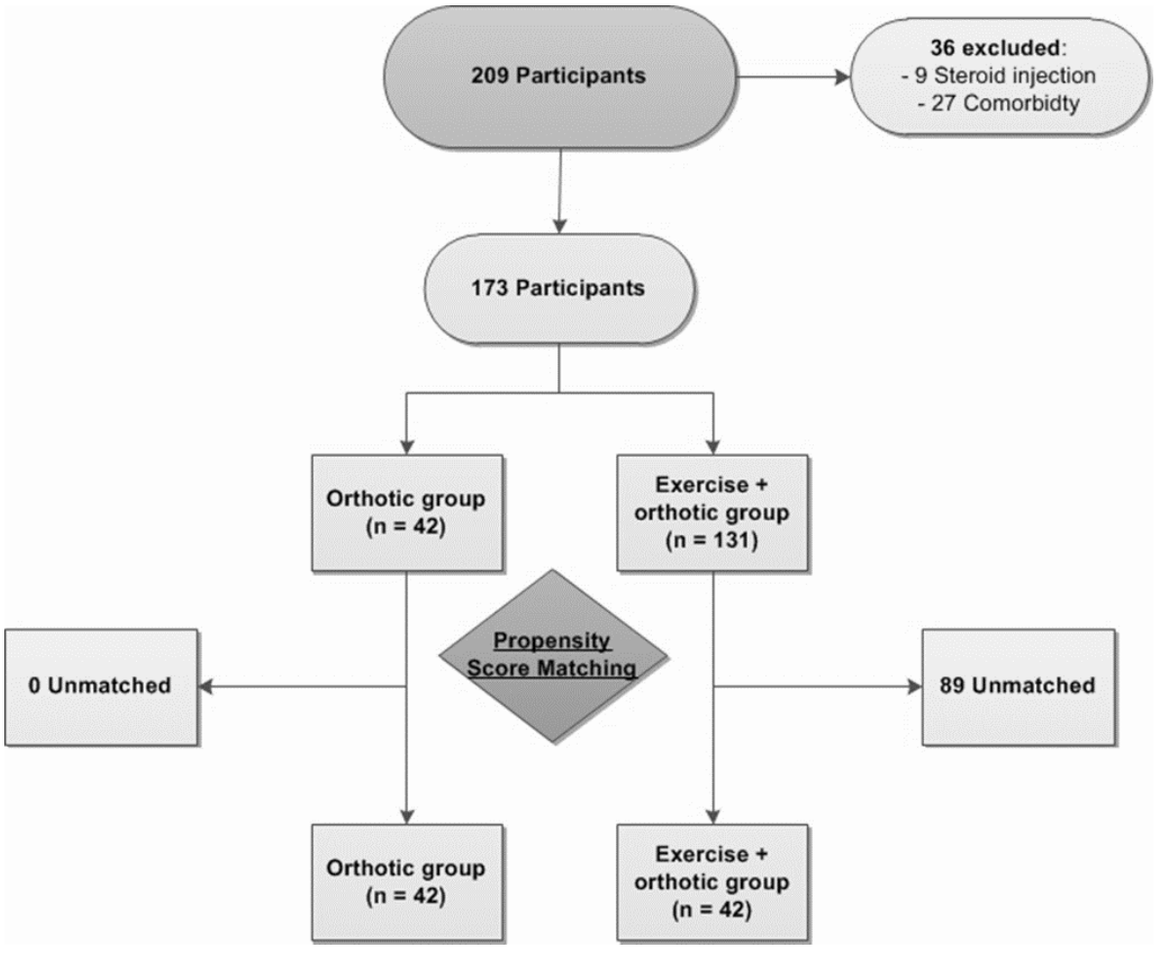


Figure 1. *Flowchart of the study. 42 Participants per group were matched using propensity score matching*

Results

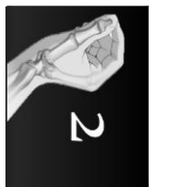
Initially, 209 participants were included (Figure 1). Twenty-seven participants were excluded due to comorbidity and nine participants were excluded because of corticosteroid injection(s). Hence, 173 participants were finally included. The orthotic group contained 42 participants while the exercise + orthotic group contained 131 participants. After matching, both groups contained 42 participants. Small between-group differences remained after matching (Table 1). The mean number of therapy sessions was 6.7 (SD=1.9) in the exercise + orthotic group.

Table 1. *Demographic characteristics at baseline. The unmatched and matched participants are displayed. Characteristics between the groups were compared using standardized mean differences*

		All Participants			**Matched Participants**		
		Orthotic group	*Exercise + orthotic group*	*Standardized mean difference*	*Orthotic group*	*Exercise + orthotic group*	*Standardized mean difference*
Participants, N		42	131		42	42	
Age in years, mean (SD)		60.8 (9.1)	60.2 (8.4)	0.06	60.8 (9.1)	58.9 (7.6)	0.23
Females, N (%)		31 (73.8%)	99 (75.6%)	0.04	31 (73.8%)	32 (76.2%)	0.06
Dominant side treated, N (%)		20 (47.6%)	62 (47.3%)	0.01	20 (47.6%)	17 (40.5%)	0.14
VAS, 0-100 (SD)	*At rest*	34.5 (23.1)	26.1 (23.5)	0.36	34.5 (23.1)	29.7 (24.6)	0.20
	During physical load	70.9 (14.5)	66.8 (16.7)	0.26	70.9 (14.5)	70.9 (15.6)	0.00
MHQ total, 0-100 (SD)		54.1 (14.4)	56.3 (19.4)	0.12	54.1 (14.4)	54.6 (17.6)	0.03
Type of work, N (%)	*Unemployed*	21 (50%)	51 (38.9%)	0.22	21 (50%)	15 (35.7%)	0.29
	Light physical labor	8 (19%)	30 (22.9%)	0.10	8 (19%)	8 (19%)	0.00
	Moderate physical labor	9 (21.4%)	34 (26%)	0.11	9 (21.4%)	12 (28.6%)	0.17
	Heavy physical labor	4 (9.5%)	16 (12.2%)	0.09	4 (9.5%)	7 (16.7%)	0.21
Symptom Duration in months, mean (SD)		22.1 (17.2)	27.3 (35)	0.18	22.1 (17.2)	31.0 (33.1)	0.33
Eaton Stage OA, N (%)	*I-III*	37	114	0.03	37	37	0.00

		(88.1%)	(87%)		(88.1%)	(88.1%)	
	IV	5 (11.9%)	17 (13%)	0.03	5 (11.9%)	5 (11.9%)	0.00
MCP-1 Hyperextension, N (%)		30 (71.4%)	96 (73.3%)	0.04	30 (71.4%)	29 (69%)	0.05
MCP-1 flexion in degrees, mean (SD)		49.8 (11.6)	52 (12.5)	0.18	49.8 (11.6)	52.7 (13.7)	0.23
IMD limited, N (%)		12 (28.6%)	45 (34.4%)	0.13	12 (28.6%)	14 (33.3 %)	0.10

Abbreviations: SD = standard deviation, OA = Osteoarthritis, MCP-1 = first metacarpophalangeal joint, IMD = inter metacarpal distance. VAS = Visual Analogue Scale, MHQ = Michigan Hand outcomes Questionnaire



Primary & secondary outcomes

VAS pain at rest decreased 11.1 points more in the exercise + orthotic group compared to the orthotic group at three months (95% Confidence interval(CI): 1.9, 20.3, p=0.002, Figure 2). Furthermore, VAS pain during physical load decreased 22.7 points more in the exercise + orthotic group compared to the orthotic group (95% CI: 13.6, 31.0, p<0.001, Figure 3).

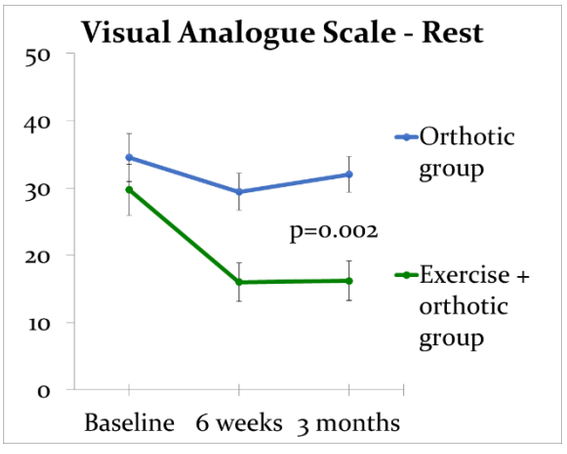


Figure 2. *Pain at rest as measured with a Visual Analogue Scale (VAS) for the orthotic group (blue line) and the exercise + orthotic group (green line). Group means and standard errors are plotted. Linear mixed model analysis demonstrates a significant difference between the groups (p=0.002).*

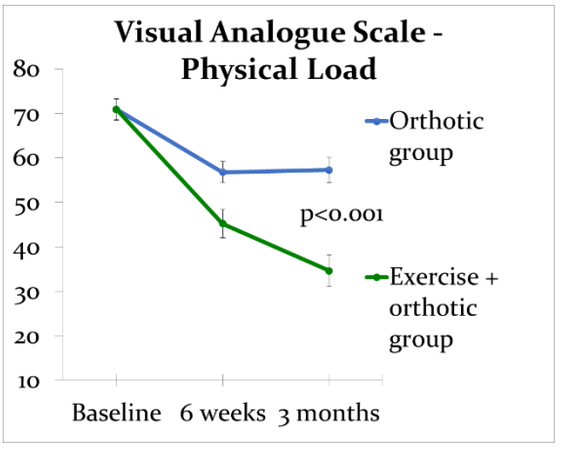


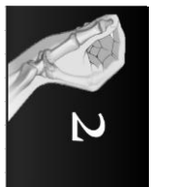
Figure 3. *Pain during physical load as measured with a Visual Analogue Scale (VAS) for the orthotic group (blue line) and the exercise + orthotic group (green line). Group means and standard errors are plotted. Linear mixed model analysis demonstrates a significant difference between the groups (p<0.001).*

No significant between-group differences were found on the MHQ total score (Table 2, p=0.273), but the subscales pain, work performance, aesthetics and satisfaction improved more in the exercise + orthotic group compared to the orthotic group with 8, 10.1, 5 and 12.9 points difference respectively (Figures 4-5, Table 2, p<0.001-0.008). No significant differences were found on other MHQ subscales or the patient satisfaction questionnaire (Table 2).

Table 2. *Outcomes of matched participants. The p-values displayed indicate significance of treatment effect in linear mixed model analysis, paired samples t-tests, Wilcoxon signed rank tests and McNemar tests. VAS = Visual Analogue Scale, SD = standard deviation, MHQ = Michigan Hand Outcomes Questionnaire – Dutch Version, ADL = activities in daily life.*

	Splint group				**Exercise program group**				**p-value**	
	Baseline	*6 weeks*	*3 months*	*Δ Within group*	*Baseline*	*6 weeks*	*3 months*	*Δ Within group*	*Δ Between groups*	
VAS pain rest, mean (SD)	34.5 (23.1)	29.4 (17.0)	32.0 (16.9)	-2.4	29.7 (24.6)	16.0 (18.4)	16.2 (18.7)	-13.5	-11.1	0.002
VAS pain physical load, mean (SD)	70.9 (14.5)	56.8 (14.4)	57.3 (17.2)	-13.6	70.9 (15.6)	45.2 (20.5)	34.6 (22.8)	-36.3	-22.7	<0.001
MHQ, mean (SD) Total	54.1 (14.4)	-	61.1 (10.0)	7	54.6 (17.6)	-	66.0 (13.4)	11.4	4.4	0.071
Subscales:										
Overall hand function										
ADL	51.5 (5.9)	-	56.6 (9.9)	5.1	54.2 (9.9)	-	59.8 (10.8)	5.6	0.5	0.258
Work performance	61.5 (8.9)	-	66.4 (13.8)	4.9	58.3 (17.2)	-	63.9 (16.5)	5.6	0.7	0.505
Pain	55.3 (15.6)	-	57.6 (17.1)	2.3	56.7 (18.7)	-	69.1 (15.8)	12.4	10.1	0.008
Aesthetics	66.8 (12.9)	-	55.6 (14.7)	-11.2	61.6 (19.0)	-	42.4 (17.7)	-19.2	-8.0	0.001
Satisfaction	73.4 (8.2)	-	74.7 (14.5)	1.3	82.8 (14.6)	-	89.1 (10.4)	6.3	5.0	<0.001
	44.0 (9.7)	-	50.6 (13.6)	6.6	46.9 (17.2)	-	66.4 (16.5)	19.5	12.9	<0.001
Experienced treatment result, %										0.317
Excellent		-	0 %	-		-	6.3%	-		
Good			40%				50%			
Fair			10%				25%			
Moderate			50%				12.5%			
Poor			0%				6.3%			
Participants that would undergo treatment again		-	60 %	-		-	75%	-		1.000

Abbreviations: VAS = Visual Analogue Scale, SD = standard deviation, MHQ = Michigan Hand Outcomes Questionnaire – Dutch Version, ADL = activities in daily life



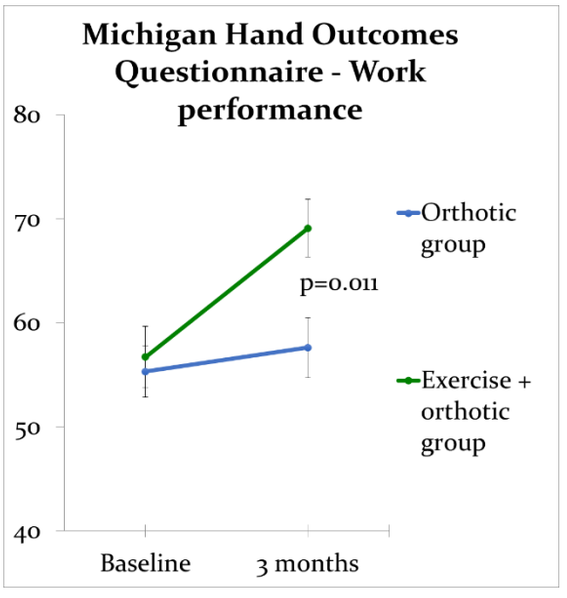


Figure 4. *Work performance as measured with the Michigan Hand outcomes Questionnaire (MHQ) for the orthotic group (blue line) and the exercise + orthotic group (green line). Group means and standard errors are plotted. Paired samples T-tests demonstrate a significant difference between the groups.*

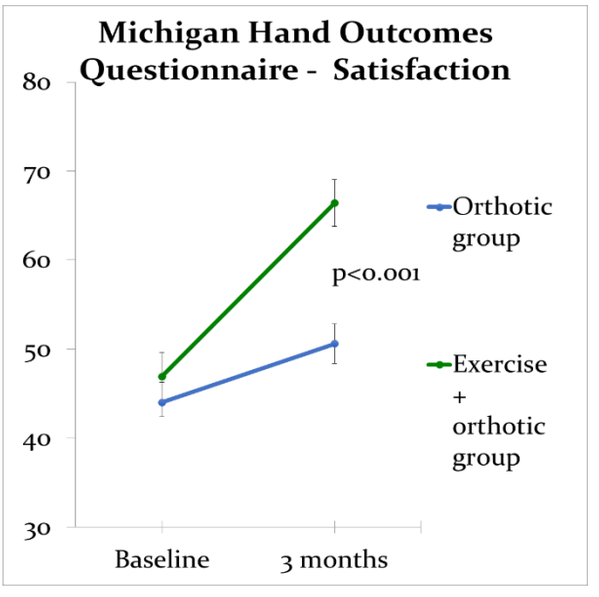


Figure 5. *Satisfaction as measured with Michigan Hand outcomes Questionnaire (MHQ) for the orthotic group (blue line) and the exercise + orthotic group (green line). Group means and standard errors are plotted. Paired samples T-tests demonstrate a significant difference between the groups (p<0.001)*

Discussion

This study found superior and clinically relevant results for the exercise + orthotic group compared to the orthotic group on VAS pain (at rest and during physical load) and the MHQ subscales pain, work performance, aesthetics and satisfaction. No significant differences were found on MHQ total score, its subscales and the patient satisfaction questionnaire.

Our findings on treatment effect are not completely in line with literature. Several studies[7,9,11,13] found positive outcomes on pain and hand function for exercises, while other studies[5,8] found insufficient or low evidence for the use of exercises. This contradiction may be related to the fact that systematic reviews reported that most studies on exercises for patients with CMC OA are of low methodological quality.[5,7,8,11] Additionally, some studies[9,13] used similar exercises as in this study, while some studies included in the systematic reviews for example applied manual mobilizations to the CMC or mainly applied exercises for general hand OA instead of CMC OA specifically.[5,7,8] Hence, more high-quality studies on exercises for patients with CMC OA are needed.

Study Limitations

The significant and clinically relevant benefits of exercises may be a result of improved thumb positioning and the strengthening exercises improving pinch strength. However, a limitation is that insufficient data was available to report outcomes on strength. Additionally, the use of multiple imputation on other outcomes may have introduced bias, despite missing value analyses and the non-significant Little's test. Furthermore, substantial statistical power was lost in the variables where no multiple imputation was used. For example, outcomes on patient satisfaction demonstrated superior but non-significant results in the exercise + orthotic group. Hence, it is recommended that future research on this topic is employed with emphasis on prevention of missing data.

While a limitation of this study is its observational character, a strength is that the results are collected in daily practice and are therefore representative for actual daily care. However, despite that the hand therapists received training in guideline usage, complete standardization of treatment could not be ensured as in randomized controlled trials. Additionally, blinding was not possible in the present design and i.e. analgesics usage is not controlled. Furthermore, indication bias may have occurred in treatment allocation if unidentified covariates were present. However, the small differences[38] in baseline characteristics (with a highest SMD of 0.33), largely already present prior to PSM gives us confidence that the results of a randomized controlled trial would be similar. Additionally, a limitation is that large variation on MCID's of the MHQ is reported in literature. Hence, the significant differences in MHQ subscales should be interpreted with caution.[33,34] Another limitation is that contextual or placebo effects may be present, since the exercise + orthotic group received more attention from the hand therapists compared to the orthotic group. Hence, studies investigating contextual effects of exercises are needed.

Lastly, a limitation of the exercise program may be the costs compared to an orthosis only. Potential cost saving could be achieved if exercise programs reduce the conversion to surgery compared to no exercises. Therefore, it is recommended that future studies investigate the cost-effectiveness of exercise programs (including conversion to surgery) in addition to an orthosis in a larger, standardized randomized controlled trial.

Conclusion

In conclusion, positive effects of exercises were found on pain in patients with CMC OA. Therefore, exercise programs are recommended in the treatment for patients with CMC OA, particularly because of the relatively large treatment effects compared to an orthosis alone. Future research should study exercises in larger randomized controlled trials.

References

1. Dahaghin S, Bierma-Zeinstra SMA, Ginai AZ, Pols HAP, Hazes JMW, Koes BW. Prevalence and pattern of radiographic hand osteoarthritis and association with pain and disability (the Rotterdam study). Ann Rheum Dis. 2005;64(5):682-7.

2. Bijlsma JWJ, Berenbaum F, Lafeber FPJG. Osteoarthritis: An update with relevance for clinical practice. The Lancet. 2011;377(9783):2115-26.

3. Haugen IK, Englund M, Aliabadi P, Niu J, Clancy M, Kvien TK, et al. Prevalence, incidence and progression of hand osteoarthritis in the general population: the Framingham Osteoarthritis Study. Ann Rheum Dis. 2011;70(9):1581-6.

4. Marshall M, van der Windt D, Nicholls E, Myers H, Dziedzic K. Radiographic thumb osteoarthritis: frequency, patterns and associations with pain and clinical assessment findings in a community-dwelling population. Rheumatology. 2011;50(4):735-9.

5. Spaans AJ, van Minnen LP, Kon M, Schuurman AH, Schreuders AR, Vermeulen GM. Conservative treatment of thumb base osteoarthritis: a systematic review. 2015(1531-6564 (Electronic)).

6. Handchirurgie NVv. Richtlijn Conservatieve en Chirurgische Behandeling van Primaire Artrose van de Duimbasis. 2014.

7. Bertozzi L, Valdes K, Vanti C, Negrini S, Pillastrini P, Villafane JH. Investigation of the effect of conservative interventions in thumb carpometacarpal osteoarthritis: systematic review and meta-analysis. Disabil Rehabil. 2015;37(22):2025-43.

8. Osteras N, Kjeken I, Smedslund G, Moe RH, Slatkowsky-Christensen B, Uhlig T, et al. Exercise for hand osteoarthritis. The Cochrane database of systematic reviews. 2017;1:Cd010388.

9. Wajon A, Ada L. No difference between two splint and exercise regimens for people with osteoarthritis of the thumb: a randomised controlled trial. Aust J Physiother. 2005;51(4):245-9.

10. Poole JU, Pellegrini Jr VD. Arthritis of the thumb basal joint complex. J Hand Ther. 2000;13(2):91-107.

11. Kjeken I, Smedslund G, Moe RH, Slatkowsky-Christensen B, Uhlig T, Hagen KB. Systematic review of design and effects of splints and exercise programs in hand osteoarthritis. Arthritis Care Res. 2011;63(6):834-48.

12. Valdes K, Von Der Heyde R. An exercise program for carpometacarpal osteoarthritis based on biomechanical principles. J Hand Ther. 2012;25(3):251-62.

13. O'Brien VH, Giveans MR. Effects of a dynamic stability approach in conservative intervention of the carpometacarpal joint of the thumb: A retrospective study. J Hand Ther. 2013;26(1):44-52.

14. Neumann DBT. The carpometacarpal joint of the thumb: stability, deformity, and therapeutic intervention. The Journal of orthopaedic and sports physical therapy. 2003;33(7):386-99.

15. Hagert E, Lee J Fau - Ladd AL, Ladd AL. Innervation patterns of thumb trapeziometacarpal joint ligaments. 2012(1531-6564 (Electronic)).

16. Ladd AL, Lee J Fau - Hagert E, Hagert E. Macroscopic and microscopic analysis of the thumb carpometacarpal ligaments: a cadaveric study of ligament anatomy and histology. 2012(1535-1386 (Electronic)).

17. Edmunds JO. Current concepts of the anatomy of the thumb trapeziometacarpal joint. 2011(1531-6564 (Electronic)).

18. Wouters RM, Tsehaie J, Hovius SER, Dilek B, Selles RW. Postoperative rehabilitation following thumb base surgery: a systematic review of the literature. Arch Phys Med Rehabil. 2017.

19. Vermeulen GM, Slijper H, Feitz R, Hovius SE, Moojen TM, Selles RW. Surgical management of primary thumb carpometacarpal osteoarthritis: a systematic review. J Hand Surg Am. 2011;36(1):157-69.

20. Vermeulen GM, Spekreijse KR, Slijper H, Feitz R, Hovius SE, Selles RW. Comparison of arthroplasties with or without bone tunnel creation for thumb basal joint arthritis: a randomized controlled trial. J Hand Surg Am. 2014;39(9):1692-8.

21. Wajon AV, T.; Carr, E.; Edmunds, I.; Ada, L. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. The Cochrane database of systematic reviews. 2015;2:Cd004631.

22. Vermeulen GM, Brink SM, Sluiter J, Elias SG, Hovius SE, Moojen TM. Ligament reconstruction arthroplasty for primary thumb carpometacarpal osteoarthritis (weilby technique): prospective cohort study. J Hand Surg Am. 2009;34(8):1393-401.

23. Vermeulen GM, Brink SM, Slijper H, Feitz R, Moojen TM, Hovius SE, et al. Trapeziometacarpal arthrodesis or trapeziectomy with ligament reconstruction in primary trapeziometacarpal osteoarthritis: a randomized controlled trial. J Bone Joint Surg Am. 2014;96(9):726-33.

24. Eaton RG, Glickel SZ, Littler JW. Tendon interposition arthroplasty for degenerative arthritis of the trapeziometacarpal joint of the thumb. J Hand Surg Am. 1985;10(5):645-54.

25. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453-7.

26. GemsTracker c, Erasmus MC and Equipe Zorgbedrijven, latest release at 2017, version 1.8.2, open source (new BSD licence), https://gemstracker.org.

27. Zhou C, Selles RW, Slijper HP, Feitz R, van Kooij Y, Moojen TM, et al. Comparative Effectiveness of Percutaneous Needle Aponeurotomy and Limited Fasciectomy for Dupuytren's Contracture: A Multicenter Observational Study. Plast Reconstr Surg. 2016;138(4):837-46.

28. Zhou C, Hovius SE, Slijper HP, Feitz R, Van Nieuwenhoven CA, Pieters AJ, et al. Collagenase Clostridium Histolyticum versus Limited Fasciectomy for Dupuytren's Contracture: Outcomes from a Multicenter Propensity Score Matched Study. Plast Reconstr Surg. 2015;136(1):87-97.

29. Handtherapie Nederland. Guideline thumb base osteoarthritis (Richtlijn duimbasisartrose/duimprogramma), Handtherapie Nederland. 2014.

30. Valdes KMT. A systematic review of conservative interventions for osteoarthritis of the hand. J Hand Ther. 2010;23(4):334-50.

31. Hawker GMSKTFM. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). Arthritis Care Res (Hoboken). 2011;63 Suppl 11:S240-S52.

32. Poole J. Measures of hand function: Arthritis Hand Function Test (AHFT), Australian Canadian Osteoarthritis Hand Index (AUSCAN), Cochin Hand Function Scale, Functional Index for Hand Osteoarthritis (FIHOA), Grip Ability Test (GAT), Jebsen Hand Function Test (JHFT), and Michigan Hand Outcomes Questionnaire (MHQ). Arthritis Care Res (Hoboken). 2011;63 Suppl 11:S189-S99.

33. London DA, Stepan Jg Fau - Calfee RP, Calfee RP. Determining the Michigan Hand Outcomes Questionnaire minimal clinically important difference by means of three methods. 2014(1529-4242 (Electronic)).

34. Shauver MJ, Chung KC. The minimal clinically important difference of the Michigan hand outcomes questionnaire. J Hand Surg Am. 2009;34(3):509-14.

35. American Society for Hand T. Clinical Assessment Recommendations, 2nd edition. 1992.

36. Murugkar PM, Brandsma JW, Anderson AM, Gurung K, Pun Y. Reliability of thumb web measurements. J Hand Ther. 2004;17(1):58-63.

37. de Kraker M, Selles RW, Schreuders TA, Stam HJ, Hovius SE. Palmar abduction: reliability of 6 measurement methods in healthy adults. J Hand Surg Am. 2009;34(3):523-30.

38. Cohen J. Statistical power analysis for the behavioral sciences, second edition. 1988.

39. de Groot JA, Janssen KJ, Zwinderman AH, Bossuyt PM, Reitsma JB, Moons KG. Correcting for partial verification bias: a comparison of methods. Ann Epidemiol. 2011;21(2):139-48.

40. Little R, J. A. A Test of Missing Completely at Random for Multivariate Data with Missing Values. Journal of the American Statistical Association. 1988;83(404):1198-202.

41. Little RJ, D'Agostino R, Cohen ML, Dickersin K, Emerson SS, Farrar JT, et al. The prevention and treatment of missing data in clinical trials. N Engl J Med. 2012;367(14):1355-60.

42. Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. Biometrics. 1986;42(1):121-30.

43. Preisser JS, Lohman KK, Rathouz PJ. Performance of weighted estimating equations for longitudinal binary data with drop-outs missing at random. Stat Med. 2002;21(20):3035-54.

44. Rubin DB. The design versus the analysis of observational studies for causal effects: parallels with the design of randomized trials. Stat Med. 2007;26(1):20-36.

45. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Biometrika. 1983;70(1):41-55.

46. Freemantle N, Marston L, Walters K, Wood J, Reynolds MR, Petersen I. Making inferences on treatment effects from real world data: propensity scores, confounding by indication, and other perils for the unwary in observational research. BMJ. 2013;347:f6409.

47. Austin PC. An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. Multivariate Behav Res. 2011;46(3):399-424.

48. Austin PC. Propensity-score matching in the cardiovascular surgery literature from 2004 to 2006: a systematic review and suggestions for improvement. J Thorac Cardiovasc Surg. 2007;134(5):1128-35.

49. Austin PC, Grootendorst P, Anderson GM. A comparison of the ability of different propensity score models to balance measured variables between treated and untreated subjects: a Monte Carlo study. Stat Med. 2007;26(4):734-53.

50. Kutner M, Nachtsheim C, J N. Applied linear statistical models.-5th ed. ISBN 0-07-238688-6. 2005.

51. Wollstein R, Clavijo J, Gilula LA. Osteoarthritis of the Wrist STT Joint and Radiocarpal Joint. Arthritis. 2012;2012:242159.

Appendix

Supplementary figure 1.

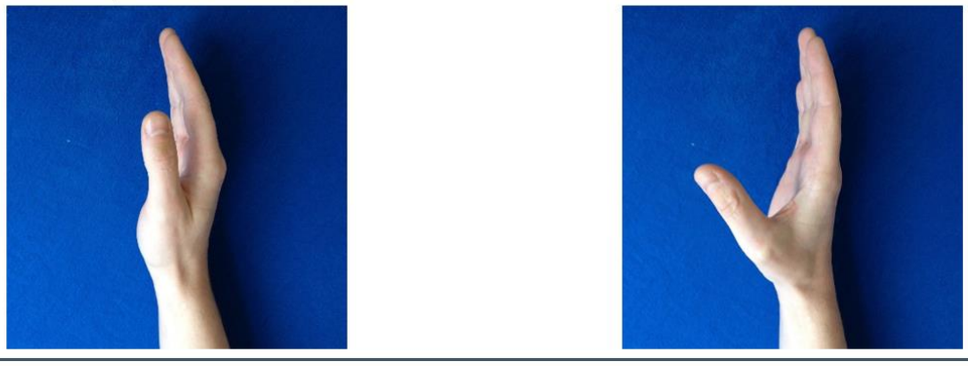
First phase of treatment (week 0-6)

Examples of the exercises, performed 4-6 times a day, 10-15 repetitions.[12,23]

The exercises aim to improve the specific function of the intrinsic thenar muscles (except the adductor pollicis), the extensor pollicis brevis and the first dorsal interosseous.

1 – Abductor pollicis brevis / longus coordination exercise

A



2 – Extensor pollicis brevis coordination exercise

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3 – Flexor pollicis brevis coordination exercise

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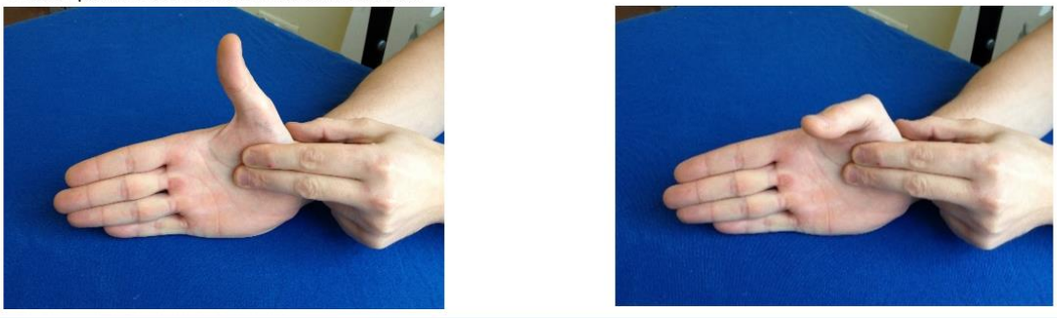
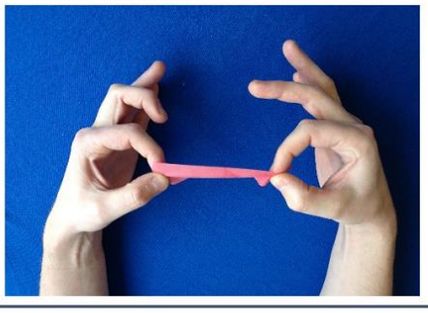


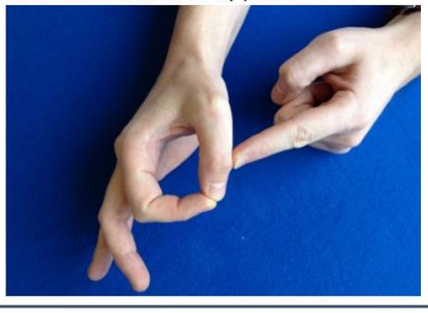
Second phase of treatment (week 6 – 3 months)

Examples of the exercises, performed 2-3 times a day. Force is applied for 2-3 seconds and build up until 50-100 repititions.[12,23]

4 – Pulling a rubber band in closed and correct key pinch



5 – Applying manual resistance at the radial part of proximal phalanx in closed and correct key pinch



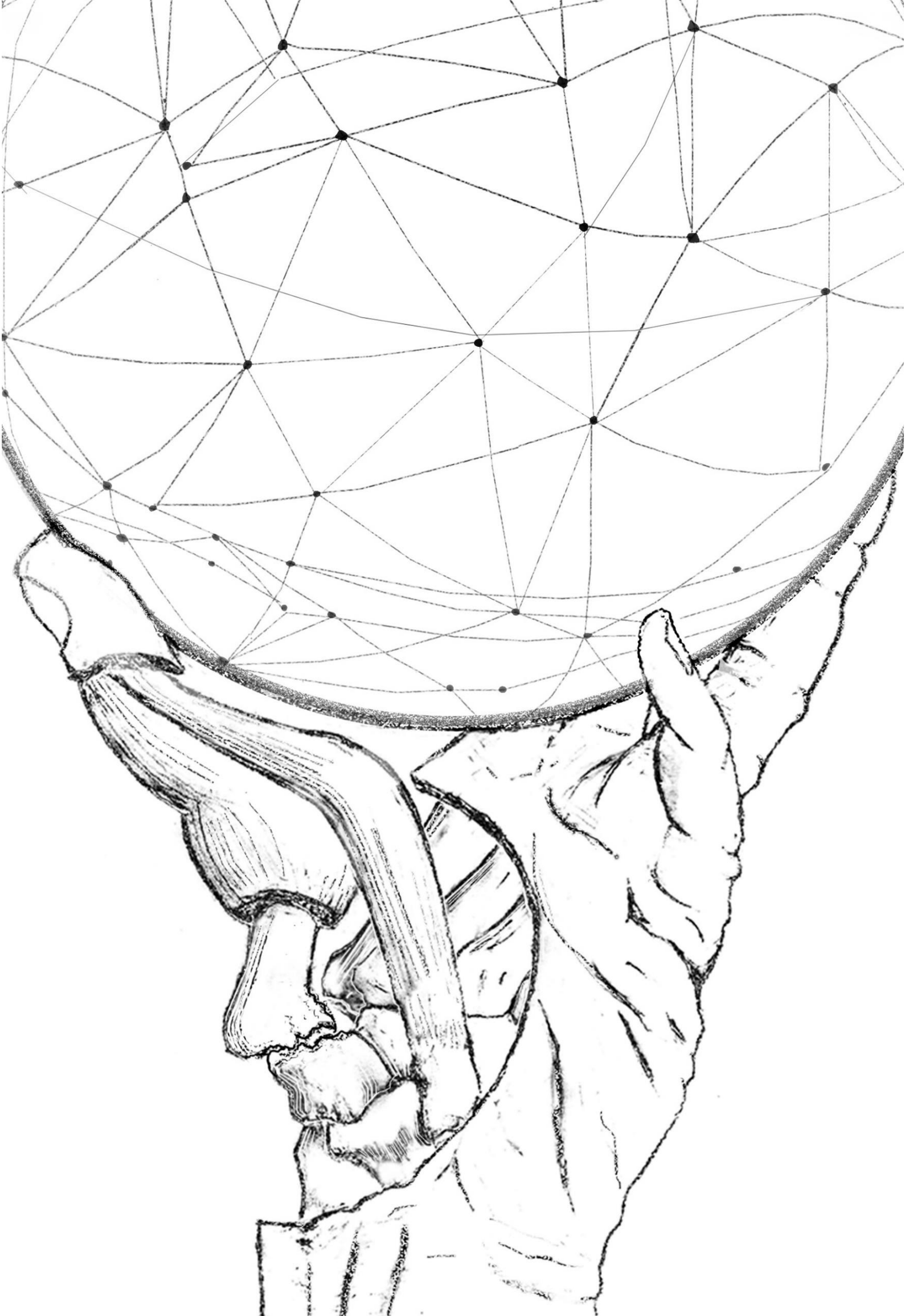
6 – Pulling a rubber band in open chain

7 – Applying manual resistance at the radial aspect of the proximal phalanx in open chain

Supplementary Table 1. *Non-responder analysis, where participants with the presence of a primary outcome at three months were compared with participants without the a primary outcome at three months using independent samples t-tests, Chi square tests and Fisher's exact tests.*

		Primary outcome at three months present	*Primary outcome at three months absent*	*p-value*
Participants, N		127 (73,4%)	46 (26,6%)	
Age in years, mean (SD)		60.2 (8.6)	60.9 (8.6)	0.662
Females, N (%)		96 (75.6%)	34 (73.9%)	0.844
Dominant side treated, N (%)		57 (44.9%)	15 (32.6%)	0.166
Type of work, N (%)	*Unemployed*	53 (41.7%)	19 (41.3%)	0.983
	Light physical labor	27 (21.3%)	11 (23.9%)	0.983
	Moderate physical labor	32 (25.2%)	11 (23.9%)	0.983
	Heavy physical labor	15 (11.8%)	5 (10.9%)	0.983
Duration of symptoms in months, mean (SD)		29.1 (28.7	24.9 (32.7)	0.443
Eaton Stage OA, N (%)	*I-III*	113 (89%)	38 (82.6%)	0.304
	IV	14 (11%)	8 (17.4%)	0.304
MCP-1 Hyperextension, N (%)		94 (80.3%)	32 (78%)	0.822
MCP-1 flexion in degrees, mean (SD)		51.0 (12.1)	52.9 (12.4)	0.394
IMD limited, N (%)		32 (32.3%)	12 (33.3%)	1.000
VAS, 0-100 (SD)	*At rest*	26.9 (24.4)	30.3 (21.2)	0.416
	During physical load	67.1 (16.4)	69.8(15.9)	0.353
MHQ total, 0-100 (SD)		57.8 (16.4)	57.1 (14.4)	0.916

Abbreviations: SD = standard deviation, OA = Osteoarthritis, MCP-1 = first metacarpophalangeal joint, IMD = inter metacarpal distance. VAS = Visual Analogue Scale, MHQ = Michigan Hand outcomes Questionnaire



OUTCOME OF A HAND ORTHOSIS AND HAND THERAPY FOR THUMB CARPOMETACARPAL OSTEOARTHRITIS IN DAILY PRACTICE: A PROSPECTIVE COHORT STUDY

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3

Abstract

Introduction: Initial treatment for symptomatic carpometacarpal (CMC) osteoarthritis (OA) of the thumb is usually non-surgical. However, evidence on the effect of a hand orthosis and hand therapy for mid and long-term results is limited, and it is unknown how many patients undergo additional surgical treatment. Therefore, the aim of this study is to describe the outcome of a hand orthosis and hand therapy for CMC OA in a large cohort study, and to evaluate the conversion rate to surgical treatment.

Methods: In this multicenter, prospective cohort study, patients treated with a hand orthosis and hand therapy for primary CMC OA between 2011 and 2014 were included. Pain (visual analog scale) and function (Michigan Hand Questionnaire) were measured at baseline, 6 weeks, 3 months, and at 12 months after the start of treatment. All patients converted to surgery were recorded between 2012 and 2016. Outcome was compared with baseline, and post hoc comparisons were made between patients who were not converted to surgery and patients who were converted to surgery after initially receiving a hand orthosis and hand therapy. Lastly, subgroup analysis was performed based on baseline pain levels.

Results: After a mean follow-up of 2.2 ± 0.9 years, 15% of all patients were surgically treated. In the group that was not converted to surgery, pain (visual analog scale) significantly improved from 49 ± 20 at baseline to 36 ± 24 at 12 months. The Michigan Hand Questionnaire score was essentially unchanged from 65 ± 15 at baseline to 69 ± 10 at 12 months. Post hoc testing showed that improvement in pain was only significant between baseline and 6weeks, and thereafter stabilized until 1 year after the start of treatment. The group that eventually converted to surgery did not show any improvement in pain and function during conservative treatment.

Conclusions: In this cohort of patients with thumb CMC OA who underwent hand therapy including an orthosis, 15% of the patients underwent additional surgical treatment. The patients (85%) who did not undergo surgery improved in pain and function, although only improvements in pain were significant and clinically relevant. Most improvement was seen in the first 6 weeks and stabilized till 1 year after the start of treatment.

Introduction

Treatment guidelines for carpometacarpal (CMC) osteoarthritis (OA) of the thumb usually advise a period of nonsurgical treatment before considering surgical treatment for all patients with primary CMC OA.[1-4] Nonsurgical treatment for CMC OA can consist of orthosis immobilization, intra-articular steroid injections, hand therapy, or a combination of modalities.[5-7] When nonsurgical treatment fails to provide enough pain relief or functional improvement in daily life, a decision may be made to proceed to surgical treatment.

However, the existing evidence on the effectiveness of nonsurgical treatment is of poor quality, primarily due to small sample sizes, non-generalizable study samples, or short follow-up time. In addition, most of these studies are limited to only comparing different types of orthoses and not the effect of combination therapy, that is, an orthosis with hand therapy.[8-10] For example, a systematic review by Egan and Brousseau[8] showed that hand orthoses may help to relieve pain, but sample sizes of the included studies were very small (N= 10-37) and follow-up times relatively short (1 wk to 6 mo). In addition, hand function was not measured. Another systematic review on comparative studies of hand orthoses or hand therapy of CMC OA[9] concluded that a hand orthosis or hand therapy may provide pain reduction, but all studies had a short follow-up time (2 wk to 3 mo) and study samples comprising only older individuals (70-90 y). In addition, none of the studies evaluated outcome after a combination of a hand orthosis and hand therapy.[1,2,11,12]

A recent meta-analysis of Aebischer et al.[10] based on studies on hand orthoses, hand therapy, and nonpharmaceutical treatment for CMC OA concluded that combination therapy is more effective for pain than single interventions. Because of the paucity of available evidence, it is unknown how many patients respond favorably, and how many patients who initially received a hand orthosis and hand therapy are eventually converted to surgical treatment. In addition, the timing of surgical intervention, in relation to receiving a hand orthosis and hand therapy (e.g., how long should surgery be delayed if patients do not respond to a hand orthosis and hand therapy), is unknown as well.

Therefore, the aim of this study was to describe the one-year outcome of providing a hand orthosis and hand therapy for thumb CMC OA, and to identify when and how many patients need additional surgical treatment.

Methods

Study population

This study was conducted as an observational, prospective cohort study, performed in a private hand surgery clinic (Xpert Clinic, the Netherlands), consisting of 11 locations,

with 13 European board-certified hand surgeons delivering care. Hand therapy was given by more than 50 hand therapists at specialized hand therapy clinics, located in or near an Xpert clinic (Handtherapie Nederland, the Netherlands).

All patients evaluated at the outpatient clinic between January 2011 and November 2014, clinically diagnosed with CMC OA and treated with a hand orthosis and hand therapy, were asked to participate in this study. All patients received an x-ray of their hand to confirm the clinical diagnosis and to grade the severity of CMC OA. However, because the grading of the osteoarthritis was done in a nonsystematic way, we did not further analyze the CMC OA severity based on the x-ray images. The study was approved by the local institutional review board, and all patients signed an informed consent. Exclusion criteria were previous CMC surgery, post-traumatic OA, isolated scaphotrapeziotrapezoid OA on the x-ray, or a history of prior intra-articular corticosteroid injections in the thumb CMC joint. Furthermore, patients with active trigger finger, carpal tunnel syndrome, OA of the interphalangeal joints, or de Quervain tendonitis were excluded when they received simultaneous treatment for these conditions at the start of treatment.

Intervention

Treatment was based on the Dutch treatment guideline.[1] In general, treatment consisted of prescribing a custom-made or prefabricated orthosis (based on the preference of the surgeon, hand therapists, and insurance of the patient) and 2 sessions of hand therapy per week of an average duration of 25 minutes per session. The hand therapists all received the same internal training on how to treat CMC OA with hand therapy. However, this was a pragmatic study in the sense that the hand therapy was not strictly protocolled and controlled, but evaluated, based on clinical practice. Therapy sessions were planned by judgment of the therapist and ability and availability of the patient. In some cases, patients received only a hand orthosis without further treatment, for example because of their insurance or schedules.

The treatment was divided into 2 phases: phase I (week 0-6) included instructions to wear the hand orthosis almost 24 hours per day and consisted of hand therapy for optimizing thumb position (training pinch and grasping movements without hyperextension in the metacarpophalangeal thumb joint and without CMC adduction) and using a full thumb range of motion (where the specific coordination of the intrinsic and extrinsic muscles of the thumb is trained); in phase II (week 7-12), the hand orthosis was slowly phased out: the patient was advised to use the hand orthosis only during heavy activities, depending on pain level and the patient's ability to perform activities with a stable thumb position. The hand therapy during this phase focused on maintaining the pain reduction, introducing the learned stability during daily activities and improving thenar muscle strength. In this phase, fewer hand

therapy sessions were scheduled and patients performed more home exercises, up to 4-6 times a day. The number of prescribed home exercises ranged between 3 and 6 exercises per day, with 10-15 repetitions each, depending on the individual patient and the level of pain.

After this period of supervised therapy, patients were encouraged to keep doing the exercises, and patients were allowed to use the hand orthosis when necessary. No corticosteroid injections were given for their CMC OA during or after hand therapy, and no anti-inflammatory medication was prescribed by the surgeon.

Measures

Baseline demographics of all patients, including duration of complaints, comorbidity, and hand medical history, were collected before the start of treatment. Outcome measures were recorded before the start of the treatment, at 6 weeks, at 3 months, and at 12 months through our web-based outcome registration. All patients had a follow-up appointment with their hand surgeon after approximately 3 months, during which progress was evaluated.

Pain and function

Pain was measured with a visual analog scale (VAS) during 2 situations: pain during activities and pain experienced during the last week. To measure patient-rated hand function, the Michigan Hand Questionnaire was used (MHQ, Dutch Language Version; 0 = poorest function, 100 = ideal function).[13-15] The MHQ is a self-reported questionnaire with 6 domains and 37 items. The Minimal Clinically Important Difference ranges between 9 and 13 points for total MHQ and between 11 and 14 points for the subdomain pain, for nontraumatic hand conditions.[16]

Surgery

All patients had a follow-up appointment with their hand surgeon after approximately 3 months; further follow-up was only scheduled when indicated. Surgical intervention was discussed when patients did not respond well to the hand orthosis and hand therapy and had functional impairments and/or residual pain. Together with the surgeon, the decision to operate was made based on the symptoms of the patient. All surgeries performed between January 2012 and February 2016, together with time until surgery, were retrieved from the clinical records, independent of whether patients responded to the questionnaires. These results were separately analyzed and not combined with the results of the questionnaires, which made it possible to report conversion to surgery on all patients eligible for inclusion (Figure 1).

Statistical analysis

We performed a sample size calculation to determine the number of patients required to detect a conventional effect size of 0.15 for pain (VAS) after receiving a hand

orthosis and hand therapy. The required sample was 90 participants.[17]

Baseline demographics were available in more than 98% of the patients. Because data were collected during daily clinical practice, we had a substantial proportion of nonresponse during follow-up (Figure 1). In addition, the data that were missing at 12 months consisted of both patients who did not fill in the questionnaires and patients who had already converted to surgery. Because of this, a thorough non-responder analysis on the whole group was performed using χ^2 statistics or t-tests for all variables measured at baseline based on the response at 1 year. No significant differences were found at baseline between patients who filled in the questionnaires at follow-up and patients who did not fill the questionnaires at follow-up. In addition, Little's MCAR test[18] for all separate outcome variables showed that more than 95% of the outcome variables were missing at random. We therefore performed all main analysis with patients who responded at all follow-up measurements (complete case analysis). As a secondary analysis, we performed multiple imputations to compare the outcome for consistency with the complete case analysis. We performed multiple imputation by chained equations by fully conditional specification and used all patients. We imputed 10 times and compared the imputed data with the complete case data using t-tests (Appendix A). Here again, no significant differences were found between the imputed analysis and the complete case analysis.

Hereafter, analysis of variance tests with repeated measures were performed to compare baseline and follow-up measurements, combined with Tukey's post-hoc tests, to determine between which follow-up points the significant difference existed. In addition, we compared patients who eventually received surgery with patients who did not convert to surgery using independent samples t-tests. Because the decision to operate was made from 3 months onward, patients who eventually received surgery filled in the questionnaires only until 3 months. This allowed us to compare the group that was not operated with the group that converted to surgery up to 3 months without having to impute any data.

To study the influence of different baseline pain levels on outcome after treatment, we divided patients into 4 subgroups based on baseline pain level (VAS), correcting for regression to the mean, which can occur if a variable is extreme on its first measurement; in that case, it will tend to be closer to the average on its second measurement.[19] Corrections were made based on a test-retest reliability of 0.85 for VAS pain.[20] For all tests, we considered a P-value smaller than .05 as statistically significant.

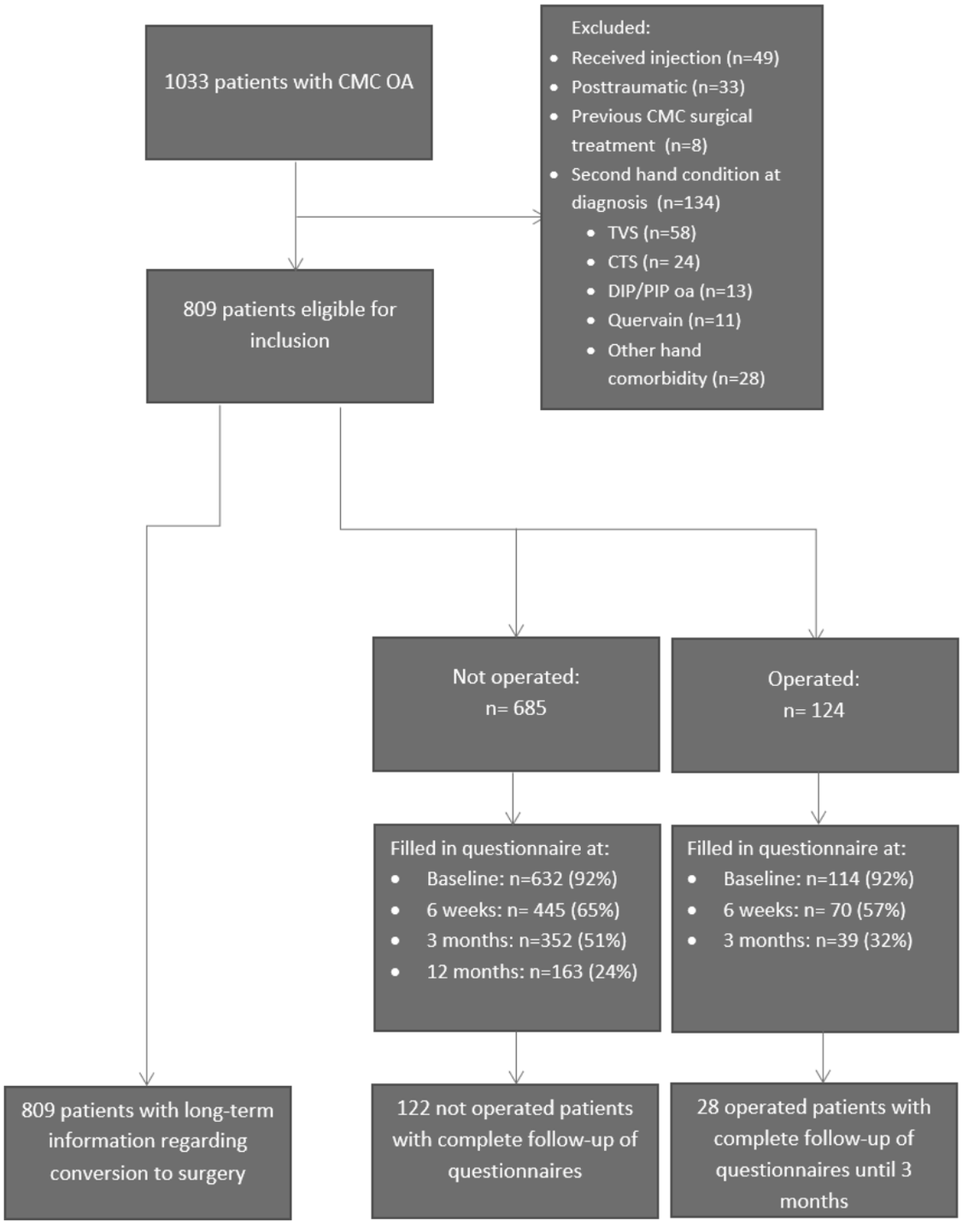


Figure 1. *Flowchart of the study. CTS, carpal tunnel syndrome; DIP, distal interphalangeal joint; PIP, proximal interphalangeal joint.*

Results

Study population

Between January 2012 and November 2014, 1,033 patients with complaints of CMC OA visited Xpert Clinic, of whom 809 were eligible for inclusion. Of those patients eligible for inclusion, 122 completed all follow-up measurements without undergoing surgery and were used to analyze the primary outcomes: pain and function. In addition, 28 patients who underwent surgery completed all follow-up measurements until 3 months. Figure 1 shows the flowchart and Table 1 shows the baseline characteristics.

Table 1. *Baseline characteristics*

Baseline Characteristics		**Total (n=122)**	
Variables		*N*	*% or mean±sd*
Age (years)		126	60±8
Duration symptoms (weeks)		126	40±72
Sex	Female	91	72
Treated hand	Right	63	50
Workload	No work	67	53
	Light physical work	22	18
	Moderate physical work	30	24
	Heavy physical work	7	6
Dominance	Left	14	11
	Right	107	85
	Both	5	4

Abbreviations: Sd = Standard deviation

To study conversion to surgery we included all 809 patients, because the recording of conversion to surgery was independent of the response of the patients to the questionnaires. Patients were followed for a minimum of 1.5 years to verify whether they had undergone surgical intervention. After a mean follow-up of 2.2 ± 0.9 (±standard deviation) years, 124 patients (15%) were surgically treated (Figure 2). The majority of the surgically treated patients (n = 93; 75%) were operated on within the first year after the start of hand therapy and the median number of days until surgery was 160 (interquartile range, 40-280) days.

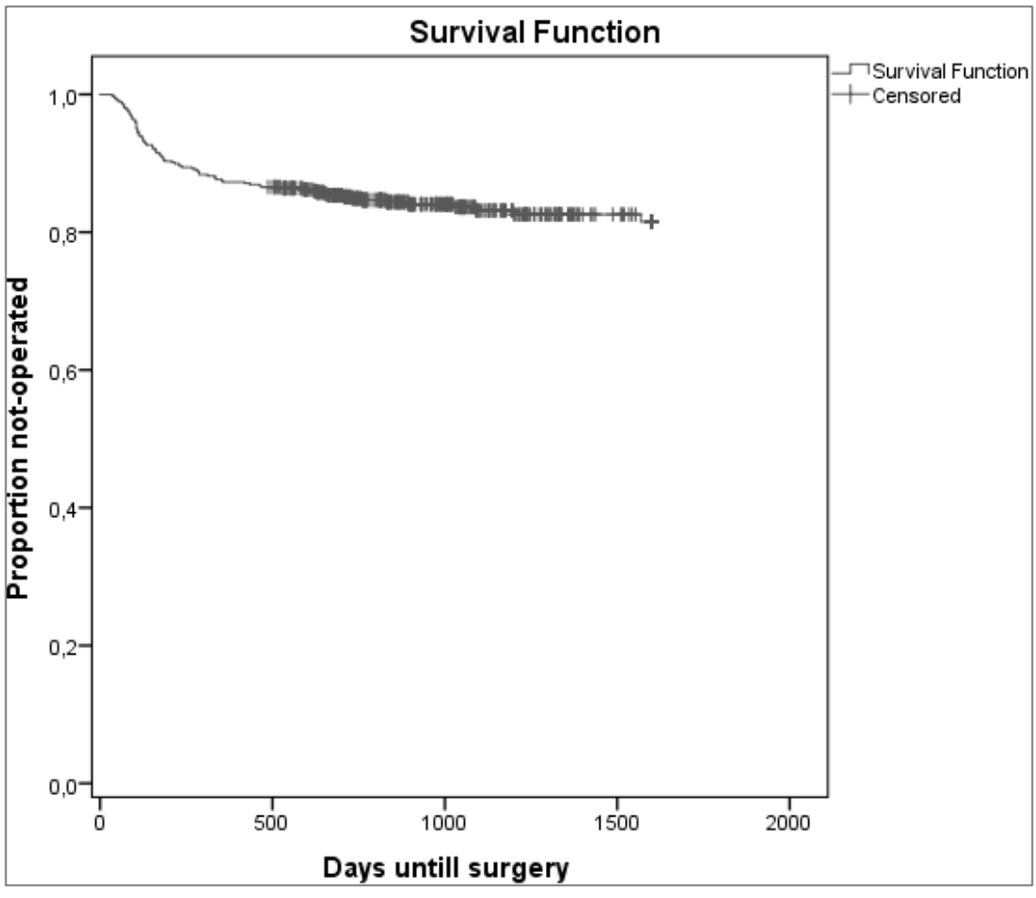


Figure 2. *Survival analysis. Chart shows the duration of time until receiving surgery. On the y axis the proportion of patients not operated is shown, and on the x axis the number of days since the start of a hand orthosis and hand therapy. A total of 15.3% converted to surgery with a median number of days until surgery of 5 months.*

Pain

The patients who did not convert to surgery showed a significant decrease in pain during the last week, VAS from 49 ± 20 (mean ± standard deviation) at baseline to 36 ± 24 at 12 months after the start of treatment ($P < .05$), and showed a significant decrease in pain during activities (VAS) from 60 ± 21 to 44 ± 27 after 12 months ($P < .05$) (Figure 3A).

Post hoc tests showed that improvements were only significant between baseline and 6 weeks: 14.5 points improvement (95% confidence interval [CI], 7.2 - 21.8; $P < .05$) for pain during the last week and 17.6 points improvement (95% CI, 9.8-25.4; $P < .05$) for pain during activities. Between 6 weeks and 12 months, no significant change occurred: 1.8 points mean difference (95% CI, -9.1 to 5.5; $P = .922$) for pain during the last week and 1.7 points mean difference (95% CI, -9.5 to 6.1; $P = .945$) for pain during activities.

The patients who chose to convert to surgery after 3 months had at baseline (at

the start of receiving a hand orthosis and hand therapy) a mean score of pain experienced during the last week of 62 ± 17, and a mean score of pain during activities of 67 ± 25. At follow-up, no significant change was seen between baseline and 3 months in pain experienced during the last week (1.6 points mean difference, 95% CI, -6.1 to 9.2; P = .677) or pain during activities (1.5 points mean difference, 95% CI, -11.0 to 8.0; P = .749).

When comparing patients who were converted to surgery with the patients who were not converted, we observed that the converted patients had at baseline 13.0 (95% CI, 5.0-21.0; P < .05) points higher pain experienced during the last week and 6.6 (95% CI, -2.3 to 15.5; P = .143) points higher pain during activities compared with the patients who were not converted. At 3 months the differences increased, with patients who were converted having 22.4 (95% CI, 12.9-32.0; P < .05) points higher pain experienced during the last week and 25.6 (95% CI, 15.9-35.4; P < .05) points higher pain during activities compared with the patients who were not converted.

Function

The patients who did not convert to surgery showed a significant change in function (total MHQ score) from 65 ± 15 at baseline to 69 ± 10 after 12 months (P < .05) (Figure 3B). Post hoc tests showed that for function, improvement was significant between baseline and 6 weeks: 6.2 (95% CI, 1.2-11.2; P < .05) points improvement, but the improvement in function was no longer significant at 1 year after the start of treatment (mean difference + 3.7 points; 95% CI, -0.95 to 11.2; P = .172) (Figure 3B).

The patients who chose to convert to surgery after 3 months had at baseline a mean function score of 58 ± 18. At follow-up, no significant improvement was seen between baseline and 3 months in function (0.2 points mean difference; 95% CI, -4.4 to 4.1; P = .939).

When comparing patients who were converted with the patients who were not converted, we observed that the converted patients had at baseline 7.0 (95% CI, 0.2-13.7; P = .044) points less function compared with the patients who were not converted. At 3 months the differences increased, with patients who were converted having 15.0 (95% CI, 8.5-21.4; P < .05) points less function compared with the patients who were not converted.

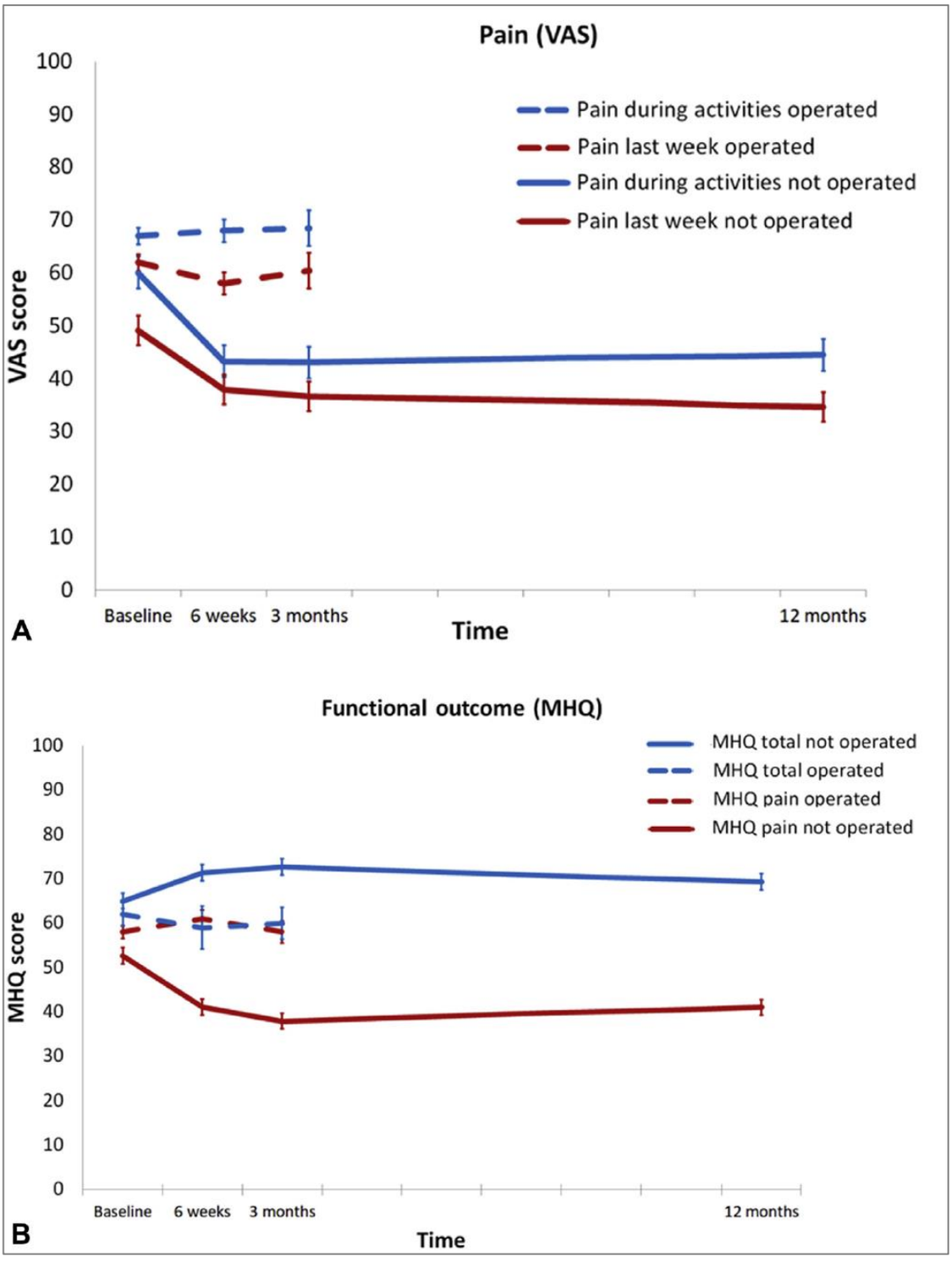


Figure 3. *Outcome in pain (VAS) and function (MHQ). In the group that was not operated, there was a significant improvement in pain between baseline and 12 months. Furthermore, most improvement was seen in the first 6 week. In the group that was eventually operated, there was no significant improvement between baseline and 3 months after receiving a hand orthosis and hand therapy. Error bars indicate standard errors.*

Subgroup analysis

When grouping patients who were not converted to surgery based on the severity of baseline pain (Figure 4), pain only improved significantly in groups where pain at baseline was higher than 50 on average (VAS); the higher the average pain level at baseline, the higher the reduction in pain. In contrast, patients with a baseline level of 25 or lower (VAS) showed a significant increase in pain after a hand orthosis and hand therapy.

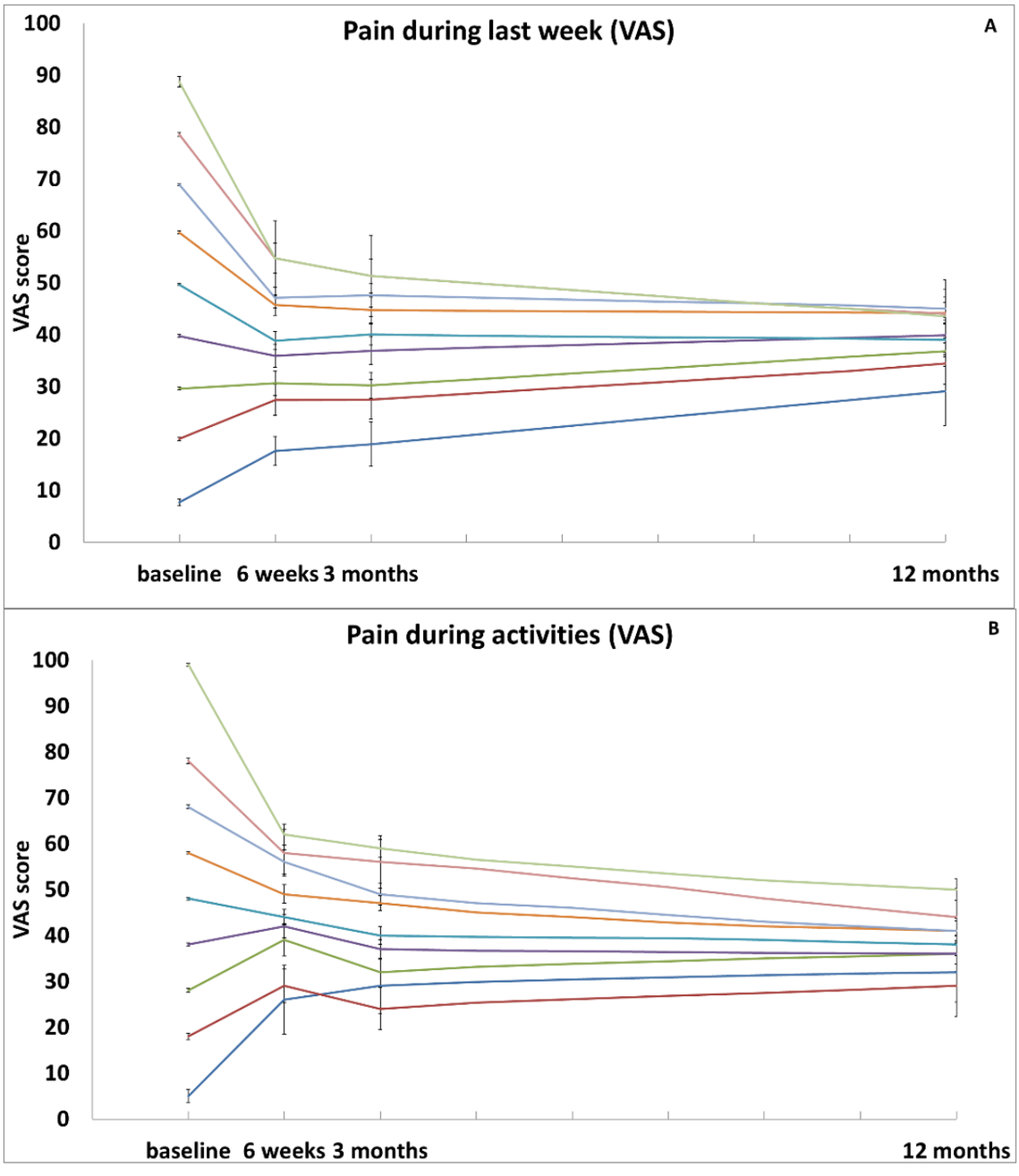


Figure 4. *Subgroup analysis for pain during last week (VAS) and pain during activities (VAS) based on baseline pain levels. The figure shows the outcome of treatment on subgroups. Patients with high baseline pain improved in outcome, whereas patients with low baseline pain deteriorated in outcome. Error bars indicate standard errors.*

Discussion

In this prospective cohort study using data collected as part of routine clinical care, we found that after a mean follow-up of 2.2 years, 15% of the patients treated with a hand orthosis and hand therapy underwent surgical treatment, after a median duration of 5 months from receiving a hand orthosis and hand therapy. When we divided patients who eventually did or did not convert to surgery, we found that the group that was not converted to surgery showed significant improvement in pain within 1 year after being treated with a hand orthosis and hand therapy for CMC OA. Most of this improvement was gained in the first 6 weeks of treatment, whereafter improvements were maintained. In addition, we saw that both pain and functional outcome were worse in the group that eventually received surgery, both at baseline and at the follow-up measurements. In the group that was converted to surgery, no improvement in pain and function was seen at follow-up measurements. Subgroup analysis, based on baseline pain levels, showed that patients with mean baseline pain levels of 50 or higher had a significant reduction in the amount of pain experienced, whereas patients with mean baseline pain levels of 25 or lower had a significant increase in pain.

The improvements on a group level in pain and function after a hand orthosis and hand therapy are in line with the limited available evidence. For example, Villafañe et al.[21] randomized 60 patients with CMC OA to manual therapy or a placebo intervention and found that the manual therapy group had a significant pain reduction after 1 month, whereas the placebo intervention did not reduce pain. Between 1 and 2 months after the start of manual therapy, pain did not change in this study, which is in line with our finding that pain reduced mostly within the first 6 weeks, although manual therapy in their study had a very different treatment protocol compared with our study, including passive nerve mobilization and joint mobilization. Similarly, the small retrospective study of O'Brien and Giveans[22] described that, within 90 days, hand therapy significantly reduced pain from 3.3 to 2.7 on a 1-5 Likert scale.

It should be noted that not all significant improvements in this study were clinically relevant. In our study, we found a clinically relevant improvement of 12 on the MHQ subdomain pain.[16] However, the improvement on the total MHQ score of 4 points did not exceed the Minimal Clinically Important Difference of 9-13 points[16], indicating that the improvement in function may not be clinically relevant. Because Frouzakis et al.[23] found that pain reduction is the primary reason for patients to seek treatment, the clinically relevant pain reduction in this study supports the implementation of a hand orthosis and hand therapy in these patients.

Although we found that only approximately 15% of our patients received additional surgical treatment, we are not aware of any other studies reporting this outcome after

a hand orthosis and hand therapy. Wajon et al.[24] concluded in a Cochrane review that they could not provide any information on the right time to convert to surgical treatment. Berggren et al.[25] reported that 23 of 33 patients (70%) waiting for operation could be treated successfully with hand therapy within 7 months before surgery, and within 7 years, only 2 more patients underwent additional surgical treatment. However, because patients in this study were already planned for surgery, we cannot compare this rate with our study.

This study has a number of specific strengths and limitations. An important strength of this study is the large sample size of 122 patients. Another strength is the pragmatic nature of this study, recording how hand therapy is performed in actual clinical practice, outside of the more controlled and potentially less natural setting of a randomized controlled trial. At the same time, the natural setting is also a limitation of the study because treatment was not completely standardized. Therapists adjusted treatment to the specific condition of the patient, severity of the complaints, time schedule, and type of insurance of the patient. Treatment in the form of purely an orthosis is very different compared with an orthosis and hand therapy. In addition, compliance with the treatment protocol by the participants was not recorded. The natural setting also resulted in the proportion of missing data, another limitation of our study. An important reason for missing data is that patients who had residual pain or functional complaints after being treated with hand therapy and an orthosis received surgical treatment and therefore were "missing" after 12 months. Another possible reason for our missing data is that patients may have gone elsewhere to receive treatment. However, because these patients visited this center seeking treatment and, as a part of protocol, first received hand therapy and orthosis, our experience is that only a very small portion of patients elect to undergo surgery elsewhere when hand therapy leads to insufficient relief of symptoms.

Another limitation of this study is that it focuses only on the combination of an orthosis and hand therapy, but cannot conclude anything on the outcome of other treatment strategies, such as topical or oral anti-inflammatory medication or intra-articular corticosteroid injections. We did not perform radiological staging, because the Dutch guideline[1] for the treatment of CMC OA indicates that x-rays can support the diagnosis of CMC OA but that radiological staging according to Eaton and Glickel does not have added value, due to only fair interobserver reliability and only fair correlation with symptoms. Inherent to the cohort nature of this study is that a control group is lacking. Therefore, this study does not provide information on what the relative effectiveness is compared with, for example, no treatment or direct surgical treatment. Finally, the relatively short follow-up is a limitation, because decisions regarding surgical treatment in patients with OA usually develop over years,

and are influenced by various other factors.

Our results support clinical guidelines stating that treatment for CMC OA should first be nonsurgical, because, at a group level, outcome significantly improved up to 1 year after treatment and the majority of patients did not undergo additional surgical treatment within the first 2 years. Subgroup analysis indicates that initial nonsurgical treatment with an orthosis and hand therapy is also relevant, particularly for patients with higher baseline pain levels, because this subgroup showed the largest improvement in pain. The implication of our findings for patients with relatively low baseline pain levels is less clear. In this group, pain significantly increased at follow-up. However, they had a relatively low conversion to surgery rate. A possible explanation may be that these patients had only minor impairments before treatment, and became more aware of the pain in their thumb and the impairments in daily living during their treatment, which could contribute to the increased pain at 12 months after receiving an orthosis and hand therapy.

Although we found that the median duration to surgery was 5 months, this finding was subject to multiple local factors, and therefore, may be less generalizable. For example, as a rule, decision making on additional surgical treatment was scheduled at the outpatient clinic after 3 months, when treatment was completed. In addition, factors such as waiting lists, personal factors, holidays, or financial reasons and insurance policies influenced the timing of surgery. To answer the question about the best timing to convert to surgery, a different study design would be preferred, using more frequent measurements.

For future research, it would be interesting to study the effect of patient adherence to therapy on treatment outcome. Future studies should also focus on identifying prognostic factors to predict which patients will have a good outcome after a hand orthosis and hand therapy and which can benefit more from early surgery. In addition, future research should focus on the optimal timing of this decision. Moreover, other possible predictors that can influence treatment outcome should be evaluated, such as coping mechanisms, catastrophizing, quality of life, emotional, and mental health.

References

1. Van Uchelen, J, Beumer A, Brink SM, Hoogvliet P, Moojen TM, Spaans AJ VG. Dutch guideline for conservative and surgical treatment for primary thumb base osteoarhtritis. Amsterdam, Netherlands NVPC, NVVH, NOV, VRA, VvBN. 2014.

2. Hochberg MC, Altman RD, April KT, et al. American College of Rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. Arthritis Care Res (Hoboken). 2012;64(4):465-474.

3. National Clinical Guideline Centre (UK). Osteoarthritis: Care and Management in Adults. NICE Clin Guidel No 177. 2014;(February). doi:http://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0068962/pdf/PubMedHealth_PMH0068962.pdf.

4. Zhang W, Doherty M, Leeb BF, et al. EULAR evidence based recommendations for the management of hand osteoarthritis: report of a Task Force of the EULAR Standing Committee for International Clinical Studies Including Therapeutics (ESCISIT). Ann Rheum Dis. 2007;66(3):377-388. doi:10.1136/ard.2006.062091.

5. Stamm TA, Machold KP, Smolen JS, et al. Joint protection and home hand exercises improve hand function in patients with hand osteoarthritis: a randomized controlled trial. Arthritis Rheum. 2002;47(1):44-49.

6. Joshi R. Intraarticular corticosteroid injection for first carpometacarpal osteoarthritis. J Rheumatol. 2005;32(7):1305-1306.

7. Colditz JC. The biomechanics of a thumb carpometacarpal immobilization splint: design and fitting. J Hand Ther. 2000;13(3):228-235.

8. Egan MY, Brousseau L. Splinting for osteoarthritis of the carpometacarpal joint: A review of the evidence. Am J Occup Ther. 2007;61(1):70-78. doi:10.5014/ajot.61.1.70.

9. Spaans AJ, Van Minnen LP, Kon M, Schuurman AH, Schreuders AR, Vermeulen GM. Conservative treatment of thumb base osteoarthritis: A systematic review. J Hand Surg Am. 2015;40(1):16-21.e5. doi:10.1016/j.jhsa.2014.08.047.

10. Aebischer B, Elsig S, Taeymans J. Effectiveness of physical and occupational therapy on pain, function and quality of life in patients with trapeziometacarpal osteoarthritis - A systematic review and meta-analysis. Hand Ther. 2016;21(1):5-15. doi:10.1177/1758998315614037.

11. Melvin JL. Rehabilitation of the Hand and Upper Extremity. Vol 5th editio. (In E. J. Mackin, A. D. Callahan, T. M. Skirven, L.H. Schneider & ALO, ed.). St.Louis, MO: Mosby.; 2002.

12. Zhang W, Doherty M, Leeb BF, et al. EULAR evidence based recommendations for the management of hand osteoarthritis: report of a Task Force of the EULAR Standing Committee for International Clinical Studies Including Therapeutics (ESCISIT). Ann Rheum Dis. 2007;66(3):377-388.

13. van der Giesen FJ, Nelissen RG, Arendzen JH, de Jong Z, Wolterbeek R, Vliet Vlieland TP. Responsiveness of the Michigan Hand Outcomes Questionnaire-Dutch Language Version in Patients With Rheumatoid Arthritis. Arch Phys Med Rehabil. 2008;89(6):1121-1126. doi:10.1016/j.apmr.2007.10.033.

14. Chung, KC, Pillsbury MS, Walter MR HR. Reliability and validity testing of the Michigan Hand Outcome Questionnaire. J Hand Surg Am. 1998;23:575-587. doi:10.1016/S0363-5023(98)80042-7.

15. Marks M, Audige L, Herren DB, Schindele S, Nelissen RGHH, Vliet Vlieland TPM. Measurement properties of the German Michigan Hand Outcomes Questionnaire in patients with trapeziometacarpal osteoarthritis. Arthritis Care Res (Hoboken). 2014;66(2):245-252. doi:10.1002/acr.22124.

16. London DA, Stepan JG, Calfee RP. Determining the Michigan Hand Outcomes Questionnaire minimal clinically important difference by means of three methods. Plast Reconstr Surg. 2014;133(3):616-625. doi:10.1097/PRS.0000000000000034.

17. Cohen J. Statistical power analysis for the behavioral sciences. Hillsdale, N.J.: L. Erlbaum Associates; 1988.

18. Little RJA RD. Statistical Analysis with Missing Data. Vol Vol (2nd e. Hoboken, N.J: Wiley; 2002.

19. Kelly C, Price TD. Correcting for Regression to the Mean in Behavior and Ecology. Am Nat. 2005;166(6):700-707. doi:10.1086/497402.

20. Visser AW, Bøyesen P, Haugen IK, et al. Instruments Measuring Pain, Physical Function, or Patient's Global Assessment in Hand Osteoarthritis: A Systematic Literature Search. J Rheumatol. 2015;42(11):2118-2134. doi:10.3899/jrheum.141228.

21. Villafañe JH, Cleland J a, Fernández-de-Las-Peñas C. The effectiveness of a manual therapy and exercise protocol in patients with thumb carpometacarpal osteoarthritis: a randomized controlled trial. J Orthop Sports Phys Ther. 2013;43(4):204-213. doi:10.2519/jospt.2013.4524.

22. O'Brien VH, Giveans MR. Effects of a dynamic stability approach in conservative intervention of the carpometacarpal joint of the thumb: a retrospective study. J Hand Ther. 2013;26(1):44-51; quiz 52. doi:10.1016/j.jht.2012.10.005.

23. Frouzakis R, Herren DB, Marks M. Evaluation of expectations and expectation fulfillment in patients treated for trapeziometacarpal osteoarthritis. J Hand Surg Am. 2015;40(3):483-490. doi:10.1016/j.jhsa.2014.10.066.

24. Wajon A, Vinycomb T, Carr E, Edmunds I, Ada L. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. Cochrane database Syst Rev. 2015;(2):CD004631. doi:10.1002/14651858.CD004631.pub4.

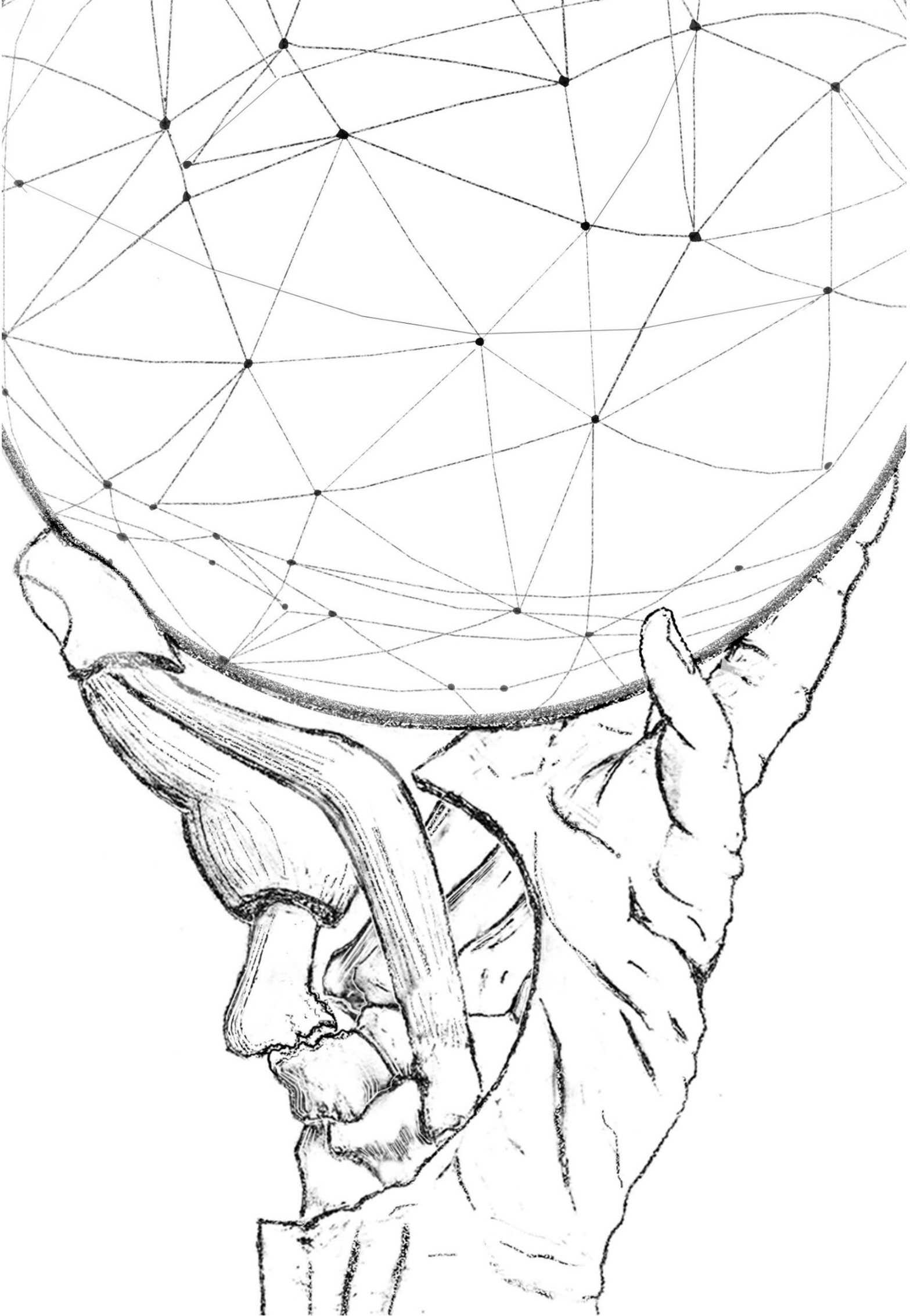
25. Berggren M, Joost-Davidsson A, Lindstrand J, Nylander G, Povlsen B. Reduction in the need for operation after conservative treatment of osteoarthritis of the first carpometacarpal joint: a seven year prospective study. Scand J Plast Reconstr Surg Hand Surg. 2001;35(4):415-417.

Appendix

Supplementary Table 1. *When applying Bonferroni correction to account for multiple testing, a P value of <.003 was required to find a significant difference. No significant differences were found for all variables.*

Variable	Mean complete cases ± SD	Mean imputed data ± SD	P-value
VAS Pain during activities baseline	57.4 ± 22	61.0 ± 22	0.154
VAS Pain during activities 6 weeks	45.3 ± 22	48.8 + 23	0.205
VAS Pain during activities 3 months	44.4 ± 23	47.2 ± 23	0.288
VAS Pain during activities 12 months	42.7 ± 26	45.7 ± 22	0.330
VAS Pain in the last week baseline	48.1 ± 19	49.6 ± 20	0.537
VAS Pain in the last week 6 weeks	35.2 ± 19	39.7 ± 21	0.060
VAS Pain in the last week 3 months	38.3 ± 22	40.4 ± 21	0.396
VAS Pain in the last week 12 months	35.1 ± 25	39.8 ± 19	0.099
MHQ Total baseline	64.3 ± 15	63.9 ± 14	0.820
MHQ Total 6 weeks	70.0 ± 9	68.7 ± 9	0.428
MHQ Total 3 months	70.8 ± 15	70.3 ± 11	0.791
MHQ Total 12 months	73.1 ± 15	71.9 ± 9.8	0.502
MHQ Pain baseline	57.7 ± 24	62.0 ± 26	0.151
MHQ Pain 6 weeks	43.8 ± 20	49.7 ± 20	0.011
MHQ Pain 3 months	41.2 ± 21	46.3 ± 21	0.040
MHQ Pain 12 months	39.1 ± 25	40.8 ± 20	0.557

Abbreviations: MHQ = Michigan Hand Questionnaire; SD =standard deviation; VAS = visual analog scale.



PREDICTING OUTCOME AFTER HAND ORTHOSIS AND HAND THERAPY FOR CARPOMETACARPAL OSTEOARTHRITIS: A PROSPECTIVE STUDY

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4

Abstract

Objective: 1) to identify predictive factors for outcome after splinting and hand therapy for CMC OA and to identify predictive factors for conversion to surgical treatment, and 2) to determine how many patients that have not improved in outcome within six weeks after start of treatment will eventually improve after three months.

Methods: In this observational prospective multi-center cohort study, 809 patients with CMC OA received splinting and weekly hand therapy for three months between 2011 and 2014. Main outcome measures were pain and satisfaction measured with a visual analog scale, and function measured with the Michigan Hand Questionnaire at baseline, six weeks and three months posttreatment. Using regression analysis, patient demographics and pretreatment baseline scores were considered as predictors for the outcome of conservative treatment after three months and for conversion to surgery.

Results: Multivariable regression model explained 34-42% of the variance in outcome ($p<0.001$) with baseline satisfaction, pain and function as significant predictors. Cox regression analysis showed that baseline pain and function were significant predictors for conversion to surgery. Of patients with no clinically-relevant improvement in pain and function after six weeks, 73-83% also had no clinically-relevant improvement after three months.

Conclusion: This study showed that patients with either high pain or low function may benefit most from conservative treatment. We therefore recommend to always start with conservative treatment, regardless of symptom severity of functional loss at start of treatment. Furthermore, it seems valuable to consider changing the content of conservative treatment or to discuss surgery with patients after six weeks of therapy, when levels of improvement are still mainly unsatisfactory.

Introduction

Primary osteoarthritis (OA) of the carpometacarpal (CMC) joint is common among the elderly.[1] Multiple options are available to treat CMC OA[2-4] and various guidelines recommend to start with conservative treatment that can include: hand therapy, topical or oral non-steroidal anti-inflammatory drugs, intra-articular steroid injection, and splinting.[5-7]

Studies on outcome after non-operative treatment are mainly based on group level analysis and large variation is reported between individual patients, e.g. some were highly satisfied and almost/fully free of pain, while others were unsatisfied and/or had residual pain.[8-10] However, the quality of most of these studies was only weak to moderate. For example, although one systematic review showed that hand orthosis may help relieve pain, the sample size of the included studies ranged from only 10 to 37 patients and follow-up ranged from only 1 week to 6 months.[8] Another systematic review on comparative studies of hand orthosis or hand therapy for CMC OA, concluded that hand orthosis or hand therapy may provide some reduction in pain; however, the follow-up of these latter studies ranged from 2 weeks to 3 months and the study samples comprised only older individuals (aged 70-90 years).[9]

Whereas for various surgical techniques for CMC OA predictive factors for outcome have been described[11,12], no predictors are reported for the outcome of conservative treatment; thus, it remains unclear which patients might benefit from conservative treatment.

Therefore, this study aims to: 1) identify predictive factors for outcome after splinting/hand therapy for CMC OA and for conversion to surgical treatment, and 2) determine how many patients with no improvement in outcome within six weeks after start of treatment will improve after three months.

Methods

This observational, prospective multi-center cohort study was conducted using data collected between January 2011and November 2014. All patients with symptomatic, clinically-diagnosed CMC OA were asked to participate and were included at Xpert Clinic in the Netherlands. This clinic comprises 15 locations in the Netherlands, with 16 European Board certified (FESSH) hand surgeons and over 50 hand therapists. No remuneration was provided to any of the patients. The study was approved by the local institutional review board (MEC-2015-691) and written informed consent was obtained from all patients.

For the present study, patients diagnosed with primary, non-traumatic CMC OA by a hand surgeon were eligible for inclusion; patients were selected that were not previously surgically treated for CMC OA and did not have simultaneous treatment for any other hand condition(s). Excluded were patients who received intra-articular

corticosteroid injection as part of their treatment, since this treatment may interact with the effectiveness of splinting and/or hand therapy.

Treatment

Treatment was based on the current treatment guideline in the Netherlands.[7] In general, treatment consisted of prescribing a custom-made or pre-fabricated orthosis (based on the preference of the surgeon, hand therapists, and medical insurance of the patient). The orthotic device was a butterfly thumb orthosis in which the CMC joint of the thumb was fixed in extension/abduction, and the metacarpophalangeal joint (MCP-1) of the thumb was fixed in mild flexion.

In addition, patients received two sessions of hand therapy per week of (on average) 25 min per session. All hand therapists received the same internal training on how to treat CMC OA with hand therapy. However, this was a pragmatic study in that the hand therapy was not strictly protocolled and controlled but was evaluated based on clinical practice. Therapy sessions were planned based on the judgment of the therapist, and the ability and availability of the patient. In a small minority of the cases, patients did not visit a hand therapist and only received a hand orthosis; however, the number of patients receiving only an orthosis was negligible.

The treatment was divided into two phases; phase one (weeks 0-6) included instructions to wear the splint (almost) 24 h/day, and consisted of hand therapy for optimizing thumb position (training pinch and grasping movements without hyperextension in the metacarpophalangeal thumb joint and without CMC adduction) and using a full thumb range of motion (i.e. training specific coordination of the intrinsic/extrinsic muscles of the thumb). The rationale for advising patients to wear the orthotic device 24 h/day was to give the thumb rest, reduce inflammation, and improve stability in the joint.[13,14] Another goal of the first phase of the study was to re-learn correct positioning of the thumb; to achieve this patients should preferably be without pain. In phase two (weeks 7-12), the splint was slowly phased out: the patients were advised to use the splint only during heavy activities, depending on the pain level and the patient's ability to perform activities with a stable thumb position. During this phase, hand therapy focused on maintaining pain reduction, introducing the stability learned during daily activities, and improving thenar muscle strength. In addition, fewer hand therapy sessions were scheduled and patients performed more home exercises (up to 4-6 times a day). The number of prescribed home exercises ranged from 3-6 exercises per day, with 10-15 repetitions each, depending on the individual patient and the level of pain.

After this period of supervised therapy, patients were encouraged to continue doing the exercises and were allowed to use the splint when necessary. No corticosteroid injections were given for CMC OA during or after hand therapy, and no anti-inflammatory medication was prescribed by the surgeon.

Measures

At the start of treatment, baseline data of all patients were collected, including duration of complaints, hand dominance, sex, age, comorbidity and occupation. Outcome measures were recorded via our web-based conservative outcome registration at i) start of treatment (baseline), and at ii) six weeks and iii) three months after start of treatment.

Conservative treatment was evaluated at the follow-up appointment at three months. Surgical intervention was discussed when patients did not respond well to the splinting and hand therapy and had functional impairments and/or residual pain. All surgeries performed between January 2012 and February 2016, together with the time until surgery, were retrieved from the clinical records; this information was collected irrespective of whether or not patients responded to the study questionnaires.

Pain, function and satisfaction

Pain was measured using a visual analog scale (VAS) where 0=no pain and 100=the worst possible pain) during two situations: i) pain during physical load, and ii) pain intensity during the week prior to the follow-up measurement. The minimal clinically important difference (MCID) for VAS pain is 9.7.[15] In the present study, for convenience, the MCID for VAS pain was considered to be 10. Hand function was measured with the Michigan Hand Questionnaire (MHQ; Dutch Language Version) where 0=poorest function and 100=ideal function).[16–18] The MHQ measures patient-rated, self-reported hand function based on 37 items, covering six domains (pain, esthetics, hand function, performance of activities of daily living, work performance, and satisfaction). For non-traumatic hand conditions, the MCID for the total MHQ ranges from 9-13 points.[19] In the present study, for convenience, the MCID for the total MHQ score was considered to be 10. Lastly, we asked patients to score overall satisfaction with their hand on a VAS where 0=completely dissatisfied and 100=completely satisfied.

Statistical analysis

Since data were collected during daily clinical practice, there was a substantial proportion of non-response during follow-up (Supplementary Table 1). Therefore, we performed an extensive responder/non-responder analysis (Supplementary Table 2) and missing data analysis and concluded that the outcome variables were missing at random. Therefore, we performed multiple imputation by chained equations (MICE) by fully conditional specification. Multiple imputation is an appropriate method to handle large amounts of missing data (up to 80%).[20]

To identify predictors for outcome, patient demographics and baseline measures of pain, function and satisfaction were examined. Outcome was defined as

pain, function and self-reported satisfaction with the hand at six weeks and at three months after start of treatment, and conversion to surgery. First, the correlation between a possible predictor and each outcome parameter was studied using Pearson's correlation. Univariate Cox regression analysis was used to examine predictors at the time of conversion to surgery. All variables with a univariate association with a significance level of <0.10 were used for backward entered multivariable linear regression analysis, and backward entered conditional Cox regression. For all tests, a p-value ≤ 0.05 was considered statistically significant.

Secondly, in the absence of a clinically relevant improvement at six weeks, we examined how often there was a clinically-relevant improvement in pain and function at three months after start of treatment. This allowed to evaluate whether further conservative treatment after six weeks was beneficial. A clinically-relevant improvement was defined as an improvement of more than the MCID of 10 for pain and of 10 for the MHQ (as described above). The diagnostic value of the six-week outcome for the outcome at three months was further tested with a receiver operating characteristic (ROC) curve.

Based on the ROC curve the following were calculated: i) the sensitivity (i.e. the proportion of patients with no clinically-relevant improvement at 0-3 months that also had no clinically-relevant improvement at 0-6 weeks), ii) the specificity (i.e. the proportion of patients with a clinically-relevant improvement at 0-3 months that also had a clinically-relevant improvement at 0-6 weeks), iii) the positive predictive value (i.e. the proportion of patients with a clinically-relevant improvement at 0-3 months that had no clinically-relevant improvement at 0-6 weeks), and iv) the false-positive rate (i.e. the proportion of patients with no clinically-relevant improvement at 0-3 months that had a clinically-relevant improvement at 0-6 weeks).

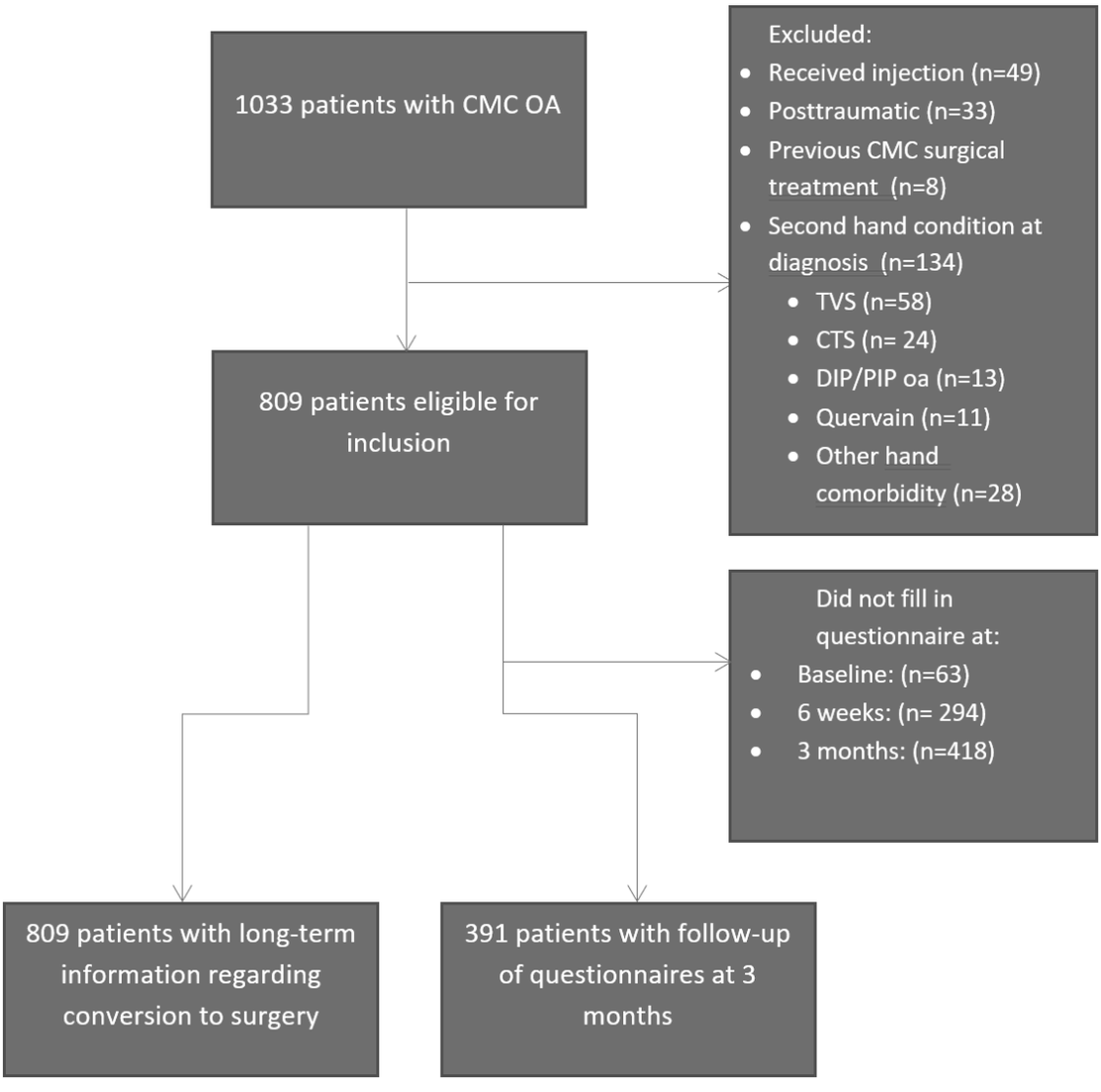


Figure 1. *Flowchart of the study*

Results

Study population and outcome of conservative treatment

The study included 809 patients who were treated for complaints due to CMC OA between January 2011 and November 2014: Figure 1 presents an overview of the study population. Table 1 lists the baseline characteristics of the patients, and outcome at six weeks and three months after start of treatment. There was a significant improvement in satisfaction (from 41± 22 at baseline to 56 ± 23 at three months), a significant decrease in pain (from 49 ± 20 at baseline to 40 ± 21 at three months) and a significant improvement in hand function (from 66 ± 14 at baseline to 72 ± 11 at three months). After a mean follow-up of 2.2 years, 15% of the patients underwent surgery.

Table 1. *Baseline characteristics and outcome of treatment with splinting and hand therapy at 6 weeks and at 3 months.*

Variables		Baseline *% or mean ±SD*	6 weeks *mean±SD*	3 months *mean±SD*
Sex	Female	76	*na*	*na*
Treated hand	Right	50	*na*	*na*
Workload	No work	43	*na*	*na*
	Light physical work	23	*na*	*na*
	Moderate physical work	23	*na*	*na*
	Heavy physical work	11	*na*	*na*
Dominance	Left	9	*na*	*na*
	Right	87	*na*	*na*
	Both	4	*na*	*na*
Age (years)		60 ± 9	*na*	*na*
Duration of symptoms (months)		34 ± 62	*na*	*na*
Pain during activities (VAS 0-100)*		61 ± 22	49±23	48±23
Pain intensity during the week prior to follow-up (VAS 0-100)*		49 ± 20	40±21	40±21
MHQ (0-100)	Total¥	66 ±14	70±9	72±11
	Daily Activities¥	77± 22	82±15	80±18
	Function¥	66 ±16	67±14	68±15
	Esthetics¥	85 ±17	86±15	86±17
	Satisfaction¥	61 ± 26	70±19	71±21
	Pain*	54 ± 25	46±19	42±21
	Work performance¥	61 ±23	63±20	68±20
Hand satisfaction (VAS 0-100) ¥		41 ± 22	54±24	56±23

**: High scores indicate worse outcome*
¥: High scores indicate good outcome
Abbreviations: MHQ = Michigan Hand Questionnaire, VAS = Visual analog scale, SD = standard deviation, na = not applicable

Predictive factors

Univariate analysis showed that pre-treatment baseline scores, sex, age, workload and treated hand side correlated with the outcome measures (Table 2).

Table 2. *Results of univariate analysis. Correlation coefficients are displayed.*

Baseline Variables	**Outcome at 6 weeks**			**Outcome at 3 months**			**Conversion to surgery**
	Δ in overall pain‡ (VAS)	Δ in hand satisfaction (VAS)	Δ in total MHQ Score	Δ in overall pain‡ (VAS)	Δ in hand satisfaction (VAS)	Δ in total MHQ Score	(hazard ratio B per 10)
Sex			0.129*			0.070*	
Age				0.109*			
Dominance					-0.07**		
Treated hand		0.073**	0.302*			0.209*	
Duration of complaints							
Workload			-0.064**				
MHQ Total	0.170*	-0.134*	-0.796*	0.156*	-0.169*	-0.648*	0.72*
Hand Satisfaction (VAS)	0.179*	-0.558*	-0.188*	0.206*	-0.616*	-0.122*	0.82*
Pain during activities (VAS)	-0.419*	0.195*	0.233*	-0.440*	0.244*	0.245*	1.23*
Pain intensity during the week prior to follow-up (VAS)	-0.581*	0.213*	0.216*	-0.581*	0.235*	0.220*	1.32*

‡ Pain refers to pain intensity during the week prior to follow-up
**Association significant at p-value <0.05.*
*** Association significant at p-value <0.10.*
Empty cells indicate a non-significant correlation at p-value >0.10

Results of the multivariable regression analysis are given in Table 3. For change in pain after three months (VAS), the multivariable regression model explained 34% of the variance in outcome ($p<0.001$), with one significant predictor i.e. pain intensity during the week prior to the baseline measurement. For change in patient satisfaction (VAS) after three months, the multivariable regression analysis model explained 38% of the variance in outcome ($p<0.001$), with baseline patient satisfaction with their hand as significant predictor. For change in function (MHQ) after three months, the multivariable regression analysis model explained 42% of the variance in outcome ($p<0.001$), with baseline function and baseline patient satisfaction with their hand as significant predictors.

For the probability of converting to surgery, Cox regression analysis resulted in two significant predictors: function (MHQ) at baseline and pain intensity during the week prior to the baseline measurement. For every 10 points of improvement in MHQ at baseline, the probability of a patient undergoing surgery decreased by 19%. For every 10 points of improvement in pain intensity during the week prior to the baseline measurement, the probability of a patient undergoing surgery decreased by 26%.

Table 3. *Multivariable regression analysis: beta-coefficients related to different outcome measures.*

Baseline variables	**Outcome at 6 weeks**			**Outcome at 3 months**			**Conversion to Surgery**
	Δ in overall pain‡ (VAS)	Δ in hand satisfaction (VAS)	Δ in total MHQ Score	Δ in overall pain‡ (VAS)	Δ in hand satisfaction (VAS)	Δ in total MHQ Score	(hazard ratio B per 10)
R^2 (% explained variance)	**35%**	**31%**	**63%**	**34%**	**38%**	**42%**	
MHQ Total		-0.780*			-0.648		0.81*
Hand satisfaction (VAS)	-0.126*	-0.697*			-0.808*	0.039	
Pain intensity during the week prior to follow-up (VAS)	-0.770*			-0.741*			1.26*

‡ Pain refers to pain intensity during the week prior to follow-up
**Association significant at p-value <0.05*
Empty cells indicate a nonsignificant correlation at p-value >0.05

Sensitivity analysis

After three months of conservative treatment, 380 patients showed a clinically-relevant improvement on pain scores (VAS). Using the ROC curve, we calculated a sensitivity of 0.765 (95% CI 0.721-0.803) and a specificity of 0.676 (95% CI 0.626-0.722). This resulted in a positive predicted value of 73% (95% CI 68-77%) (Table 4), indicating that 73% of the patients that had no clinically-relevant improvement in pain after six weeks also had no clinically-relevant improvement in pain after three months.

After three months, 259 patients showed a clinically-relevant improvement in function (MHQ). Again, using the ROC curve, we calculated a sensitivity of 0.896 (95% CI 0.867-0.920) and a specificity of 0.618 (95% CI 0.555-0.677). This resulted in a positive predicted value of 83% (95% CI 80-86%) (Table 4), indicating that 83% of the patients who had no clinically-relevant improvement in function after six weeks also had no clinically-relevant improvement in function after three months of conservative treatment. We redid the sensitivity analysis using the dataset with only complete cases and observed very similar outcome (Supplementary Table 3).

Table 4. *Positive predictive values for pain and function at six weeks, i.e. the percentage of patients that did not show a clinically-relevant improvement at three months and did not show a clinically-relevant improvement at six weeks.*

Pain (VAS)		**Clinically-relevant improvement at 0 to 3 months[Þ]**				
		Yes	No	Total	Positive predictive value (95% CI)	Negative likelihood ratio (95% CI)
Clinically-relevant improvement 0 to 6 weeks[‡]	No[†]	123	328	451	0.73 (0.67-0.79)	0.35 (0.29-0.41)
	Yes	257	101	358		
	Total	380	429	809		

Function (MHQ)		**Clinically-relevant improvement at 0 to 3 months[‡]**				
		Yes	No	Total	Positive predictive value (95% CI)	Negative likelihood ratio (95% CI)
Clinically-relevant improvement at 0 to 6 weeks[‡]	No[†]	99	492	592	0.83 (0.80-0.86)	0.17 (0.13-0.22)
	Yes	160	57	217		
	Total	259	550	809		

[Þ] Clinically-relevant improvement defined as an improvement of 10 or more on the 0-100 VAS scale[15,16]
‡ Clinically-relevant improvement defined as an improvement of 10 or more on the 0-100 MHQ scale[10]
Abbreviations: MHQ: Michigan Hand Questionnaire, VAS: Visual analog scale

Discussion

This study had two main aims. The first was to identify predictive factors for outcome of conservative treatment and predictive factors for conversion to surgical treatment. The multivariable regression model explained 34-42% of the variance in satisfaction, pain and function (MHQ) after three months, with baseline satisfaction with the hand, baseline pain and baseline function (MHQ) as predictive factors. In addition, every 10 points of improvement in baseline pain led to a 26% decrease in the risk of conversion to surgery of 26% and every 10 points of improvement in baseline MHQ score led to a 19% decrease in the risk of conversion to surgery.

The second aim was to determine how many patients that showed no improvement in pain within six weeks after start of conservative treatment also showed no improvement after three months of treatment. A negative predictive value of 73% was found for pain and 83% for function (MHQ). This indicates that, in the absence of a clinically-relevant improvement after six weeks, 73% of the patients show no clinically-relevant improvement on the VAS pain score after three months, and 83% of the patients show no clinically-relevant improvement on the MHQ score after three months.

To our knowledge, the present study is the first to identify baseline predictive factors for conservative treatment of CMC OA. For surgery, a study on predictive factors for outcome showed that patients with CMC OA with hyperextension of the MCP joint or a restricted thumb web had a worse outcome after surgery; however, that study did not report the percentage of explained variance.[11] In daily practice, patients with considerable pain often undergo surgical treatment without first receiving hand therapy. The present study shows that patients with the most pain and the lowest level of function may benefit most from hand orthosis and hand therapy. Therefore, we recommend to always start with conservative treatment, irrespective of symptom severity or functional loss at start of treatment.

Since the present study found only moderate levels of explained variances, we can only partially predict which patients will have a greater chance of benefitting from conservative treatment. The predictors for conversion to surgery indicate which patients are more likely to undergo surgery and which will not. For example: in our patients with a baseline pain score of >75, 31% will undergo surgery, whereas in patients with a baseline pain score of <25, only 5% will undergo surgery. Overall, at baseline we could not identify subgroups of patients with such a high probability of undergoing surgery after conservative treatment that this warranted selection for immediate surgery, without prior conservative treatment.

Although the baseline factors we found have only moderate predictive value, we did establish that a lack of clinical improvement in outcome after six weeks is a good

indicator for a lack of clinical improvement in pain and function after three months. Only 17-27% of our patients that showed no clinically-relevant improvement in pain and function after six weeks showed a clinically-relevant improvement in these parameters after three months. In daily practice, surgeons tend to prescribe hand therapy for an arbitrary number of weeks/months, without knowing exactly when to evaluate treatment. Our findings indicate that, when the outcome is still unsatisfactory at six weeks, it may be worthwhile to evaluate treatment, potentially adjust the content of hand therapy or to discuss surgery with patients at that time. Future studies will hopefully elucidate whether changing the content of hand therapy or early termination of unsuccessful conservative treatment and conversion to surgery will lead to more efficient and cost-effective healthcare.

Study limitations

This study has both strengths and limitations. The main strength is the large sample size and another is the study's observational design, i.e. recording how conservative treatment is performed in actual clinical practice, rather than within the stricter and potentially less-natural setting of a randomized controlled trial. However, this was also a limitation since the measurements took place in multiple locations with the risk of large variation in treatment; this precluded the possibility of completely standardizing the treatment protocol. Also, unfortunately, from our database we were unable to retrieve the total number of therapy sessions for each patient and adjust outcomes based on these sessions. Future research could investigate to what extent the number of therapy sessions received might influence outcome.

One limitation is the lack of a control group. Therefore, the predictors found for outcome after three months of conservative treatment provide no information on the effectiveness of conservative treatment compared to no treatment, or compared to direct surgical treatment.

Secondly, there was a substantial amount of missing data. Since a small number of patients had failed conservative treatment before three months and received surgical treatment, their outcome measurements at three months were missing. However, the data missing for patients at three months were missing completely at random and no underlying mechanisms could be identified.

Another limitation is that, after being treated conservatively in our clinic, patients may have been treated surgically elsewhere, which may lead to underreporting of the rate of surgery. However, since our clinic specializes in treating hand and wrist conditions, we assume that the number of patients treated elsewhere is negligible.

Future research

Since we found only moderate baseline predictors for outcome after conservative treatment, future studies could focus on other predictive factors, e.g. psychosocial factors. For example, a recent systematic review[21] found that depression and anxiety were highly prevalent in patients with osteoarthritis and that patients with these symptoms experienced more pain and had less optimal outcomes. Another study found that patients seeking care for CMC OA had more catastrophic thinking and higher rates of depression compared to patients that did not seek treatment for CMC OA.[22] Moreover, according to a report describing predictors for outcome after surgical treatment for osteoarthritis[12], future research could also focus on other objective measures, such as range of motion (hyperextension of MCP and narrow first web) and strength of thumb.

Conclusion

In these patients with CMC OA, the present study found that: 1) satisfaction, pain and function measured at baseline explained 32-42% of the outcome of these parameters after three months of conservative treatment and the probability of undergoing surgery, and 2) a lack of improvement after six weeks resulted in a 73-83% negative predictive value for a lack of improvement in pain and function after three months. Therefore, for all patients with CMC OA, we recommend to start with hand orthosis and hand therapy irrespective of symptom severity. In addition, it may be beneficial to evaluate treatment after a relatively short period of conservative treatment (e.g. six weeks) when there has been no demonstrable clinically-relevant improvement during that period.

References

1. Marshall M, van der Windt D, Nicholls E, Myers H, Dziedzic K. Radiographic thumb osteoarthritis: frequency, patterns and associations with pain and clinical assessment findings in a community-dwelling population. Rheumatology (Oxford). 2011;50(4):735-739. doi:10.1093/rheumatology/keq371.

2. Stamm TA, Machold KP, Smolen JS, et al. Joint protection and home hand exercises improve hand function in patients with hand osteoarthritis: a randomized controlled trial. Arthritis Rheum. 2002;47(1):44-49.

3. Joshi R. Intraarticular corticosteroid injection for first carpometacarpal osteoarthritis. J Rheumatol. 2005;32(7):1305-1306.

4. Colditz JC. The biomechanics of a thumb carpometacarpal immobilization splint: design and fitting. J Hand Ther. 2000;13(3):228-235.

5. Hochberg MC, Altman RD, April KT, et al. American College of Rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. Arthritis Care Res (Hoboken). 2012;64(4):465-474.

6. Zhang W, Doherty M, Leeb BF, et al. EULAR evidence-based recommendations for the management of hand osteoarthritis: report of a Task Force of the EULAR Standing Committee for International Clinical Studies Including Therapeutics (ESCISIT). Ann Rheum Dis. 2007;66(3):377-388.

7. Van Uchelen, J, Beumer A, Brink SM, Hoogvliet P, Moojen TM, Spaans AJ VG. Dutch guideline for conservative and surgical treatment for primary thumb base osteoarthritis. Amsterdam, Netherlands NVPC, NVVH, NOV, VRA, VvBN. 2014. URL: Dutch guideline for treatment of CMC osteoarthritis.

8. Egan MY, Brousseau L. Splinting Hand orthosis for osteoarthritis of the carpometacarpal joint: A review of the evidence. Am J Occup Ther. 2007;61(1):70-78. doi:10.5014/ajot.61.1.70.

9. Spaans AJ, Van Minnen LP, Kon M, Schuurman AH, Schreuders AR, Vermeulen GM. Conservative treatment of thumb base osteoarthritis: A systematic review. J Hand Surg Am. 2015;40(1):16-21.e5. doi:10.1016/j.jhsa.2014.08.047.

10. Aebischer B, Elsig S, Taeymans J. Effectiveness of physical and occupational therapy on pain, function and quality of life in patients with trapeziometacarpal osteoarthritis - A systematic review and meta-analysis. Hand Ther. 2016;21(1):5-15. doi:10.1177/1758998315614037

11. Degreef I, Smet L. Predictors of outcome in surgical treatment for basal joint osteoarthritis of the thumb. Clin Rheumatol. 2006;25(2):140-142. http://link.springer.com/10.1007/s10067-005- 1108-7%5Cnpapers2://publication/doi/10.1007/s10067-005-1108-7.

12. Moineau G, Richou J, Liot M, Le Nen D. Prognostic factors for the recovery of hand function following trapeziectomy with ligamentoplasty stabilisation. Orthop Traumatol Surg Res. 2009;95(5):352-358. doi:10.1016/j.otsr.2009.03.015.

13. Kjeken I, Smedslund G, Moe RH, Slatkowsky-Christensen B, Uhlig T, Hagen KB. Systematic review of design and effects of splints and exercise programs in hand osteoarthritis. Arthritis Care Res (Hoboken). 2011;63(6):834-848. doi:10.1002/acr.20427.

14. Neumann DA, Bielefeld T. The Carpometacarpal Joint of the Thumb: Stability, Deformity, and Therapeutic Intervention. J Orthop Sport Phys Ther. 2003;33(7):386-399. doi:10.2519/jospt.2003.33.7.386.

15. Ehrich EW, Davies GM, Watson DJ, Bolognese JA, Seidenberg BC, Bellamy N. Minimal perceptible clinical improvement with the Western Ontario and McMaster Universities osteoarthritis index questionnaire and global assessments in patients with osteoarthritis. J Rheumatol. 2000;27(11):2635-2641.

16. van der Giesen FJ, Nelissen RG, Arendzen JH, de Jong Z, Wolterbeek R, Vliet Vlieland TP. Responsiveness of the Michigan Hand Outcomes Questionnaire-Dutch Language Version in Patients With Rheumatoid Arthritis. Arch Phys Med Rehabil. 2008;89(6):1121-1126. doi:10.1016/j.apmr.2007.10.033.

17. Chung, KC, Pillsbury MS, Walter MR HR. Reliability and validity testing of the Michigan Hand Outcome Questionnaire. J Hand Surg Am. 1998;23:575-587. doi:10.1016/S0363- 5023(98)80042-7.

18. Marks M, Audige L, Herren DB, Schindele S, Nelissen RGHH, Vliet Vlieland TPM. Measurement properties of the German Michigan Hand Outcomes Questionnaire in patients with trapeziometacarpal osteoarthritis. Arthritis Care Res (Hoboken). 2014;66(2):245-252. doi:10.1002/acr.22124.

19. London DA, Stepan JG, Calfee RP. Determining the Michigan Hand Outcomes Questionnaire minimal clinically important difference by means of three methods. Plast Reconstr Surg. 2014;133(3):616-625. doi:10.1097/PRS.0000000000000034.

20. Lee, J. H., & Huber, J., Jr. (2011). Multiple imputation with large proportions of missing data: How much is too much? United Kingdom Stata Users' Group Meetings 2011 23, London: Stata Users Group.

21. Sharma A, Kudesia P, Shi Q, Gandhi R. Anxiety and depression in patients with osteoarthritis: impact and management challenges. Open access Rheumatol Res Rev. 2016;8:103-113.doi:10.2147/OARRR.S93516.

22. Becker SJE, Makarawung DJS, Spit SA, King JD, Ring D. Disability in patients with trapeziometacarpal joint arthrosis: incidental versus presenting diagnosis. J Hand Surg Am. 2014;39(10):2009-2015.e8. doi:10.1016/j.jhsa.2014.07.009.

Appendix

Supplementary Table 1. *Number of complete cases per variable*

Variable	Number of cases
Sex	809 (100%)
Treated hand	809 (100%)
Workload	806 (100%)
Dominance	806 (100%)
Age (years)	809 (100%)
Duration of symptoms (months)	806 (100%)
Pain during activities at baseline	746 (92%)
Pain during previous week at baseline	746 (92%)
Satisfaction with hand at baseline	746 (92%)
Pain during activities at 6 weeks	515 (64%)
Pain during previous week at 6 weeks	515 (64%)
Satisfaction with hand at 6 weeks	515 (64%)
Pain during activities at 3 months	391 (48%)
Pain during previous week at 3 months	391 (48%)
Satisfaction with hand at 3 months	391 (48%)
MHQ at baseline	610 (75%)
MHQ at 6 weeks	290 (36%)
MHQ at 3 months	380 (47%)

Abbreviations: MHQ = Michigan Hand Questionnaire

Supplementary Table 2. *Baseline characteristics and responder/non-responder analysis.*

Baseline characteristics		**Total (n=809)**	**Responders at 3 months (n=391)**	**Non-responders at 3 months (n=418)**	
		% or mean±SD	*% or mean±SD*	*% or mean±SD*	*p-value†*
Sex	Female	76	75	77	*0.735*
Treated hand	Right	50	48	51	*0.445*
Workload	No work	45	47	44	*0.141*
	Light physical work	23	19	24	
	Moderate physical work	23	27	22	
	Heavy physical work	9	6	10	
Dominance	Left	9	11	8	*0.359*
	Right	87	83	88	
	Both	4	5	4	
Age (years)		60±9	60±8	60±9	*0.630*
Duration of symptoms (weeks)		34±62	45±92	32±50	*0.070*
Pain during activities (VAS 0-100)*		61±22	61±21	61±23	*0.985*
Pain intensity during the week prior to follow-up (VAS 0-100)*		49±21	50±20	49 ±21	*0.856*
MHQ (0-100)	Total¥	64 ±15	63±16	64±15	*0.443*
	Daily Activities¥	77± 23	76±24	78 ±23	*0.408*
	Function¥	66 ±18	67±17	66 ±18	*0.640*
	Esthetics¥	85 ±18	85 ±19	85 ±18	*0.753*
	Satisfaction¥	60±28	58 ±27	60±29	*0.539*
	Pain*	63±27	62 ±25	63 ±28	*0.589*
	Work performance¥	61±25	57±23	62±25	*0.016*
Hand satisfaction (VAS 0-100) ¥		41±22	42±21	40±23	*0.387*

† Significance of comparison between baseline characteristics of the responders and non-responders at 3-month measurement.
** High scores indicate worse outcome*
¥: High scores indicate good outcome

Supplementary Table 3. *Positive predictive values for pain and function at six weeks, i.e. the percentage of patients that did not show a clinically-relevant improvement at three months and did not show a clinically-relevant improvement at six weeks using the dataset with only complete cases. No differences in outcome between the imputed dataset (Table 4) and the dataset with only complete cases were seen.*

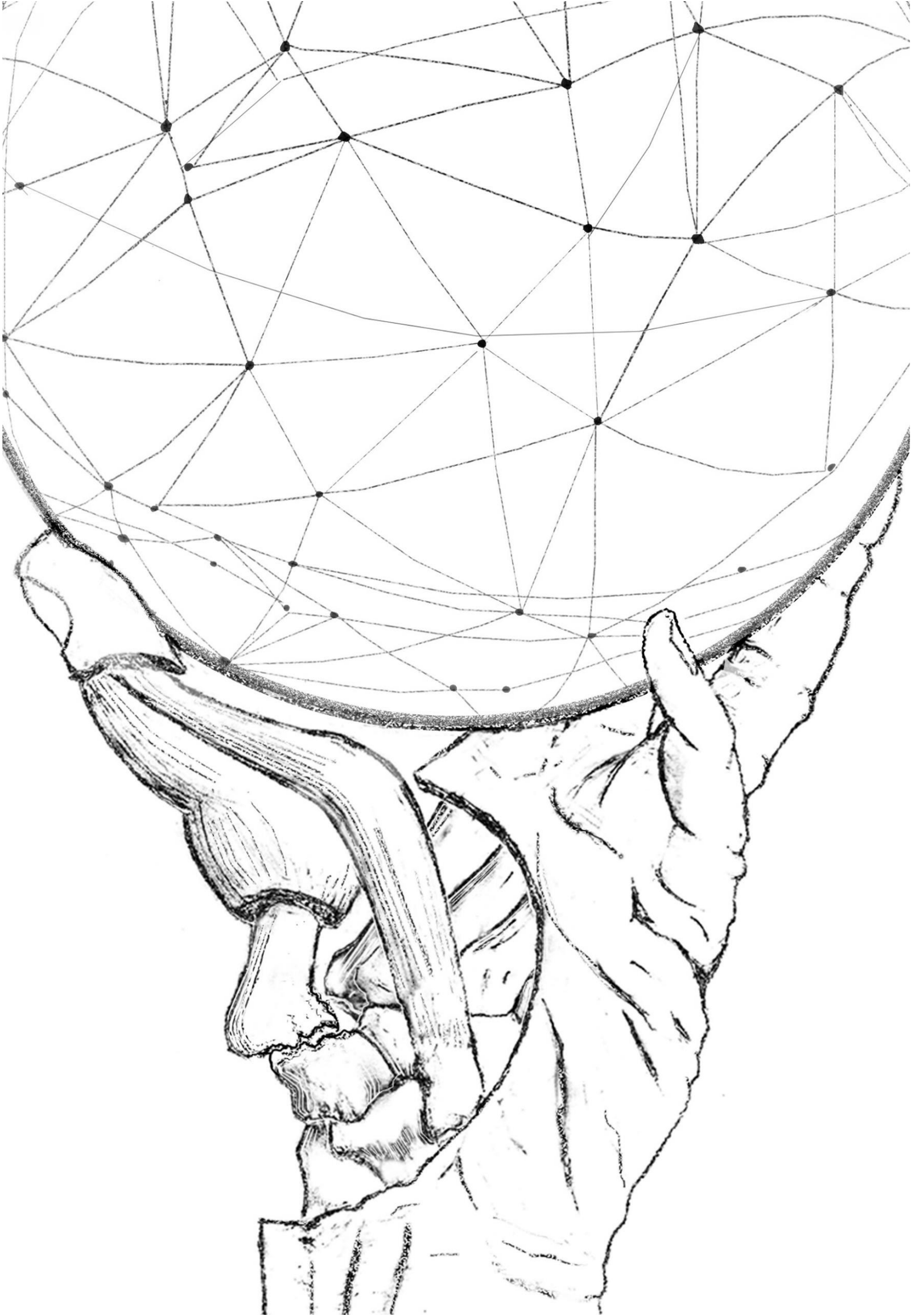
Pain (VAS)		**Clinically-relevant improvement at 0 to 3 months[Þ]**				
		Yes	No	Total	Positive predictive value (95% CI)	Negative likelihood ratio (95% CI)
Clinically-relevant improvement 0 to 6 weeks[‡]	No[†]	39	119	158	0.75 (0.68-0.82)	0.35 (0.27-0.45)
	Yes	122	43	165		
	Total	161	162	323		

Function (MHQ)		**Clinically-relevant improvement at 0 to 3 months[‡]**				
		Yes	No	Total	Positive predictive value (95% CI)	Negative likelihood ratio (95% CI)
Clinically-relevant improvement at 0 to 6 weeks‡	No†	28	87	115	0.76 (0.67-0.83)	0.17 (0.09-0.33)
	Yes	34	9	43		
	Total	62	96	158		

[Þ] Clinically-relevant improvement defined as an improvement of 10 or more on the 0-100 VAS scale[15,16]

‡ Clinically-relevant improvement defined as an improvement of 10 or more on the 0-100 MHQ scale[10]

Abbreviations: MHQ: Michigan Hand Questionnaire, VAS: Visual analog scale



RESPONSE TO CONSERVATIVE TREATMENT FOR THUMB CARPOMETACARPAL OSTEOARTHRITIS IS ASSOCIATED WITH CONVERSION TO SURGERY: A PROSPECTIVE COHORT STUDY

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Abstract

Introduction: Current guidelines for treatment of carpometacarpal osteoarthritis recommend starting with conservative treatment before surgery is considered. The aim of this study is to investigate how response to conservative treatment, in terms of pain and hand function, influences the hazard that patients convert to surgery.

Methods: In this multi-center prospective cohort study, 809 patients received three months of hand therapy and an orthosis; pain and function were measured with the Michigan Hand Questionnaire (MHQ) at baseline, six weeks and three months follow-up. Conversion to surgery was recorded from clinical records. Joint modeling (a statistical method of combining prediction models) was used to perform the analysis and to calculate Hazard Ratio's (HR).

Results: The joint analytical model showed that both MHQ pain at a certain point (HR 0.93, 95% C.I 0.92-0.94, p<0.001) as well as change in MHQ pain score (HR 1.07, 95% C.I 1.06-1.09, p<0.001) during conservative treatment was significantly associated with conversion to surgery. The joint analytical model between functional outcome and conversion to surgery showed only a significant association between MHQ function at a certain point (HR 0.97, 95% C.I 0.95-0.99, p=0.003) , and no significant association between the change in MHQ score for function (HR 1.0, 95% C.I 1.0-1.0, p<0.098) and conversion to surgery.

Conclusion: Self-reported pain and function, as well as change in self-reported pain during treatment was associated with the hazard of conversion to surgery, whereas change in self-reported functioning was not associated with conversion. Since a reduction in pain during conservative treatment appears to decrease the rate of conversion to surgery, it is advised to structurally monitor pain levels during treatment and potentially adjust treatment accordingly.

Introduction

For symptomatic carpometacarpal (CMC) osteoarthritis (OA) of the thumb, treatment guidelines recommend to start with conservative treatment.[1-4] The suggested treatments include [either or not in combination with topical or oral non-steroid anti-inflammatory drugs (NSAIDs)], analgesics, hand therapy, an orthosis, or intra-articular steroid injection.[5-7] When the patient experiences insufficient pain relief or functional improvement after conservative treatment, the surgeon and patient may decide for surgical treatment.

After hand therapy and an orthosis, considerable variation has been found in outcome, i.e. some patients report substantial pain relief and functional improvement while others experienced no improvement or even a deterioration.[8-10] Although the primary goal of conservative treatment for CMC osteoarthritis is to reduce pain and improve function, an indirect goal is to avoid surgery. The decision to undergo elective surgery is based on many factors, including treatment guidelines, scientific evidence, and patient characteristics and, in contrast to non-elective surgery, patient and surgeon preferences are likely to play an important role. Therefore, it is important to assess the extent to which this decision is based on quantifiable improvement in pain and function, as recorded during the conservative treatment.

Therefore, in patients with CMC OA, the aim of the present study was to investigate the relationship between pain and hand function at begin, during and end of conservative treatment, and the hazard of converting to surgery.

Methods

Study design and setting

This prospective cohort study was conducted between January 2011 and November 2014 at Xpert Clinic in the Netherlands. Xpert Clinic is an outpatient treatment center specialized in treating hand- and wrist problems with 17 different locations, 16 European Board certified (FESSH) hand surgeons working at the multiple locations, and ≥140 hand therapists. The study was approved by the local institutional review board and written informed consent was obtained from all patients.

Data were collected during routine clinical care based on the Dutch treatment guideline which, in case of CMC OA, recommends to start with hand therapy and an orthosis.1 In general, treatment consisted of prescribing a custom-made or pre-fabricated butterfly orthosis in which the CMC joint was fixed in extension/abduction, and the metacarpophalangeal joint (MCP-1) fixed in mild flexion (see Supplementary Figures 1 and 2). The choice for custom-made or pre-fabricated orthosis was based on the preference of the hand therapist and the terms of the patient's insurance company. In addition, two 25-min sessions of hand therapy were given per week. However, additional or fewer sessions could be planned based on the therapist's

judgment, and the ability and/or availability of the patient.

All hand therapists received the same internal training on how to treat CMC OA with hand therapy. Patients received treatment under the supervision of (generally) the same therapist, using a standardized protocol. Treatment was divided into two phases of six weeks per phase (i.e. total treatment of three months). Phase one included instruction on how to wear the orthosis throughout the day, and consisted of hand therapy for correct thumb position (training pinch/grasping movements without hyperextension in the MCP thumb joint, and without CMC adduction) and using a full thumb range of motion (which trains specific coordination of the intrinsic/extrinsic muscles of the thumb). Phase two included instruction to wear the orthosis only during heavy activities, depending on the pain level and the patient's ability to perform activities with a stable thumb position. During this phase, hand therapy focused on improving active stability during daily activities and improving thenar muscle strength. In Phase two, patients performed home exercises 4-6 times a day. The number of prescribed home exercises ranged from 3-6 exercises per day, with 10-15 repetitions each, depending on the individual patient and the level of pain. After Phase two, patients were encouraged to keep doing the exercises, and were allowed to use the orthosis when necessary. Corticosteroid injections were not part of the treatment, and no NSAIDs were prescribed.

Participants

Included in this study were all patients diagnosed by a hand surgeon with primary non-traumatic CMC OA and receiving conservative treatment. Excluded were patients who were previously surgically treated for their CMC OA or were receiving simultaneous treatment for other hand conditions. Patients were also excluded when they received intra-articular corticosteroid injection prior to their treatment, since this may interact with the effectiveness of hand therapy.

Baseline demographics

Baseline characteristics of all patients (including gender, age and which hand was treated) were collected before start of treatment to correct for potential confounding.

Treatment outcome

To evaluate outcome of conservative treatment, patients filled out the Michigan Hand Questionnaire (MHQ; Dutch language version), in which score 0 = poorest function/highest pain, and 100 = ideal function/no pain.[11-13] The MHQ is a self-reported questionnaire with six domains (pain, esthetics, hand function, performance of activities of daily living, work performance, and satisfaction) and 37 items. For the present study, the domains 'pain' and 'hand function' of the MHQ were investigated, since patients with CMC OA mainly have complaints of pain and loss of hand

function.[14] The test-retest reliability for MHQ pain is 0.91 and for MHQ hand function is 0.92.[12] The minimal clinically important difference was 11 points for MHQ pain and was 13 points for MHQ function.[15] Furthermore, both domains have excellent internal consistency, with a Cronbach's alpha 0.86 for pain and 0.93 for function.[12] As part of our web-based outcome registration, the MHQ was filled in before the start of conservative treatment (baseline), and again at six weeks and three months.

Conversion to surgery

All patients had a follow-up appointment with their hand surgeon approximately three months after the start of therapy. At the follow-up appointment the surgeon, together with the patient, evaluated the effects of the conservative treatment and the current health complaints. Based on this evaluation, surgery was discussed as an option. However, patients could schedule a follow-up appointment before the planned appointment at three months when patients did not see any benefit during conservative treatment and opted for surgery.

For patients who underwent surgery after conservative treatment between January 2011 and February 2016, the number of days from the start of conservative treatment until surgery was recorded. Throughout the manuscript, the term 'conversion to surgery' is used to denote the decision made by surgeon and patient to actually undergo surgery.

Statistical methods

To describe the patient-specific course of self-reported pain over time, and account for the correlation in the repeated measurements of each patient, the framework of linear mixed models (LMM) was used. We modelled time as a continuous variable, meaning that we modelled the evolution of outcome in pain and function over time (in days) following a linear pattern.

To examine the association between the response to conservative treatment in terms of self-reported pain and function, and the hazard of conversion to surgery, a joint analytical model was utilized that combines the longitudinal course obtained from the LMM with a Cox regression model.

Using a standard Cox regression model without utilizing the joint analytical model would be theoretically invalid, because it would assume that change in MHQ pain & function is time independent and constant between the follow-up moments.[16,17] Joint analytical models adjust for the variability between measured MHQ pain & function scores over time. In the created Cox regression model (which served as input for the joint analytical model) correction was made for the following baseline characteristics: gender, age and which hand was treated.

Since we were not only interested in the influence in outcome after conservative treatment at a certain time, but also on the influence of change in

outcome after conservative treatment between follow-up and relation to surgery, we added a time-dependent slope parametrization to the joint analytical model.

To assess the discriminative ability of the MHQ pain and function scores, internal validation was performed using Monte Carlo simulations. We relied on the receiver operating curve (ROC) to examine how well the joint analytical model could discriminate between patients who would convert to surgery and patients who would not convert to surgery (up to two years later), using the longitudinal development of outcome in pain and function over three months of conservative treatment.

For the LMM and Cox regression, the R packages Nlme and Survival were used; for the joint modeling package, JMbayes was used.[18] For all tests, a p-value ≤0.05 was considered to be statistically significant.

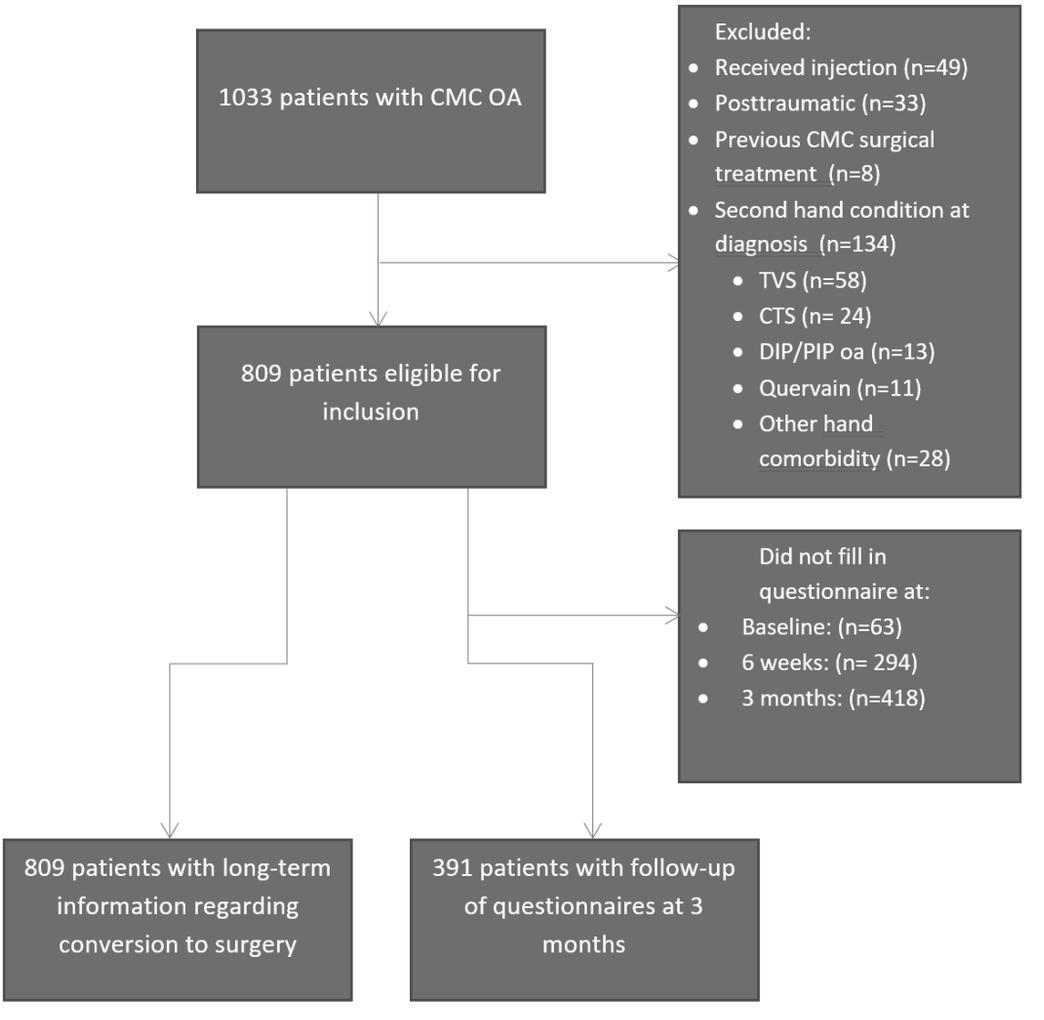


Figure 1. *Flowchart of study participation. Abbreviations: CMC OA= Carpometarcarpal Osteoarthritis, TVS= Tenovaginitis stenosans, CTS= Carpal tunnel syndrome, DIP/PIP oa = Distal interphalangeal joint / promixal interphalangeal joint osteoarthritis.*

Results

Response to conservative therapy: pain and function

Between January 2012 and November 2014, we included 809 patients diagnosed with CMC OA who received conservative treatment (Figure 1). Table 1 presents the baseline characteristics and outcome at six weeks and three months after start of treatment. Figure 1 also shows the response rates at the subsequent follow-up moments. Since missing data may have biased the results, a responder/non-responder analysis was performed to test whether patients that did not fill in the MHQ at six weeks and at three months showed differences with regard to baseline characteristics; however, no significant differences were found (Supplementary Table 1). The modeling framework of the LMM allowed to use data of all patients, even when patients did not fill in the questionnaires at all follow-up measurements. As a result, data of all 809 patients were used in the analysis.

After three months therapy, MHQ pain score improved from 46 ± 17 at baseline to 58 ± 21, and MHQ function score improved from 66 ± 16 at baseline to 68 ± 15 (Table 1).

The LMM showed that the improvement in pain between baseline and three months was significant (B=0.122 ±0.009, p<0.001). To interpret these numbers: For each day, the expected improvement in pain is 0.122 points. Moreover, the expected score in pain at three months is 62 for someone who started with a baseline pain score of 50.

Furthermore, The LMM showed that the improvement in function between baseline and three months was significant ((B=0.038 ± 0.009, p<0.001). To interpret these numbers: For each day, the expected improvement in function was 0.038. Moreover, the expected score in function at three months is 53 for someone who started with a baseline function score of 50.

Table 1. *Baseline characteristics and outcome after conservative treatment.*

		Baseline *% or Mean ± SD*	**6 weeks** *Mean ± SD*	**3 months** *Mean ± SD*
Sex	Female	76	*na*	*na*
Treated hand	Right	50	*na*	*na*
Age in years		60 ± 9	*na*	*na*
Duration of symptoms in months		34 ± 62	*na*	*na*
MHQ	Function*	66 ±16	67±14	68±15
	Pain*	46 ± 25	54±19	58±21

** Higher scores indicate better outcome*
Abbreviations: MHQ = Michigan Hand Questionnaire, SD = standard deviation, na = not applicable

Conversion to surgery

After a mean follow-up period of 2.2 years, 15% underwent surgery. The constructed Cox model predicting conversion to surgery, showed no significant association between the baseline patient characteristics gender, age and side (left or right hand treated) and conversion to surgery.

The joint analytical model predicting the effect of MHQ pain score on conversion to surgery showed that the both MHQ pain at a certain point as well as change in MHQ pain score during conservative treatment was significantly associated with conversion to surgery (Table 2). For example, for each 5 points higher on the MHQ pain at a certain point (i.e. at baseline, 6 weeks or 12 weeks), i.e. a score of 65 instead of 60 at baseline, the hazard of converting to surgery decreased with 30.5%. Furthermore, for each 5 points improvement in MHQ pain at follow-up (e.g. an improvement of 5 points instead of 0 point at three months), the hazard of converting to surgery decreased with 40.3%.

The joint analytical model between functional outcome and conversion to surgery showed only a significant association between MHQ function at a certain point, and no significant association between the change in MHQ score for function and conversion to surgery (Table 2). For example, for each 5 points higher on the MHQ function at a certain point (i.e. a score of 65 instead of 60 at baseline), the hazard of converting to surgery decreased with 14.1%.

Internal validation showed that the area under the curve (AUC) for MHQ pain was 0.738, indicating that the model has moderate to good discriminative ability.

Internal validation showed that the AUC for MHQ function was 0.658, indicating that the model has moderate discriminative ability.

Table 2. *Outcome of joint analytical model: relation between response to therapy and hazard of conversion to surgery.*

Outcome	Variable	Hazard ratio (95% CI)	p-value
MHQ Pain			
	Gender	0.79 (0.49-1.30)	0.301
	Age	0.98 (0.96-1.0)	0.186
	Treated hand	1.27 (0.70-1.93)	0.347
	MHQ Pain at certain time	0.93 (0.92-0.94)	<0.001
	MHQ Pain change at certain time	1.07 (1.06-1.09)	<0.001
MHQ Function			
	Gender	0.95 (0.95-1.62)	0.893
	Age	0.98 (0.95-1.01)	0.243
	Treated hand	1.51 (1.00-2.28)	0.050
	MHQ Function at certain time	0.97 (0.95-0.99)	0.003
	MHQ Function change at certain time	1.0 (1.0-1.0)	0.098

Abbreviations: CI = confidence interval; MHQ = Michigan Hand Questionnaire

Discussion

For patients with CMC1 OA seeking treatment, treatment guidelines recommend to first start with hand therapy and an orthosis. Therefore, in these patients, this study investigated to what extent outcome in pain and hand function influenced the hazard of converting to surgery after conservative treatment. It was found that pain levels and change in pain levels during conservative treatment significantly influenced the hazard of converting to surgery. Furthermore, function levels significantly influenced the hazard of converting to surgery, whereas change in function levels was marginal and had no significant influence on conversion to surgery.

Only one other study has evaluated the percentage of patients that convert to surgery after initiating conservative treatment. Berggren et al. showed a slightly higher conversion rate of 10 of 33 patients (30%) waiting for operation; these patients were treated successfully with hand therapy within seven months before surgery and, within seven years, only two more patients had received additional surgical treatment.[19] However, that study did not analyze the outcome of conservative treatment and how it might be linked to conversion to surgery. In the present prospective cohort, improvement in pain during conservative treatment resulted in a lower rate of conversion to surgery.

A possible explanation for change in function not being related to surgery is that, for these patients, the main reason to visit an outpatient clinic is pain.[14] This is in

line with the functional outcome in the present study: on group level, only a minimal improvement in function was achieved after conservative treatment, without exceeding the minimal clinically relevant improvement of 13. Even though function levels at a certain time point influenced conversion to surgery, the effect was limited. This was in contrast to the outcome in pain, where improvement after conservative treatment exceeded the minimal clinically relevant improvement of 11. In addition, pain levels at a certain timepoint (e.g. baseline), appeared to influence the hazard of converting to surgery more than the function levels at a certain timepoint (e.g. baseline).

Furthermore, we found that the change in pain during treatment was more important in the decision to convert to surgery than pain levels measured at a certain timepoint (i.e. baseline) and that, of all patients, only 15% converted to surgery. Therefore, we postulate that pain is the most important motive for patients to seek care for CMC OA, and we advise to always start with conservative treatment before considering surgical intervention, even when the pain level at baseline is high.

To our knowledge, this is the first study that quantitatively supports current guidelines to start with conservative treatment before discussing the option of surgical treatment. Furthermore, based on our findings, we suggest to monitor pain levels during conservative treatment to potentially intervene when the response to therapy suggests a higher risk to convert to surgery. For example, hand therapists could adjust their treatment, focusing more on alleviating pain and less on improving functional outcome, or vice versa. In this way, a more individualized treatment might be provided based on the patient's response, possibly leading to better treatment outcome. In our patients, improvement in pain was achieved without a clinically relevant change in functional outcome. However, additional studies are required to further evaluate the long-term relationship between function and pain.

In the case that patients decide to convert to surgery, good postoperative pain outcome is expected. For example, in a Cochrane review, Wajon et al. compared different surgical techniques in terms of outcome in pain for patients with CMC OA; on average patients had a postoperative pain score of 26-30 points on a 0-100 scale.[20]

Although our joint analytical models for conversion to surgery had moderate to good discriminative ability, there might be room for improvement, i.e. other variables (e.g. psychological factors) might also be important in the decision to convert to surgery. A recent systematic review found that depression and anxiety were highly prevalent in patients with osteoarthritis, and that patients with these symptoms experienced more pain and had less optimal outcomes.[21] In addition, Becker et al.[22] found that patients seeking care for CMC OA had more catastrophic thinking and higher rates of depression compared to patients that did not seek treatment for CMC OA. In the present study, however, none of these psychological factors were examined.

This study has a number of strengths and limitations. The main strength is the large sample size and its prospective nature; another strength is the high external validity, since we studied predictive factors of conversion to surgery in daily clinical practice.

A limitation is the lack of a control group receiving no conservative treatment. This implies that it is unknown whether the change in pain level during conservative treatment was caused by the conservative treatment or by other unrelated factors, such as regression to the mean or spontaneous improvement. Moreover, the multi-center, multi-surgeon design of our study might have caused clustering by these factors, resulting in standard errors that could have been too small. Due to the already complex joint models, we decided to not add another factor (i.e. location, surgeon) to our analysis in order to reduce complexity. Another limitation is the substantial amount of missing data, which might have resulted in biased estimates. However, based on responder/non-responder analysis, we can justify that data missing at three months were missing at random (MAR), meaning that the hazard of the missing values is dependent on the observed data, but independent of the unobserved data. Using the maximum likelihood approach of our LMM allowed to take this into consideration, thereby reducing bias.

In conclusion, this study found that pain, function and change in self-reported pain level of the treated hand during treatment was associated with the probability of conversion to surgery, whereas change in self-reported function had no significant influence on conversion. Therefore, we suggest that structured monitoring of self-reported pain during and after conservative treatment might help to adjust treatment based on the response of the patient, thereby providing a more patient-specific treatment and potentially preventing patients from converting to surgery.

References

1. Van Uchelen J, Beumer A, Brink SM, Hoogvliet P, Moojen TM, Spaans AJ VG. Dutch guideline for conservative and surgical treatment for primary thumb base osteoarhtritis. Amsterdam, Netherlands NVPC, NVVH, NOV, VRA, VvBN.; 2014.

2. Zhang W, Doherty M, Leeb BF, Alekseeva L, Arden NK, Bijlsma JW, et al. EULAR evidence based recommendations for the management of hand osteoarthritis: report of a Task Force of the EULAR Standing Committee for International Clinical Studies Including Therapeutics (ESCISIT). Ann Rheum Dis. 2007 Mar;66(3):377-88.

3. National Clinical Guideline CU. Osteoarthritis: Care and Management in Adults. NICE Clin Guidel No 177. 2014 Feb.

4. Hochberg MC, Altman RD, April KT, Benkhalti M, Guyatt G, McGowan J, et al. American College of Rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. Arthritis Care Res (Hoboken). 2012 Apr;64(4):465-74.

5. Colditz JC. The biomechanics of a thumb carpometacarpal immobilization splint: design and fitting. J Hand Ther. 2000 Jul-Sep;13(3):228-35.

6. Joshi R. Intraarticular corticosteroid injection for first carpometacarpal osteoarthritis. J Rheumatol. 2005 Jul;32(7):1305-6.

7. Stamm TA, Machold KP, Smolen JS, Fischer S, Redlich K, Graninger W, et al. Joint protection and home hand exercises improve hand function in patients with hand osteoarthritis: a randomized controlled trial. Arthritis Rheum. 2002 Feb;47(1):44

8. Egan MY, Brousseau L. Splinting for osteoarthritis of the carpometacarpal joint: A review of the evidence. Am J Occup Ther. 2007;61(1):70-78. doi:10.5014/ajot.61.1.70.

9. Spaans AJ, Van Minnen LP, Kon M, Schuurman AH, Schreuders AR, Vermeulen GM. Conservative treatment of thumb base osteoarthritis: A systematic review. J Hand Surg Am. 2015;40(1):16-21.e5. doi:10.1016/j.jhsa.2014.08.047.

10. Aebischer B, Elsig S, Taeymans J. Effectiveness of physical and occupational therapy on pain, function and quality of life in patients with trapeziometacarpal osteoarthritis - A systematic review and meta-analysis. Hand Ther. 2016;21(1):5-15. doi:10.1177/1758998315614037

11. van der Giesen FJ, Nelissen RG, Arendzen JH, de Jong Z, Wolterbeek R, Vliet Vlieland TP. Responsiveness of the Michigan Hand Outcomes Questionnaire--Dutch language version in patients with rheumatoid arthritis. Arch Phys Med Rehabil. 2008 Jun;89(6):1121-6. Epub 2008/05/28.

12. Chung KC, Pillsbury MS, Walters MR, Hayward RA. Reliability and validity testing of the Michigan Hand Outcomes Questionnaire. J Hand Surg Am. 1998 Jul;23(4):575-87.

13. Marks M, Audige L, Reissner L, Herren DB, Schindele S, Vliet Vlieland TP. Determinants of patient satisfaction after surgery or corticosteroid injection for trapeziometacarpal osteoarthritis: results of a prospective cohort study. Arch Orthop Trauma Surg. 2015 Jan;135(1):141-7. Epub 2014/11/22.

14. Frouzakis R, Herren DB, Marks M. Evaluation of expectations and expectation fulfillment in patients treated for trapeziometacarpal osteoarthritis. J Hand Surg Am. 2015 Mar;40(3):483-90.

15. Shauver MJ, Chung KC. The Minimal Clinically Important Difference of the Michigan Hand Outcomes Questionnaire. J Hand Surg Am. 2009;34(3):509-514. doi:10.1016/j.jhsa.2008.11.001.

16. Tsiatis A, Davidian M (2004). Joint Modeling of Longitudinal and Time-to-Event Data: An Overview." Statistica Sinica, 14, 809{834.

17. Sweeting MJ, Thompson SG. Joint modelling of longitudinal and time-to-event data with application to abdominal aortic aneurysm growth and rupture. Biom J 2011; 53: 750–763.

18. Rizopoulos D. The R package JMbayes for fitting joint models for longitudinal and time-to-event data using MCMC. J Stat Softw. 2016;72 ((7)):pp. 1-46.

19. Berggren AJ-DJLGNBPM. Reduction in the need for operation after conservative treatment of osteoarthritis of the first carpometacarpal joint: a seven year prospective study. Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery. 2001 2001/01/01;35(4):415-7.

20 Wajon A, Vinycomb T, Carr E, Edmunds I, Ada L. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. Cochrane database Syst Rev. 2015;(2):CD004631. doi:10.1002/14651858.CD004631.pub4.

21. Sharma A, Kudesia P, Shi Q, Gandhi R. Anxiety and depression in patients with osteoarthritis: impact and management challenges. Open Access Rheumatol. 2016;8:103-13.

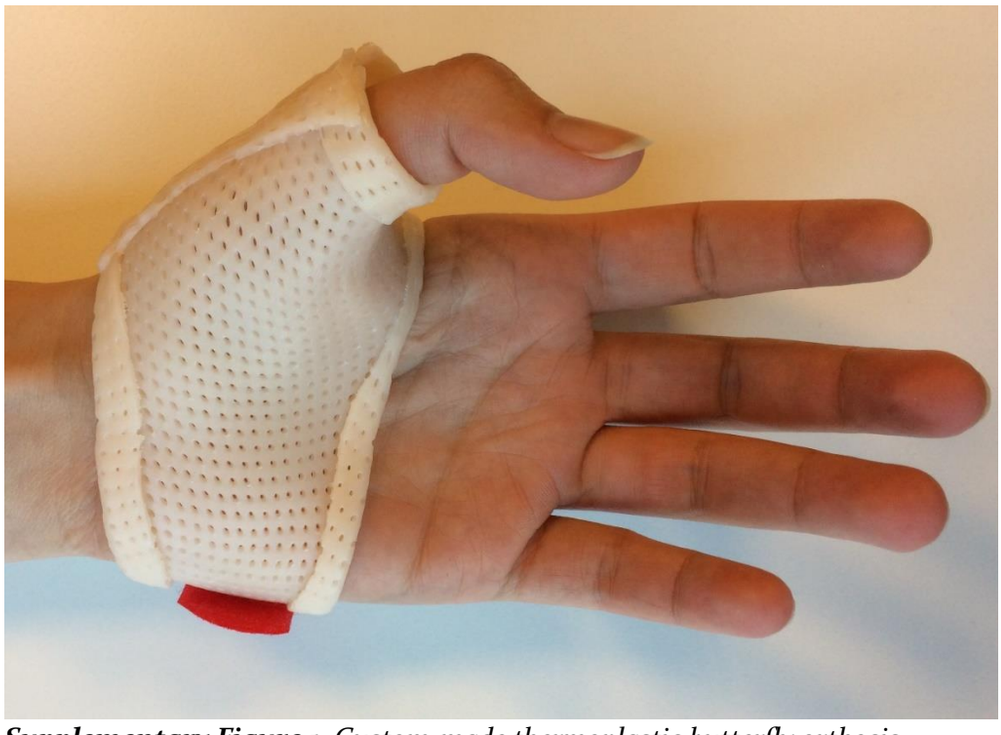
22. Becker SJ, Makarawung DJ, Spit SA, King JD, Ring D. Disability in patients with trapeziometacarpal joint arthrosis: incidental versus presenting diagnosis. 20140926 DCOM- 20150618(1531-6564 (Electronic)).

Appendix

Supplementary Table 1.

		Total (n=809)	**Non-responders at 3 months (n=310)**	**Responders at 3 months (n=391)**	
Baseline characteristics		% or Mean ± SD	% or mean	% or mean	p-value
Sex	Female	76	76	77	0.757
Treated hand	Right	50	49	50	0.871
Age in years		60 ± 9	60	60	0.545
Duration of symptoms in months		34 ± 62	36	33	0.469
MHQ	Function*	56 ±16	56	56	0.645
	Pain*	46 ± 25	46	47	0.17

**Higher scores indicate better outcome*
MHQ: Michigan Hand Questionnaire, SD: standard deviation, na = not applicable

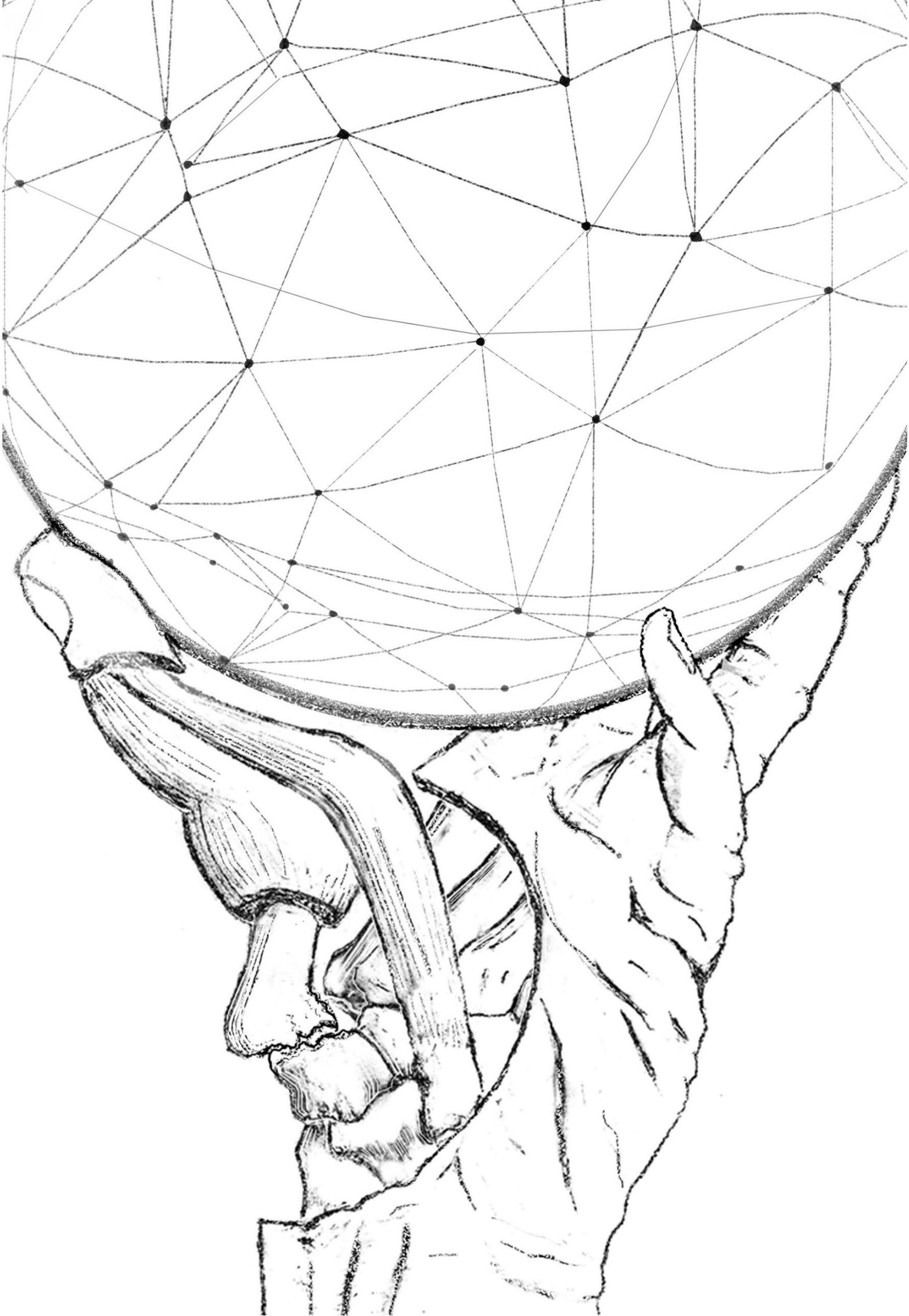


Supplementary Figure 1. *Custom-made thermoplastic butterfly orthosis.*

Supplementary Figure 2. *Pre-fabricated butterfly orthosis.*

PART 2

POSTOPERATIVE REHABILITATION AFTER CMC ARTHROPLASTY



POSTOPERATIVE REHABILITATION FOLLOWING THUMB BASE SURGERY: A SYSTEMATIC REVIEW OF THE LITERATURE.

Wouters RM
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Hovius SER
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Selles RW

Arch Phys Med Rehabil. 2018 June
Doi: 10.1016/j.apmr.2017.09.114.

6

Abstract

Objective: When conservative treatment fails to alleviate symptoms in patients with thumb carpometacarpal (CMC) osteoarthritis (OA), CMC arthroplasty is indicated. However, there is no consensus regarding the components of postoperative rehabilitation for patients who underwent CMC arthroplasty. This systematic review provides an overview of rehabilitation for patients who underwent CMC arthroplasty, with emphasis on early active mobilization.

Methods: PubMed/MEDLINE, Embase, CINAHL and Cochrane were searched for articles written in English that described postoperative regime (including immobilization period/method and/or description of exercises/physical therapy, follow-up ≥six weeks) on CMC arthroplasty. The PRISMA statement was used as guidance in this review and methodological quality was assessed using the Effective Public Health Practice Project quality assessment tool. Randomized studies were additionally scored using the Physiotherapy Evidence Database scale.

Results: Twenty-seven studies were included, concerning 1015 participants in whom 1118 surgical procedures were performed. A summary on the components of postoperative rehabilitation used in the included studies on CMC OA is presented for different surgical interventions. We found that early active recovery (including short immobilization, early initiation of ROM and strength exercises) provides positive outcomes on pain, limitations in ADL and grip & pinch strength, but comparative studies are lacking. Furthermore, three postoperative exercises/therapy phases were identified in the literature: the 'acute phase', the 'unloaded phase' and the 'functional phase', but again comparative studies are lacking.

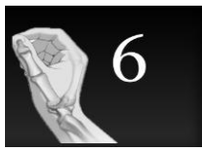
Conclusions: Early active recovery is used more often in the literature and does not lead to worse outcomes or more complications. This systematic review provides guidance for clinicians in the content of postoperative rehabilitation on CMC arthroplasty. The review also clearly identifies the almost complete lack of high quality, comparative studies on postoperative rehabilitation after CMC arthroplasty.

Introduction

Osteoarthritis (OA) of the thumb carpometacarpal joint (CMC) is a common disorder in the elderly.[1] The prevalence of radiologically diagnosed CMC OA amongst females aged ≥50 years is 33-36%.[2,3] The number of patients with CMC OA is expected to increase because of the ageing population.[4] Patients with CMC OA often experience pain, have reduced pinch- and/or grip strength and report limitations in activities of daily life (ADL).[5]

When conservative treatment fails to reduce pain and limitations in ADL, CMC arthroplasty may be indicated.[6] In the past decades, a variety of surgical techniques are described.[7,8] When CMC OA is treated surgically, usually a trapeziectomy is performed, with or without ligament reconstruction and/or tendon interposition.[6-8] CMC arthrodesis and implants are also used, but the usage of these techniques has been associated with a higher risk of complications (i.e. non-union or dislocation).[6-8]

Some studies emphasize the importance of postoperative rehabilitation for patients who underwent CMC arthroplasty in order to improve pain intensity, limitations in ADL and improve range of motion (ROM) and grip & pinch strength.[6,8] However, the lack of consensus on the content of postoperative rehabilitation for patients who underwent CMC arthroplasty is mentioned as well.[6,8]



A systematic review by Wolfe et al. in 2014 on postoperative rehabilitation following CMC arthroplasty concluded that no recommendations on postoperative rehabilitation could be made, due to a large reported variation regarding type and duration of postoperative immobilization, postoperative exercises, and duration before patients returned to full activities.[9] Furthermore, no overview of postoperative rehabilitation and variations as used in literature (i.e. differences in immobilization period) is presented for different types of surgery. Additionally, their search in 2013 was limited to PubMed and Cochrane and limited information on the search strings and the inclusion and exclusion criteria is provided.[9] Therefore, an overview of the postoperative rehabilitation as used in the literature on CMC arthroplasty remains desirable.

The aim of this systematic review is to describe and to create an overview on the different components and phases of postoperative rehabilitation protocols for patients who underwent CMC arthroplasty and to quantify how often these are used. Furthermore, we investigated several specific components or variations in postoperative rehabilitation protocols that are presently discussed. We formulated the following research questions:

1) What type of postoperative rehabilitation (including immobilization period and initiation of ROM & strengthening exercises) is used in literature for different types of surgery, categorized by used tendonplasty?
2) What are the outcomes of short immobilization (4-6 weeks or ≤4 weeks) with

regard to pain intensity, limitations in ADL, grip & pinch strength and complications?
3) What are the outcomes of ROM and strengthening exercises in an early phase (≤4 weeks) with regard to pain intensity, limitations in ADL and grip & pinch strength and complications?

Methods

Design

This systematic review was conducted using the PRISMA statement as guidance.[11] The inclusion of eligible articles was conducted by 2 reviewers (RW & BD), disagreements were resolved in a consensus meeting between the two raters.

The electronic databases MEDLINE (PubMed, from 1950), Embase (Elsevier, from 1974), CINAHL (EBSCO, from 1961) and the Cochrane Library (time limit unknown) were searched for eligible articles (search date: June 15th 2017). The references of the included articles were scanned for eligibility after primary and secondary screening. The following MeSH terms and keywords (and their synonyms) were employed: 'carpometacarpal joint', 'thumb', 'arthroplasty', 'trapeziectomy', 'ligament reconstruction and tendon interposition', 'rehabilitation' and 'hand therapy'. The complete search strategy can be found in Appendix 1. We considered each tendon plasty as ligament reconstruction and tendon interposition (LRTI), except if authors specifically stated that only ligament reconstruction or tendon interposition was used.

Articles were eligible for inclusion if they (1) concern patients who underwent CMC arthroplasty due to symptomatic CMC OA; (2) concern human males/females aged ≥18 years; (3) describe an intervention with a follow-up of ≥six weeks postoperatively; (4) Provide an adequate description of postoperative regime, including immobilization period, immobilization method or description of exercises/physical therapy treatment; (5) provide a description of the type of surgery performed; (6) describe a comparison of results over time (i.e. preoperative vs. postoperative); (7) included pain intensity and/or limitations in ADL and/or grip & pinch strength as outcome measures and (8) were written in English.

Articles were excluded when they (1) provide an abstract only, clinical commentary, research letter, editorial note, review presented at meetings, preliminary study, case reports with complications/exceptions or when full-texts was unavailable; (2) concern revision arthroplasty, external fixation, implant/prosthesis, arthrodesis, osteotomy, structural involvement of the first metacarpophalangeal (MCP-1) joint (i.e. volar capsulodesis) or other procedures; (3) are (systematic) reviews or (4) are long-term follow-up studies with already included study populations.

Initially, articles were screened for eligibility on title and abstract. When titles

and abstracts implied that an article was potentially eligible for inclusion, a full-text copy of the report was obtained. Additionally, reference tracking was performed in all included articles (see Figure 1: Flowchart).

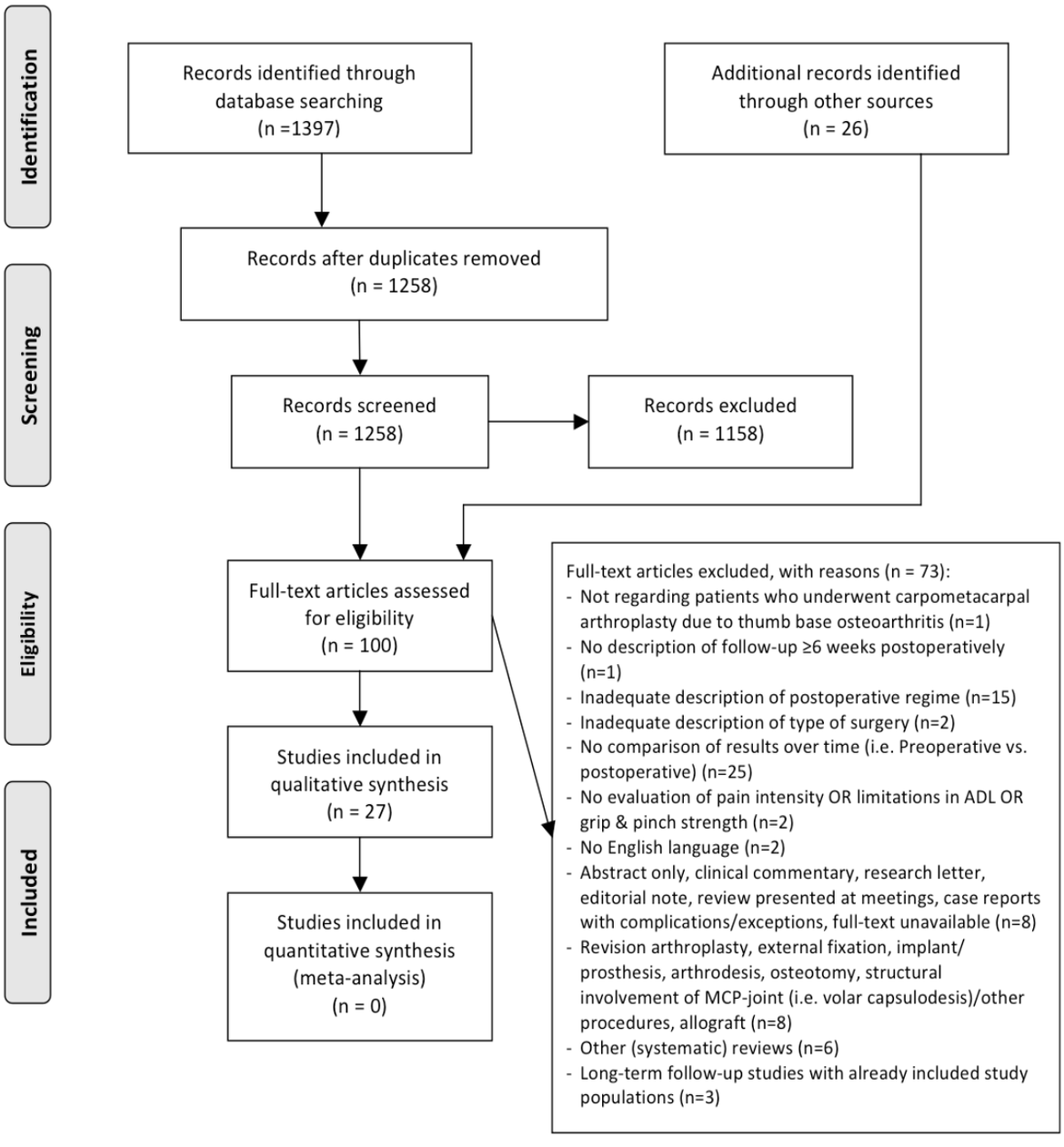


Figure 1. *Flowchart of the search process (derived from PRISMA[11])*

Data extraction, assessment of methodological quality, and data analysis

Two reviewers (RW and JT) extracted data using a standard extraction form, disagreements were resolved in a consensus meeting between the two. Data extracted from the included articles were: (1) authors, publication year, and study location; (2) study design; (3) study population; (4) surgical intervention; (5) immobilization period; (6) therapy/exercises (7) outcome measurements; and (8) outcomes. If data were missing or further information was required, serious attempts were made to contact the first two authors to request the required information. The rehabilitation protocol of the included studies was identified and summarized.

Two reviewers (RW and JT) independently assessed the methodological validity of the included articles. The methodological quality (risk of bias) was scored using the Effective Public Health Practice Project quality assessment tool (EPHPP), 12 randomized studies were scored using the Physiotherapy Evidence Database (PEDro) scale as well.[13] Disagreements were resolved in a consensus meeting between the two raters. The strength of inter-rater agreement was measured by Cohen`s κ coefficient.[14]

Effect sizes were calculated for comparative studies included in this review when means and standard deviations for pre and posttest outcomes were provided. If data were missing or further information was required, we contacted the first two authors to request the required information. When standard deviations were obtained, the pretest standard deviations were pooled to calculate effect sizes.[15,16] Cohen[16] defined conventional values for effect sizes, where a value of 0.20 reflects a small, 0.50 a medium and 0.80 reflects a large effect size. Results of individual studies were not statistically pooled due to a limited number of comparative studies per research question and large heterogeneity.

Table 1: *Overview of the characteristics, measurements and outcomes of the included studies.*

Author, year	**Study design**	**Study population (N, F/M, age (mean, range/±SD), right/left, dominance)**	**Surgical intervention**	**Co-interventions**	**Postoperative rehabilitation - immobilization period**	**Postoperative rehabilitation - Exercises**	**Measurements (instruments, follow-up)**	**Outcomes**
Abbas et al.[23] 2012	Case series	N = 10 F/M = 10/0 Age = 50-60 (N=4), 61-70 (N=3), 71-80 (N=2), 81-90) N=1) Dominance: 7	Modified LRTI using PL for interposition and FCR for ligament reconstruction	Unknown/not described	0-6 weeks: short arm thumb spica cast, K-wire excision after six weeks	6 weeks: Range of motion exercises were begun with gradual progression to resistive pinch and grip strengthening by 12 weeks postoperatively	Limitations in ADL (Quick DASH). Measures at: To (pre-operative), T1 (3 months), T2 (6 months)	Quick DASH Score at To: 58.8, T1: 40.5, T2: 31.3 (p=0.005)
Başar et al.[22] 2012	Retrospective Cohort	N =19 F/M = 18/1 Age = 55 (±5,7 years) Dominance: 18/19	Modified LRTI using full-thickness FCR	None	0-4 weeks: thumb spica 4-8 weeks: removable splint 8 weeks: splint removed	4-8 weeks: MCP & IP joint exercises and isometric thenar abduction amplification exercises 8 weeks - 3 months: CMC joint mobilization allowed. Easy grasping exercises and progressive thenar abduction amplification exercises against resistance were started. + 3 months: resistive grasping and gripping exercises were started and increased progressively	Pain intensity (VAS 0-10 + other), ROM (Buck-Gramcko score, Kapandji), grip & pinch (tip pinch & lateral pinch) strength, joint imaging (SMD) Measures at: To (pre-operative) and T1 (60 months ± 15)	Pain intensity To: 7(±0.9), T1: 0.9 (±1.4) ROM: Grip & pinch strength: Grip To: 13.15, T1: 19.28, tip pinch To: 2.78, T1: 4.45, lateral pinch To: 4.13, T1: 5.60, all strength measures significant (p<0.0001) At T1, 0.2 mm height, not significant.

***Table 2** (continued)*

Author, year	Study design	Study population (N, F/M, age (mean, range/±SD))	Surgical intervention	Co-interventions	Postoperative rehabilitation - immobilization period	Postoperative rehabilitation - Exercises	Measurements (instruments, follow-up)	Outcomes
Ataker et al.[38] 2012	Retrospective Cohort	N = 23 consecutive patients, 27 thumbs F/M = 21/2 Age = 63.5 years (range: 30-83 years) Dominance: 13/27	Modified LRTI according to Burton-Pellegrini using FCR	CTR (n=3), trigger release (n=3), de Quervain tenosynovitis surgery (n=2), and extensor pollicis brevis tenodesis for MCP-1 joint reconstruction (n=1).	0-2 weeks: spica plaster cast (wrist in 20° extension, thumb in midway between extension and abduction, and the IP joint of the thumb is free) 2-6 weeks: CMC butterfly (24h/day), 6-8 weeks: CMC butterfly (only at night)	Mean of 16.8 therapy sessions 0-4 weeks: ROM exercises for the unaffected fingers, IP 1, elbow, and shoulder; and flexor and extensor tendon gliding exercises as a home-based program. 4-6 weeks: AROM exercises for CMC and MCP1 supervised by a PT. 6-8 weeks: progressive ROM and strengthening: isometric abduction, extension, and adduction. 8-10 weeks: Isotonic strength, gentle pinch, grip using putties, and power webs.	Pain intensity (VAS 0-10), Limitations in ADL (DASH), ROM, Grip & pinch strength, joint imaging (SMD) Measures at: To (pre-operative): T1 (12 weeks): and T2 (31.5 months, range: 12-57 months)	VAS at To: 8, T1: 3, T2: 3 ($p<0.001$). DASH at To: 56, T1: 29, T2: 24 ($p<0.001$). Increase in palmar and radial abduction, Kapandji score ($p<0.001$). Grip strength (kg) at To: 12, T1: 18 ($p<0.001$), T2: 13, Lateral pinch at To: 3, T1: 5, T2: 4 ($p<0.001$). Joint imaging at To: 11 mm, T1: 5 mm, T2: 3 mm
Burton et al.[24] 1986	Retrospective Cohort	N = 24 patients, 25 thumbs (4 revisions, 1 bilateral), F/M = 21/3, Age = 55.4. Dominance = 3/24	Partial (6 cases) or complete trapeziectomy (19 cases) with LRTI using FCR, all with K-wire	Unknown/not described	0-4 weeks: thumb spica cast immobilization followed by pin removal 4-6 weeks: isoprene thumb Spica splint support, worn constantly except for hand exercises and washing. Splinting is stopped when full ROM is attained.	4-6 weeks: 1). AROM CMC abduction and extension while avoiding flexion adduction position, 2) AROM flexion of the MCP and IP joints with MC1 supported in abduction by the patient's opposite hand. 6 weeks, continued to 4-6 months: Thenar strengthening is emphasized. 8 weeks: grip and pinch strengthening is begun	Grip & pinch strength, Pain relief (self designed), joint imaging (method not described) Measures at: To (pre-operative) and T1 (postoperative follow-up at 2 years, range 1-4,5 years). Pain relief only measured at T1	Pain relief: 92% of patients enjoyed excellent pain relief and were satisfied with the thumb. T1 showed an overall improvement in grip and pinch strength of 19% compared with To values (no significance mentioned). Average loss of 11% of the initial postoperative arthroplasty space

Davis et al.[37] 2004	Randomized controlled trial investigating different surgical procedures	N = 162 patients, 183 thumbs (Trapeziectomy group: 62, PL group: 59, FCR group: 62) F/M = 162/0 Age = Trapeziectomy group: 58 (range: 44-82), PL group: 60 (range: 41-74), LRTI group: 59 (range: 40-75) (3 groups) Dominance: Trapeziectomy group: 34/58, PL group: 38/60, LRTI group: 36/59	Trapeziectomy, trapeziectomy with PL interposition, trapeziectomy with LRTI with 50% FCR.	Total group: CTR (n=42), MCP K-wire (n=9), MCP capsulodesis (n=9), MCP arthrodesis (n=4), Quervain release (n=4), trigger thumb release (n=5), Trigger finger release (n=2)	0-6 weeks: plaster of Paris splint, wrist neutral & thumb abduction 4 weeks: K-wire excision if applicable	6 weeks: Physiotherapy was not arranged routinely but when the thumb plaster was discarded each patient was shown a series of exercises to mobilize and strengthen her thumb.	Pain intensity, stiffness, weakness and restriction of ADL (measured at once in categorical scores, self-designed), grip & pinch strength, ROM. Measures at: To (pre-operative), T1 (3 months), T2 (12 months)	Pain intensity, stiffness, weakness and restriction of ADL improved 'markedly' at T1 and further at T2 (no significance described). There was no significant difference between the different types of surgery ROM improved at T2 compared to To (no significance mentioned), there was no significant difference between different types of surgery. Thumb key and tip-pinch and grip strength in the whole study group at T1 were not different from To. However, thumb key- and tip- pinch and grip strength in the whole group at the T2 were all significantly stronger compared to To ($p<0.001$ for all 3 types of surgery)
Eaton et al.[36] 1985	Retrospective cohort	N = 21 patients, 25 thumbs (4 bilateral) F/M = 14/7 men. Age = 57.3 years (range: 31-72). Dominance of the 17 patients with unilateral involvement = 12/17	Partial trapeziectomy with LRTI using FCR.	Stabilization of the MP joint for MP hyperextension >30° (n=5). Advancement or plication of a somewhat lax APL tendon (n=6).	0-4 weeks: plaster shell immobilizing CMC and MCP1, along with K-wire. 4 weeks: K-wire excision	4-6 weeks: extension and circumduction of the CMC joint emphasized. 6-8 weeks: thumb is progressively opposed beginning with kapandji 3 gradually extended to kapandji 10. Pinch strengthening is emphasized once full ROM has been achieved.	Pinch strength, clinical results were graded as excellent, good, fair or failure Measures at: To (pre-operative) and T1 (follow-up 37,5 months, range 14-60 months).	Pinch strength at To: 5.5 kg, T1: 6.1 kg (no significance reported) All patients had 'relief of pain' at T1. 55% reported no pain whatsoever, and 44% described 'an occasional twinge or rare mild ache'. No patient had postoperative pain, even those whose clinical results were graded as fair.

***Table 2** (continued)*

Author, year	Study design	Study population (N, F/M, age (mean, range/±SD), right/left, dominance)	Surgical intervention	Co-interventions	Postoperative rehabilitation - immobilization period	Postoperative rehabilitation - Exercises	Measurements (instruments, follow-up)	Outcomes
Horlock et al.[25] 2002	Randomized controlled trial investigating short vs. long immobilization	N = 39 patients, 40 thumbs (Early group: 20, Late group: 20) F/M = 30/10 (Early group: 14/6, Late group: 16/4) Age = Early group: 58 ± 7 years, Late group: 59 ± 9 years Dominance: 20/40	Trapeziectomy	Unknown/not described	Early group: 0-1 week: Scotchcast application 1-6 weeks: Custom made Spica only during physical load and night Late group: 0-2 week: Scotchcast application 2-4 weeks: Custom made Spica 24/7 4-6 weeks: gentle motion aloud out of splint	Early group: 1+ week: Light use allowed of the hand and were taught active exercises for the thumb Late group: 4-6 weeks: Gentle use and mobilization were then allowed out of the splint	Pain intensity, hand function, opinion about rehabilitation regimen, satisfaction with operation (VAS 0-100), ROM, grip & pinch strength and joint imaging (SMD & TMD). Measures at: To (preoperative), T1 (6-8 months)	No significant difference in pain intensity decrease. The early group experienced more convenience compared to the late group ($p<0.05$). Significant decrease in MCP-1 ROM was found in the late mobilization group but not in de early group (within group $p<0.02$). No significant difference in grip & pinch strength, although the early group performed slightly better when pooling effect sizes of grip, pulp pinch and key pinch strength.
Krieg s-Au et al.[21] 2004	Randomized controlled trial investigating different surgical procedures	N = 43 patients, 52 thumbs. F/M = 25/6 (LR group: 13/2, LRTI group: 12/4) Age = LR group: 58.4 / LRTI group: 59 years	Trapeziectomy with LR with FCR vs. Trapeziectomy with LRTI with FCR	None	Both groups: 0-3 week: Spica cast immobilization 3-6 weeks: Individually fitted thumb spica splint that was worn constantly, except during bathing	Both groups: 6 weeks: Active and active-assisted range-of- motion and thenar muscle-strengthening exercises were performed	Grip & pinch strength, Buck-Gramcko score, ROM, self-administered questionnaire (pain, strength, dexterity, cosmetic appearance, willingness to undergo surgery again, overall satisfaction).	All outcomes: Significant improvements, although no differences for different types of surgery mentioned. Proximal migration of the first metacarpal was 37-42%.

Kuhns et al.[39] 2003	Prospective, Single-Surgeon Study	N = 26 F/M = 19/7 Age = 65 years range: 52-82 years Dominance: unknown	Trapeziectomy with k-wire immobilization	MCP-1 volar plate capsulodesis to correct hyperextension (n=7), CTR (n=4), trigger digit release (n=4 digits in 2 patients), ganglion excision (n=1), lipoma excision (n=1).	0-10 days: short-arm thumb spica splint 10 days - 5-6 weeks: thumb spica cast 5-6 weeks: K-wire removal +5-6 weeks: elastic roller bandage then was used to protect the thumb from extreme movements	5 weeks: warm water soaks with range-of-motion exercises were initiated. 7 weeks: those who were not adducting their thumb fully into the plane of the palm and opposing it to the fifth metacarpal head (N=8) were referred for hand therapy for recovery of motion, instructed not to initiate strengthening exercises	Jebsen subtests II and III dexterity tests, AIMS2, pain relief, ROM opposition, Grip & pinch strength, joint imaging (SMD) Measures at: To (preoperative), T1 (6 months), T2 (24 months)	At final follow-up, 92% was pain free. Significant improvements in 3 subscales of the AIMS 2 At T1, 92% adducted fully into the plane of the palm and 96% opposed to the fifth metacarpal head Significant improvements in grip (+47%), key pinch (+33%), and tip pinch (+23%) strength at T2. SMD decreased with 51% at T1 compared to T0, no correlation between proximal migration and functional outcomes.
Lee et al.[26] 2015	Retrospective Cohort	N = 19 F/M = 13/6 Age = 62 years range 43-82 years Dominance: 11/19	Trapeziectomy with APL sling	Unknown/not described	0-4 week: thumb spica cast in abduction	4 weeks +: activity of the thumb was encouraged	Pain intensity (VAS 0-10), limitations in ADL (DASH) patient satisfaction (self designed), returning to work (self designed), ROM, grip & pinch strength, joint imaging (SMD) Measures at: To (preoperative), T1 (36 months, range 19 to 73.7 months)	VAS at T0: 7.2, T1: 1.7 ($p<0.05$) DASH at T0: 41, T1: 18, ($p<0.05$) Significant improvements in al ROM measurements at T1. Of the working participants, 77% returned to their work or activities without any difficulty or occupation modification, in 23% modifications were required. "All patients expressed their satisfaction for improved postoperative appearance of the hand." Increase of 1.1 kg in power pinch ($p<0.05$) at T1, no difference in tip pinch and grip strength at T1. SMD decreased 34.3% ($p<0.05$)

***Table 2** (continued)*

Author, year	Study design	Study population (N, F/M, age (mean, range/±SD), right/left, dominance)	Surgical intervention	Co-interventions	Postoperative rehabilitation - immobilization period	Postoperative rehabilitation - Exercises	Measurements (instruments, follow-up)	Outcomes
Lins et al.[40] 1996	Retrospective Cohort	N = 27 patients, 30 thumbs F/M = 25/2 Age = 64 years range 43-77 years Dominance: 19/30	LRTI with (partial N=20/whole N=10) FCR and k-wire.	CTR (n=4), IP-1 joint arthrodesis (n=1)	0-4 weeks: Thumb spica cast followed by Kirschner pin removal. Removable thumb spica splint at 4 weeks until 12 weeks	4 weeks: gentle ROM exercises 12 weeks: unrestricted thumb movement allowed	Pain intensity (self designed), functional status / satisfaction (self designed), grip & pinch strength, web space, joint imaging (SMD). Measures at: To (preoperative), T1 (42-43 months, range 14-88 months)	At T1, 85% patients considered the frequency of pain 'improved a lot or resolved completely' compared to To and 89% considered the duration and severity as 'improved a lot or completely' at T1, compared to To. At T1, 89% of the patients were satisfied with the 'relief of pain' Web space increased with 1.09 cm (p<0.02) Grip strength increased with 5.9 kg (p<0.001) and pinch strength increased with 1.4 kg (p<0.01) SMD decreased with 30% (p<0.05)
Mo et al.[27] 2004	Case series	N = 14 patients, 14 thumbs F/M = 11/3 Age = 59.6 years range 31-79 years Dominance: 5/11	LRTI with FCR (sometimes scaphotrapeziotrapezoid joint excision) & K-wire	Unknown/not described	0-4 weeks: thumb spica cast followed by pin removal at 4 weeks 4-8 weeks: removable spica	4 weeks: exercises with emphasis on extension/abduction, on maintaining MCP joint flexion and avoiding hyperextension 8 weeks: strengthening exercises	Limitations in ADL (DASH), ROM, grip & pinch strength. Joint imaging (SMD) Measures at: To (preoperative), T1 (20 months, range 12-44 months)	DASH outcomes associated with strength, no results over time reported The distance from thumb tip to the base of the small finger during maximum flexion decreased with 0.4 cm (p=0.02) Grip strength improved with 26% at T1 compared to To (p=0.01), pinch strength improved 11% (p=0.11).

Nylen et al.[43] 1993	Prospective cohort	N = 93 patients, 102 thumbs F/M = 89/11 Age = 59 years range 40-78 Dominance: 56%	LRTI with FCR without K-wire	MCP arthrodesis (n=6) MCP-1 temporary pinned (n=13). 4 other procedures were performed in the similar hand (procedure unknown)	0-5 weeks: plaster spica with thumb in RAB/PAB. An abduction splint was sometimes used intermittently for a few weeks thereafter.	5 weeks: physiotherapy was started (therapy content unknown)	Pain intensity (self designed), limitations in ADL (self designed) Adduction contracture (self designed: severe, moderate, slight, none), ROM, grip & pinch strength, satisfaction. Return to work, joint imaging (SMD)	At T1, 49% was 'pain free' and 51% had 'some pain' Of the patients with limitations in ADL preoperatively, 73% reported no limitations at T1. Adduction contracture 'diminished' in 57% of the patients, decrease was not significant Significant improvements in pinch strength, no significant difference in grip strength. At T1, 88% was satisfied. Average SMD at T1 was 4 mm.
Poole et al.[28] 2011	Randomized controlled trial investigating the added value of postoperative exercises/therapy	N = 9 participants (splint/HT group: 4, splint/HP group: 5) F/M = 8/1 (splint/HT group: 3/1, splint/HP group: 5/0) Age = 58.0 (splint/HT group: 59.3 (range 49–68) splint/HP group: 58.4 (range 52–64)) Dominance: 4/9	Partial trapeziectomy with LRTI using PL and The joint was pinned in 1 cm of distraction with K-wires	Unknown/not described (first stated excluded, later included)	0-4 weeks: bulky dressing and a splint was applied 3-4 weeks: K-wire removal. Both groups: 4 weeks: thumb spica or c-bar splint, no description of discontinuation	The splint/HP group: 4 weeks postoperatively: 1 consult, which included thumb spica or c-bar splint, and home program (included information regarding splint wear, methods to control edema, AROM exercises, and massage of the hand). The splint/HT group: 4 weeks postoperatively: receive a thumb spica or c-bar splint followed by outpatient occupational therapy 1 hour, one time a week for approximately 4 weeks. Therapy included: application of a thumb spica or c-bar splint, reduction of edema, instructions in range of motion and strength exercises, and ADL	Pain intensity (Boston Questionnaire), Limitations in ADL (JHFT, AHFT), Grip & pinch strength, Quality of life (AIMS 2) Measures at: To (pre-op) and T1 (6 months postoperatively).	Improvements in pain intensity in both groups, although no significant within group differences due to small sample size. No significant differences between groups, although a larger decrease in symptom severity was found in the hand therapy group (ES = 0.53) Higher improvements in limitations in ADL in the hand therapy group for both the JHFT (ES = 0.52) as the AHFT (ES = 0.33), although not significant due to sample size. Improvements in grip (+13%) & 3-point pinch strength (+27%) were only found in the hand therapy group, while grip (-8%) & 3-point pinch strength (-6%) decreased in the home program group (ES grip strength = 0.77, ES 3-point pinch = 0.95).

***Table 2** (continued)*

Author, year	Study design	Study population (N, F/M, age (mean, range/±SD))	Surgical intervention	Co-interventions	Postoperative rehabilitation - immobilization period	Postoperative rehabilitation - Exercises	Measurements (instruments, follow-up)	Outcomes
Prosser et al.[29] 2014	Randomized Controlled Trial investigating partial vs. complete immobilization	N=56 (3 lost to follow-up, Rigid: 28, Semi-rigid: 28). F/M = 45/11 (Rigid: 23/28, Semi-rigid: 22/28) Age = 67.8 ±8.0 (Rigid 66.9 ±8.5, Semi-rigid 69.6 ±7.8)	Trapeziectomy & LRTI using FCR (N= 53), or trapeziectomy alone (N=3, (rigid N=1, semi-rigid N=2))	Unknown/not described	Both groups: 0-2 weeks: dorsal plaster back slab immobilizing wrist and thumb. Thereafter: randomization. Semi-rigid group: 2-6 weeks: custom made neoprene with a bonded thermoplastic piece from IP 1 to distal 2/3 of the forearm.	Both rigid/semi-rigid: 0-2 weeks: composite extension/flexion advised by surgeon Week 2-3: thumb IP flexion/extension, wrist flexion/extension 4x day 10 reps Week 3-4: isolated AROM MCP flexion/extension to neutral only (0) out of orthosis. Emphasis placed on flexion. 4-6 weeks: TMC AROM PAB, no opposition.	Pain intensity and limitations in ADL (PRWHE, MHQ), and pinch strength. Measures at: To (pre-operative), T1 (6 weeks), T2 (3 months) and T3 (1 year)	No significant differences in pain intensity and limitations in ADL. No significant differences in pinch strength Complications were observed in 14% of the participants in the rigid group compared to 7% in the semi-rigid group.
Roberts et al.[30] 2001	Retrospective Cohort	N = 23, 25 thumbs F/M = unknown Age = median 60 (Q1 = 53, Q3 =65), Dominance = unknown	Trapeziectomy with LRTI using FCR (N =7) or partial trapeziectomy with LRTI using FCR (N=18)	Unknown/not described	0-10 days: bivalve radial plaster thumb spica splint, and ulnar plaster gutter splint. Wrist in approximately 15° DF, thumb midway abduction & extension, and thumb IP free. 10 days: new radial gutter splint was fabricated 3 weeks: splint discontinued	3 weeks: AROM wrist and thumb 3-4 times a day scar management initiated, Swelling and pain modalities (i.e. paraffin, Coban, gloves). 6 weeks: strengthening exercises begun for patients "who complained of weakness with pinch and grip." exercises consisted of isometrics and active motion against resistance. Education in joint protection, modification of pinch, and the use of adaptive equipment was provided	Pain intensity (VAS 0-10), limitations in ADL (self designed: 15-item daily living checklist). Preoperative pain intensity and limitations in ADL were measured retrospectively, Grip & pinch strength. Measures at: To (pre-operative), T1 (postop, median 1 year and 11 months.	Hemi-trapezium resections: VAS median improvement: 7.0 cm (p=0.001, N=12) ADL median improvement: 33% (p=0.001, N=13). Grip & pinch strength median improvements between To-T1: grip 10.2 kg (p=0.01, N=12), lateral pinch 2.3 kg (p=0.01, N=13), tripod pinch 2.6 kg (p=0.01, N=8), and tip-to-tip pinch 1.6 kg (p=0.03, N=7) Full-trapezium resections: VAS median improvement: 8.0 cm (p = 0.04, N=5)

Rocchi et al.[31] 2011	Retrospective Cohort	N=50, 8 lost to follow-up F/M = 34/8 Age = 60 ±9, range 49 - 79) Dominance = 31/50	Trapeziectomy with LRTI using APL	Unknown/not described	Week 0-1: plaster splint with wrist encompassed, MC1 in slight abduction. Week 1-4: thermoplastic splint with thumb in incremented abduction and opposition. Week 4-6: Splinting only at night	0-4 weeks: IP1 movements prescribed. 4+ weeks: exercises to regain full ability; i.e. opposition exercises which gradually progressed from aiming at the tip of the fifth finger, then towards reaching its base. Only for 8/42 patients a rehabilitation program was deemed necessary and exercises of passive, active-assisted and active range-of-motion were started.	Pain intensity (VAS mentioned, but results expressed as no pain and restriction, mild pain with use and some restriction, pain at rest and some restriction and pain at rest and severe restriction), satisfaction (VAS), limitations in ADL (DASH), Grip & key pinch strength, joint imaging (SMD). Measures at: To (pre-operative), T1 (3 months), T2 (6 months) and T3 (12 months)	N=42, 8 lost to follow-up At T3, zero patients had any pain at rest, only 1 occasional mild pain. No significance mentioned. Satisfaction 9.6, time point unknown. DASH at To: 43.3, T1: 25.5, T2: 19.1 T3: 14.5, no significance mentioned. Grip strength at To: 16.0 kg, at T3: 19.2 kg, key pinch at To: 3.7 kg and at T3: 5.6 kg, no significance mentioned. At T3, SMD averaged 6.4 mm
Saehle et al.[32] 2002	Retrospective Cohort	N = 47, 55 thumbs F/M = 44/3 Age = 58 years, range: 44-73 years Dominance: unknown	Trapeziectomy with LRTI using APL	Unknown/not described	0-4/5 weeks: Plaster of Paris	Unknown	Pain intensity (VAS 0-100, only at T1), Limitations in ADL (self-designed at To and T1 & DASH, only at T1), ROM (only at T1), Grip & pinch strength (compared with other hand, only at T1), Cosmetics (VAS 0-100, only at T1), joint imaging (SMD)	Median VAS pain intensity at T1: 11 ADL function measured with self-designed questionnaire improved in 51% of the patients at T1 compared to To. Median DASH scores for the disability/symptom and work scales were both 28. The distal phalanx of the 5th finger could be reached by 52 of the 55 operated hands Average key pinch and grip strengths of the operated hands were reduced with 11% and 22% respectively compared to unaffected side.

***Table 2** (continued)*

Author, year	Study design	Study population (N, F/M, age (mean, range/±SD), right/left)	Surgical intervention	Co-interventions	Postoperative rehabilitation - immobilization period	Postoperative rehabilitation - Exercises	Measurements (instruments, follow-up)	Outcomes
Sirotakova et al.[41] 2007	Case series	N = 74, 104 thumbs F/M = 59/15 Age = 59 years range 40-82 years Dominance: unknown	Trapeziectomy with APL sling (around FCR/ECRL)	CTR (n=19 hands in 15 (20%) patients)	0-2 weeks: plaster of Paris splint. 2-4 weeks: thermoplastic splint. 4+ weeks: Most remove the splint and only wear it at night. Sometimes during day	The patient is seen weekly by the therapists 0-2 weeks: IP-1 joint flexion and extension exercises, which are performed 5 times on 3 occasions each day 2-6 weeks: opposition exercises.	Pain intensity, stiffness, weakness of the hand, functional disability (self designed), ROM, grip & pinch strength, joint imaging (SMD) Measures at: To (preoperative), T1 (6 months), T2 (12 months)	'Excellent' results in terms of pain relief were achieved in 91% Improvements in all ROM measures at T2 (not statistically tested) Grip & pinch strength improved in all measures at T2 (not statistically tested), SMD decreased with 29% at T2
Soejima et al.[33] 2006	Prospective cohort	N = 18, 21 thumbs F/M = 16/2 Age = 63 years range: 52-77 years Dominance: unknown	Trapeziectomy with LRTI using APL	Unknown/not described	0-2 weeks: short arm spica splint.	2 weeks: range-of-motion and grip-strengthening exercises were initiated.	Pain intensity (self designed), ROM, and grip & pinch strength, joint imaging (SMD) Measures at: To (preoperative), T1 (33 months	At T1, 61% had no pain, 24% had mild pain with strenuous activities and 14% had mild pain with light work ROM radial and palmar abduction increased with 14° (p=0.09) and 8° (p=0.07) degrees respectively
Varitimidis et al.[42] 2000	Retrospective Cohort	N = 58, 62 thumbs F/M = 48/10 Age = 58.4 years range: 28-80 years Dominance: 31/58	Trapeziectomy with LRTI using entire FCR, partial trapeziodectomy in 32 cases	MCP-1 arthrodesis (n=3), CTR (n=4), trigger finger release (n=3), IP-1 arthrodesis (n=2).	0-4 weeks: Radial thumb spica splint. 4 weeks: Removable splint is applied. 6 weeks: weaning from splint begins. 3 months: free from immobilization	4 weeks: Physical therapy is started if significant stiffness exists. 3 months: more intense strengthening exercises are started if necessary. Physical therapy usually is continued until the end of the fourth month.	Pain intensity (self designed), ROM, grip & pinch strength, joint imaging (SMD) Measures at: To (preoperative), T1 (42.5 months, range 21-86 months)	T1: 95% had no pain, compared to 0% at To. Increase of pain in 0% of participants 8% improvement in palmar abduction and a 10% improvement in radial abduction at T1 compared to To Significant improvement in strength at T1 in all measurements. SMD decreased with 10%

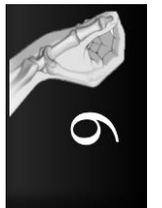
Vermeulen et al.[19] 2009	Prospective cohort	N = 19, 20 thumbs F/M = 17/2 Age = 58 years range: 51-80 years Dominance: unknown	Trapeziectomy with LRTI (Weilby) using FCR	None	0-4 weeks: spica cast. 4 weeks: removable protective orthosis	4 weeks: physiotherapy was started by a hand therapist (therapy content unknown)	Limitations in ADL (DASH, Specific Personal Questionnaire), grip & pinch strength, ROM. Measures at: To (preoperative), T1 (0 months), T2 (3 months), T3 (6 months), T4 (12 months)	DASH score: at To: 51, T2: 36, T3: 30.5, T4: 30 (p<.001) Significant improvements in inter metacarpal distance, Kapandji score Significant improvements in 3-point pinch strength, and overall grip strength at final follow-up.
Vermeulen et al.[20] 2014	Randomized controlled trial investigating different surgical procedures	N = 72 (BP group: 36, Weilby group: 36) F/M = 72/0 Age = BP Group: 64.7 ± 9.1, Weilby group: 63.5 ± 8.5 years Dominance: 36/72 (BP group: 18/36, Weilby group: 18/36)	Trapeziectomy with LRTI using FCR (BP) vs. Trapeziectomy with Weilby sling	None	0-4 weeks: spica cast. 4 weeks: removable protective orthosis	4 weeks: a hand therapist started standardized hand therapy focused on reducing edema and regaining functionality by increasing mobility, stability, and strength of the thumb	Pain intensity and limitations in ADL (PRWHE, DASH), ROM, Grip & pinch strength, complications, joint imaging (SMD) Measures at: To (preoperative), T1 (3 months), T2 (12 months)	Pain intensity (PRWHE) decreased significantly for both types of surgery at T2 (Weilby: -17 points vs. Burton-Pellegrini: -18 points (score range 0-50)). DASH: significant improvements for both types of surgery (Weilby: -16 points vs. Burton-Pellegrini: -20 points (score range 0-100)). No differences between different types of surgery, except in CMC extension (decrease in Burton-Pellegrini group) Increase in grip strength for both types of surgery (Weilby: +3 kg vs. Burton-Pellegrini: +4 kg). Key pinch decreased 0.1 kg for both types of surgery, Tip-pinch increased 0.4 kg for both types of surgery and 3-point pinch increased for both types of surgery (Weilby: +0.3 kg vs. Burton-Pellegrini: +0.5 kg). Statistical testing for group differences was not reported.

***Table 2** (continued)*

Author, year	Study design	Study population (N, F/M, age (mean, range/±SD), right/left)	Surgical intervention	Co-interventions	Postoperative rehabilitation - immobilization period	Postoperative rehabilitation - Exercises	Measurements (instruments, follow-up)	Outcomes
Werthel et al.[34] 2016	Prospective cohort	N = 43, 49 thumbs, 4 were lost to follow-up. F/M = unknown Age = 67 years range 53-85 years Dominance: 18/39	Trapeziectomy with LRTI using FCR	Unknown/not described	0-5 weeks: thumb and wrist immobilized in a cast	Physiotherapy was not required on a systematic basis postoperatively	Pain intensity (VAS), limitations in ADL (DASH) grip & pinch strength, ROM. Measures at: To (preoperative), T1 (37 months, range 29–72 months)	VAS during rest at To: 2.3, at T1: 0.3 ($p<0.05$), VAS during key pinch at To: 5.4, at T1: 1.3 ($p<0.05$) Quick DASH at To: 49.4, at T1: 22.1 ($p<0.05$) Significant improvements in all ROM measures, except MCP-1 hyperextension. Pinch strength at To: 3.3, T1: 5.1 ($p<0.05$), no change in grip strength.
Wong et al.[18] 2009	Retrospective Cohort	N = 22 patients, 22 thumbs F/M = 16/6 Age = 50 years range: 43-75 years Dominance: 13/22	Trapeziectomy with LRTI using FCR & PL	None	0-6 weeks: thermoplastic removable thumb spica splint	6 weeks: Gentle thumb and wrist mobilization exercise and control of the swelling immediately after removal of the splint. 8 weeks: Active thumb and wrist joint mobilization exercise (i.e. putty exercise and sandbag). 12 weeks: Passive thumb and wrist joint mobilization exercise together with vigorous strengthening exercise such as Dexter training, Theraband exercise were started	Pain intensity (self designed), grip & pinch strength, ROM, joint imaging (SMD) Measures at: To (preoperative) T1 (2 weeks) T2 (4 weeks), T3 (8 weeks), T4 (12 weeks), T5 (24 weeks) and T6 (52 weeks), T7 (final follow-up: average 48 months, range 12-72 months)	At final follow-up, 82% was 'pain free' Kapandji score increased from 4 at To to 6 at T7 ($p=0.04$) When comparing To with T7, differences were found in grip strength (+4 kg, $p=0.03$), tip pinch (+0.7 kg, $p=0.04$) and key pinch (+1.0 kg, $p=0.03$), at T7 SMD space ratio decreased with 9% and SMD in mm decreased with 13%

Yang et al.[35] 2014	Retrospective Cohort	N = 19, 21 thumbs F/M = 18/1 Age = 60 years range 52-75 years Dominance: unknown	Trapeziectomy with modified LRTI using FCR	Unknown/not described	0-2 weeks: volar plaster splint. 2-6 weeks: thumb spica cast with which the thumb is placed in an abducted position. 6-12 weeks: patient wears brace intermittently	6 weeks: range of motion and strengthening exercises are started	Pain intensity (VAS 0-10) ROM, grip & pinch strength, joint imaging (SMD) Measures at: To (preoperative), further examined at 2 weeks, 6 weeks and 3 months after surgery, then every 3 months for the first year, and every 6 months thereafter. Final follow-up analyzed: T1 (13.9 months, range 9-28 months))	VAS pain at To: 6.6, T1: 0.5 ($p<0.05$), Improvement in ROM at T1 compared to To ($p<0.05$) Grip strength at To: 18.6, T1: 20.5 ($p>0.05$), Tip pinch strength at To: 4.4, T1: 4.5 ($p>0.05$). At T1 SMD space ratio decreased with 56% and SMD in mm decreased with 55%
J. Yao et al.[17] 2014	Case study	N = 1, F/M= 1/0 Age = 63 Dominance: unknown	Trapeziectomy with tightrope suspension	None	0-10 days: plaster thumb spica orthosis. 10-18 days: custom fabrication spica orthosis. 18 days-10 weeks: butterfly splint if needed, discontinued after 10 weeks	10-18 days: AROM exercises (unspecified). 18 days - 2 months +18 days: edema control, scar massage, isometric exercises lateral pinch strength, guidance regarding ADL	Limitations in ADL (DASH). Measures at: To (pre-operative), T1 (11 months)	DASH at To: 63, at T1: 10

Note: N = number of participants, F/M = Females/Males, LRTI = Ligament Reconstruction and Tendon Interposition, FCR = Flexor carpi radialis, CMC = thumb base joint, IP-1 = thumb interphalangeal joint, MCP-1 = thumb metacarpophalangeal joint, ROM = range of motion, AROM = active range of motion, VAS = Visual Analogue Scale, DASH = Disabilities of the Arm, Shoulder and Hand, APL = Abductor pollicis longus, PL = Palmaris longus, HT = Hand therapy, HP = Home program, ADL = Activities of daily life, PAB = Palmar abduction, CTR = carpal tunnel release, Dominance = number of treatments of dominant side, BP = Burton-Pellegrini, SMD = distance between base of first metacarpal and distal end of scaphoid, TMD = distance between base of first metacarpal and radial border of trapezoid



Results

Study selection and study characteristics

The initial search identified 1397 articles. After applying the inclusion and exclusion criteria, 27 studies were included in this systematic review (see Figure 1). An overview of the included studies, their characteristics, measurements and outcomes are shown in Table 1. In the 27 selected studies, a total of 1015 participants were included in which 1118 procedures were performed. Twelve different surgical procedures were performed in the 27 included studies (Table 2). In eight studies, eleven surgical co-interventions were performed (Supplementary Table 1, Appendix 2). Six studies[17-22] described that no other co-interventions were performed and it is unclear if other co-interventions were performed in the thirteen remaining studies.[23-35]

On methodological quality (risk of bias), a Kappa score of 0.84 and 0.82 was found between the reviewers (RW & JT) with regard to the EPHPP and the PEDro scale respectively; both scores representing very good agreement.[14] Supplementary Table 2 (Appendix 2) gives an overview of the methodological quality of the included studies.

Results of individual studies and synthesis of results.

Six comparative studies were included, of which three investigated the research questions of the present study (the other three studies compared different surgical procedures). Given the low amount of comparative studies on the research questions, no statistical pooling was performed. A summary of the rehabilitation protocols as used in the included studies (including total immobilization period, initiation of ROM and strengthening exercises) is displayed per surgical intervention (categorized by used tendon plasty) in Figure 2. Figure 2 shows that the most progressive postoperative rehabilitation (including short immobilization and early initiation of ROM and strength exercises) is used in the literature for simple trapeziectomy or for LRTI with either a slip, a strip of or the entire Abductor Pollicis Longus (APL) tendon.

Postoperative immobilization.

An overview of the immobilization periods and methods per study, sorted by year of publication in Table 3, shows that the total immobilization varied substantially, from 2 to 12 weeks. In most studies, emphasis was placed on immobilization in palmar abduction and extension of the CMC-joint. Type of immobilization consisted of plaster cast immobilization only[18,23,26,32-34,36,37], plaster cast immobilization followed by a removable splint which is gradually reduced[17,24,29,31,35,38-42] or completely discontinued at a certain moment.[21,22,25,27,30] Splint usage gradually reduced over time consisted of only night usage[31,38,41], the use of a butterfly splint if needed[17] or the splint is stopped when full ROM is attained and thenar strength is improved to a functional level.[24] The discontinuation criterion was not described clearly in eight studies.[19,20,28,35,39,40,42,43]

Table 2. *Types of surgical interventions performed in the included studies. No distinction was made between half or complete tendon use or the presence or absence of a bone tunnel in this classification.*

Surgical intervention	**N**	**Reference(s)**
Trapeziectomy with LRTI using the FCR	448	19-22,29,30,34,38,42,43,56
Trapeziectomy with LRTI using the APL	249	26,31-33,41
Trapeziectomy with LRTI using the FCR and PL	32	18,23
Trapeziectomy with LRTI using the FCR and Kirschner-wire fixation	125	24,27,40,57
Trapeziectomy with tendon interposition using the PL and Kirschner-wire fixation	59	57
Trapeziectomy with ligament reconstruction using the FCR	15	21
Partial trapeziectomy with LRTI using the FCR	18	30
Partial trapeziectomy with LRTI using the FCR and Kirschner-wire fixation	31	24,36
Partial trapeziectomy with LRTI using the PL and Kirschner-wire fixation	9	58
Trapeziectomy	43	25,29
Trapeziectomy with Kirschner-wire fixation	88	39,57
Trapeziectomy with tightrope suspension	1	17
Total	1118	

N = number of interventions per hand (multiple interventions were performed in several cases due to bilateral disease), FCR = Flexor Carpi Radialis, PL = Palmaris Longus, APL = Abductor Pollicis Longus, LRTI = Ligament Reconstruction & Tendon Interposition

Table 3. *An overview of the immobilization period per week for the individual studies.*

YEAR	AUTHOR	N	TYPE SURGERY / TENDON	WEEK 1 2 3 4 5 6 7 8 9 10 11 12 13 14
1985	Eaton et al.[36]	25	***FCR***	
1986	Burton et al.[24]	25	***FCR***	
1993	Nylen et al.[43]	102	***FCR***	
1996	Lins et al.[40]	30	***FCR***	
2000	Varitimidis et al.[42]	62	***FCR***	
2001	Roberts et al.[30]	25	***FCR***	
2002	Saehle et al.[32]	55	***APL***	
2002	Horlock et al.[25]	40		
	Late group	20	***Simple***	
	Early group	20	***Simple***	
2003	Kuhns et al.[39]	26	***Simple***	
2004	Mo et al.[27]	14	***FCR***	
2004	Kriegs-Au et al.[21]	52	***FCR***	
2004	Davis et al.[37]	62	***FCR***	
		59	***PL***	
		62	***Simple***	
2006	Soejima et al.[33]	21	***APL***	
2007	Sirotakova et al.[41]	104	***APL***	
2009	Vermeulen et al.[19]	20	***FCR***	
2009	Wong et al.[18]	22	***FCR + PL***	
2011	Rocchi et al.[31]	50	***APL***	
2011	Poole et al.[28]	9		
	Home program	5	***PL***	
	Occupational	4	***PL***	
2012	Ataker et al.[38]	27	***FCR***	
2012	Başar et al.[22]	19	***FCR***	
2012	Abbas et al. [23]	10	***FCR + PL***	
2014	Prosser et al.[29]	53		
	Rigid group	27	***FCR***	

=

Legend Table 3

Cast immobilization 24h/day	=	
Splint immobilization 24h/day	=	
Splint gradually reduced	=	
Immobilization completely discontinued	=	
Immobilization content unknown	=	

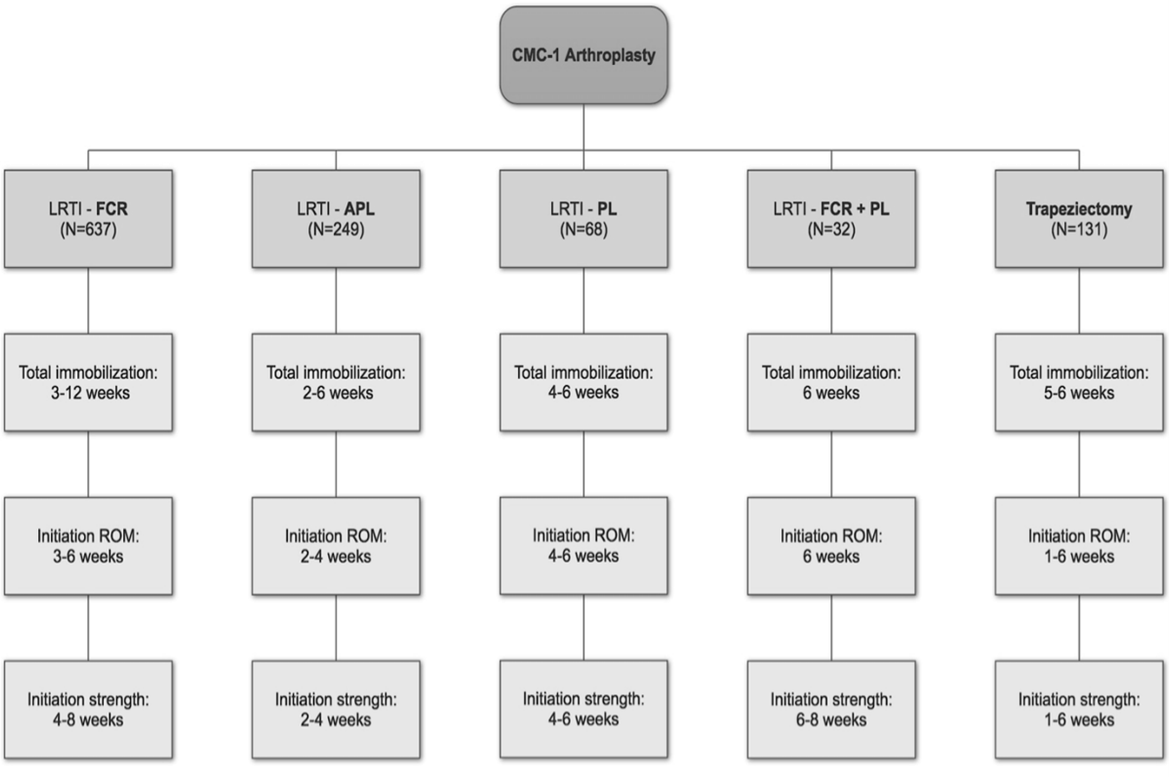


Figure 2. *A summary of the rehabilitation protocols used in the included studies regarding total immobilization period, initiation of range of motion (ROM) and strengthening exercises is displayed per surgical intervention (categorized by used tendon). The displayed time frames indicate the range (minimum – maximum period) of the used period in the literature. CMC = Thumb base joint, FCR = Flexor Carpi Radialis, APL = Abductor Pollicis Longus, PL = Palmaris Longus*

Two comparative studies[25,29] on postoperative immobilization were found (Table 4). In these studies, partial immobilization until 6 weeks was compared with complete immobilization until 6 weeks. The authors did not find more complications or worse outcomes at six to twelve months postoperatively when partial immobilization was used; on the contrary, the same or better outcomes were found in the groups that used partial immobilization compared to complete immobilization. Insufficient data was provided by Prosser et al.[29] to calculate effect sizes. In the study by Horlock et al. effect sizes on pain intensity, satisfaction, ROM and grip & pinch strength range from -0.66 to 0.66, where positive values indicate superior results for partial immobilization (Table 4).

Table 4 also provides the outcomes for studies using a total immobilization period 4-6 weeks or ≤4 weeks respectively. Fourteen studies[18-21,23,25,28,29,31,34,37,39,41,43] used a total immobilization period of 4-6 weeks and five studies[26,30,32,33,36] used a total immobilization period ≤4 weeks. We found similar complications and outcomes in studies using a total immobilization period of 4-6 or ≤4 weeks compared to studies that used an immobilization period ≥6 weeks.

Table 4. *Overview of studies comparing different types of immobilization and of studies using a total immobilization period of 4-6 weeks or ≤4 weeks. Immobilization methods and outcomes per study are displayed.*

Studies comparing immobilization	Immobilization methods	Measures at	Measurements & instruments	Outcomes
Horlock et al.[25] 2002	Late vs. early mobilization: Cast immobilization for two weeks followed by thermoplastic splint 24h/day until six weeks vs. cast immobilization for one week followed by thermoplastic splint only during physical load until six weeks.	To (preoperative) T1 (6-8 months)	1) Pain intensity, Hand function, Opinion about rehabilitation regimen, Satisfaction with operation (VAS 0-100) 2) ROM 3) Grip & pinch strength.	1) No significant difference in pain intensity decrease, although ES = -0.66 due to preoperative group differences, but VAS score at T1: Late group = 30, Early group = 28. The early group experienced more convenience compared to the late group (ES = 0.66, p<0.05). 2) Significant decrease in MCP-1 ROM was found in the late mobilization group but not in de early group (ES = 0.19, within group p<0.02). 3) No significant difference in grip & pinch strength, although the early group performed slightly better when pooling effect sizes of grip, pulp pinch and key pinch strength (ES = 0.05).
Prosser et al.[29] 2014	Rigid vs. semi-rigid immobilization: Thermoplastic splint until 6 weeks with full immobilization of the thumb and wrist vs. combined thermoplastic and neoprene splint until 6 weeks allowing thumb and wrist motion	To (preoperative) T1 (6 weeks) T2 (3 months) T3 (1 year)	1) Pain intensity and limitations in ADL (PRWHE, MHQ) 2) Pinch strength 3) Complications	1) No significant differences in pain intensity and limitations in ADL. Insufficient data was provided to calculate ES. 2) No significant differences in pinch strength. Insufficient data was provided to calculate ES. 3) Complications were observed in 14% of the participants in the rigid group compared to 7% in the semi-rigid group.
Abbas et al.[23] 2012	Only plaster cast immobilization	To (preoperative) T1 (3 months) T2 (6 months)	1) Limitations in ADL (Quick DASH)	1) Quick DASH Score at To: 58.8, T1: 40.5, T2: 31.3 (p=0.005)

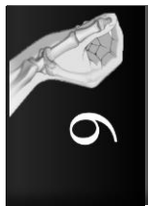


Table 4 *(continued)*

Studies comparing immobilization	Immobilization methods	Measures at	Measurements & instruments	Outcomes
Davis et al.[37] 2004	Only plaster cast immobilization	To (preoperative) T1 (3 months) T2 (12 months)	1) Pain intensity, stiffness, weakness and restriction of ADL (measured at once in categorical scores, self-designed) 2) ROM 3) Grip & pinch strength	1) Pain intensity, stiffness, weakness and restriction of ADL improved 'markedly' at T1 and further at T2 (no significance described). There was no significant difference between the different types of surgery 2) ROM improved at T2 compared to To (no significance mentioned), there was no significant difference between different types of surgery. 3) Thumb key- and tip-pinch and grip strength in the whole study group at T1 were not different from To. However, thumb key- and tip- pinch and grip strength in the whole group at the T2 were all significantly stronger compared to To ($p<0.001$ for all 3 types of surgery)
Horlock et al.[25] 2002	Late vs. early mobilization: Cast immobilization for two weeks followed by thermoplastic splint 24h/day until six weeks vs. cast immobilization for one week followed by thermoplastic splint only during physical load until six weeks.	To (preoperative) T1 (6-8 months)	1) Pain intensity, Hand function, Opinion about rehabilitation regimen, Satisfaction with operation (VAS 0-100) 2) ROM 3) Grip & pinch strength. 4) Complications	1) No significant difference in pain intensity decrease, although ES = -0.66 due to preoperative group differences, but VAS score at T1: Late group = 30, Early group = 28. The early group experienced more convenience compared to the late group (ES = 0.66, $p<0.05$). 2) Significant decrease in MCP-1 ROM was found in the late mobilization group but not in de early group (ES = 0.19, within group $p<0.02$). 3) No significant difference in grip & pinch strength, although the early group performed slightly better when pooling effect sizes of grip, pulp pinch and key pinch strength (ES = 0.05). 4) Complications were observed in 15% of the participants in the early group compared to 5% in the late group.
Kriegs-Au et al.[21] 2004	Plaster cast immobilization + removable splint	To (preoperative), T1 (48.2 months, range 32-64 months)	1) ROM 2) Grip & pinch strength 3) Buck-Gramcko score 4) Self-designed questionnaires: pain, strength, daily function,	All outcomes: Significant improvements, although no differences for different types of surgery mentioned. Proximal migration of the first metacarpal was 37-42%.
Kuhns et al.[39] 2003	Plaster cast immobilization +	To (preoperative), T1	1) Pain relief (measurement instrument unclear)	1) At final follow-up, 92% was pain free. 2) Significant improvements in 3 subscales of the AIMS 2

	removable splint gradually reduced	(6 months), T2 (24 months)	2) Limitations in ADL (Jebsen subtests II and III dexterity tests, AIMS2) 3) ROM (descriptive only) 4) Grip & pinch strength. 5) Joint imaging	3) At T1, 92% adducted fully into the plane of the palm and 96% opposed to the fifth metacarpal head 4) Significant improvements in grip (+47%), key pinch (+33%), and tip pinch (+23%) strength at T2 5) SMD decreased with 51% at T1 compared to To, no correlation between proximal migration and functional outcomes.
Nylen et al.[43] 1993	Plaster cast immobilization + removable splint	To (preoperative), T1 (36 months, range 24-54 months)	1) Pain intensity (self designed) 2) Limitations in ADL (self designed) 3) ROM: Adduction contracture (self designed: severe, moderate, slight, none) 4) Grip & pinch strength 5) Satisfaction, return to work (self-designed) 6) Joint imaging (SMD)	1) At T1, 49% was 'pain free' and 51% had 'some pain' 2) Of the patients with limitations in ADL preoperatively, 73% reported no limitations at T1. 3) Adduction contracture 'diminished' in 57% of the patients, decrease was not significant 4) Significant improvements in pinch strength, no significant difference in grip strength. 5) At T1, 88% was satisfied 6) Average SMD at T1 was 4 mm
Poole et al.[28] 2011	Both groups: Plaster cast immobilization + removable splint	To (pre-op) and T1 (6 months postoperatively).	1) Pain intensity (Boston Questionnaire) 2) Limitations in ADL, (JHFT, AHFT) 3) Grip & pinch strength	1) Improvements in pain intensity in both groups, although no significant within group differences due to small sample size. No significant differences between groups, although a larger decrease in symptom severity was found in the hand therapy group. 2) Higher improvements in limitations in ADL in the hand therapy group for both the JHFT as the AHFT, although not significant due to sample size. 3) Improvements in grip (+13%) & 3-point pinch strength (+27%) were only found in the hand therapy group, while grip (-8%) & 3-point pinch strength (-6%) decreased in the home program group

Table 4 *(continued)*

Studies comparing immobilization	Immobilization methods	Measures at	Measurements & instruments	Outcomes
Prosser et al.[29] 2014	Rigid vs. semi-rigid immobilization: Thermoplastic splint until 6 weeks with full immobilization of the thumb and wrist vs. combined thermoplastic and neoprene splint until 6 weeks allowing thumb and wrist motion	To (preoperative) T1 (6 weeks) T2 (3 months) T3 (1 year)	1) Pain intensity and limitations in ADL (PRWHE, MHQ) 2) Pinch strength 3) Complications	1) No significant differences in pain intensity and limitations in ADL. Insufficient data was provided to calculate ES. 2) No significant differences in pinch strength. Insufficient data was provided to calculate ES. 3) Complications were observed in 14% of the participants in the rigid group compared to 7% in the semi-rigid group.
Rocchi et al.[31] 2011	Plaster cast immobilization + removable splint gradually reduced	To (preoperative) T1 (3 months) T2 (6 months) T3 (12 months)	1) Pain intensity (VAS mentioned, but results expressed as no pain and restriction, mild pain with use and some restriction, pain at rest and some restriction and pain at rest and severe restriction) 2) Satisfaction (VAS) 3) Limitations in ADL (DASH) 4) Grip & key pinch strength. 5) Joint imaging (SMD)	1) At T3, zero patients had any pain at rest, only 1 occasional mild pain. No significance mentioned. 2) Satisfaction 9.6, time point unknown. 3) DASH at To: 43.3, T1: 25.5, T2: 19.1 T3: 14.5, no significance mentioned. 4) Grip strength at To: 16.0 kg, at T3: 19.2 kg, key pinch at To: 3.7 kg and at T3: 5.6 kg, no significance mentioned. 5) At T3, SMD averaged 6.4 mm
Sirotakova et al.[41] 2007	Plaster cast immobilization + removable splint gradually reduced	To (preoperative), T1 (6 months) T2 (12 months)	1) Pain intensity, stiffness, weakness of the hand, functional disability (self designed) 2) ROM 3) Grip & pinch strength 4) Joint imaging (SMD)	1) 'Excellent' results in terms of pain relief were achieved in 91% 2) Improvements in all ROM measures at T2 (not statistically tested) 3) Grip & pinch strength improved in all measures at T2 (not statistically tested) 4) SMD decreased with 29% at T2
Vermeulen et al.[19] 2009	Plaster cast immobilization + removable splint	To (preoperative) T1 (0 months) T2 (3 months) T3 (6 months) T4 (12 months)	1) Limitations in ADL (DASH, Specific Personal Questionnaire) 2) ROM 3) Grip & pinch strength	1) DASH score: at To: 51, T2: 36, T3: 30.5, T4: 30 ($p<.001$) 2) Significant improvements in inter metacarpal distance, Kapandji score 3) Significant improvements in 3-point pinch strength, and overall grip strength at final follow-up.

Vermeulen et al.[20] 2014	Plaster cast immobilization + removable splint	To (preoperative) T1 (3 months) T2 (12 months)	1) Pain intensity and limitations in ADL (PRWHE, DASH) 2) ROM 3) Grip & pinch strength 4) Complications	1) Pain intensity (PRWHE) decreased significantly for both types of surgery at T2 (Weilby: -17 points vs. Burton-Pellegrini: -18 points (score range 0-50)). DASH: significant improvements for both types of surgery (Weilby: -16 points vs. Burton-Pellegrini: -20 points (score range 0-100)). 2) No differences between different types of surgery, except in CMC extension (decrease in Burton-Pellegrini group) 3) Increase in grip strength for both types of surgery (Weilby: +3 kg vs. Burton-Pellegrini: +4 kg). Key pinch decreased 0.1 kg for both types of surgery, Tip-pinch increased 0.4 kg for both types of surgery and 3-point pinch increased for both types of surgery (Weilby: +0.3 kg vs. Burton-Pellegrini: +0.5 kg). Statistical testing for group differences was not reported 4) In total, complications were observed in 27,8% of the participants (Weilby: 23,1% vs. Burton-Pellegrini: 32,5%, difference not significant)
Werthel et al.[34] 2016	Only plaster cast immobilization	To (preoperative) T1 (37 months, range: 29–72 months)	1) Pain intensity (VAS) 2) Limitations in ADL (DASH) 3) ROM 4) Grip & pinch strength	1) VAS during rest at To: 2.3, at T1: 0.3 ($p<0.05$), VAS during key pinch at To: 5.4, at T1: 1.3 ($p<0.05$) 2) Quick DASH at To: 49.4, at T1: 22.1 ($p<0.05$) 3) Significant improvements in all ROM measures, except MCP-1 hyperextension. 4) Pinch strength at To: 3.3, T1: 5.1 ($p<0.05$), no change in grip strength.
Wong et al.[18] 2009	Only plaster cast immobilization	To (pre),T1 (2 wk), T2 (4 wk), T3 (8 wk), T4 (12 wk), T5 (24 wk, T6 (52wk)	1) Pain intensity (self designed) 2) ROM 3) Grip & pinch strength	1) At final follow-up, 82% was 'pain free' 2) Kapandji score increased from 4 at To to 6 at T7 ($p=0.04$) 3) When comparing To with T7, differences were found in grip strength (+4 kg, $p=0.03$), tip pinch (+0.7 kg, $p=0.04$) and key pinch (+1.0 kg, $p=0.03$)

Table 4 *(Continued)*

Studies with a total immobilization period ≤4 weeks	Immobilization methods	Measures at	Measurements & instruments	Outcomes
Eaton et al.[36] 1985	Only plaster cast immobilization	To (preoperative) T1 (37,5 months, range 14-60 months)	1) Pinch strength 2) Clinical results were graded as excellent, good, fair or failure	1) Pinch strength at To: 5.5 kg, T1: 6.1 kg (no significance reported) 2) All patients had 'relief of pain' at T1. 55% reported no pain whatsoever, and 44% described 'an occasional twinge or rare mild ache'. No patient had postoperative pain, even those whose clinical results were graded as fair. According to the grading system, 41.7% of the cases were graded as excellent, 50% were good, and 8.3% were fair
Lee et al.[26] 2015	Only plaster cast immobilization	To (preoperative) T1 (36 months, range 19 to 73.7 months)	1) Pain intensity (VAS) 2) Limitations in ADL (DASH) 3) ROM 4) Grip & pinch strength 5) Patient satisfaction (self designed) 6) Returning to work (self designed) 7) Joint imaging	1) VAS at To: 7.2, T1: 1.7 ($p<0.05$) 2) DASH at To: 41, T1: 18, ($p<0.05$) 3) Significant improvements in al ROM measurements at T1 4) Increase of 1.1 kg in power pinch ($p<0.05$) at T1, no difference in tip pinch and grip strength at T1. 5) "All patients expressed their satisfaction for improved postoperative appearance of the hand." 6) Of the working participants, 77% returned to their work or activities without any difficulty or occupation modification, in 23% modifications were required 7) SMD decreased 34.3% ($p<0.05$)
Roberts et al.[30] 2001	Plaster cast immobilization + removable splint	To (preoperative) T1 (median 1 year and 11 months, range 3 months-11 years, Q1 1 year, Q3 3 years 4 months)	1) Pain intensity (VAS 0-10), measured retrospectively 2) Limitations in ADL (self designed: 15-item daily living checklist), measured retrospectively 3) Grip & pinch strength	1) VAS scores decreased with 8 points ($p=0.04$) 2) Limitations in ADL showed 60% improvement ($p=0.4$) 3) Significant improvements in grip & pinch strength in group with hemi-resections, except in groups with full-trapezium resections
Saehle et al.[32] 2002	Only plaster cast immobilization	To (preoperative) T1 (41 months, range 16-60 months)	1) Pain intensity (VAS 0-100, only at T1) 2) Limitations in ADL (self-designed at To and T1 & DASH, only at T1) 3) ROM (only at T1) 4) Grip & pinch strength (compared with other hand, only at T1)	1) Median VAS pain intensity at T1: 11 2) ADL function measured with self-designed questionnaire improved in 51% of the patients at T1 compared to To. Median DASH scores for the disability/symptom and work scales were both 28. 3) The distal phalanx of the 5th finger could be reached by 52 of the 55 operated hands

			5) Cosmetics (VAS 0-100, only at T1) 6) Joint imaging (SMD)	4) Average key pinch and grip strengths of the operated hands were reduced with 11% and 22% respectively compared to unaffected side. 5) Median VAS score for the cosmetic result at T1: 5 6) SMD decreased with 55% at T1 compared to To, no correlation between proximal migration and clinical results.
Soejima et al.[33] 2006	Only plaster cast immobilization	To (preoperative) T1 (33 months, range 12-71 months)	1) Pain intensity (self designed) 2) ROM 3) Grip & pinch strength 4) Joint imaging (SMD)	1) At T1, 61% had no pain, 24% had mild pain with strenuous activities and 14% had mild pain with light work 2) ROM radial and palmar abduction increased with 14° (p=0.09) and 8° (p=0.07) degrees respectively 3) Grip and the pinch strength increased with 2 kg (p=0.18) and from 1.3 kg (p=0.23), respectively 4) SMD decreased with 15% (p<0.05)

Note: VAS = Visual Analogue Scale, ROM = Range of Motion, ES = Effect Size (positive scores indicate better performance of experimental treatment compared to control treatment), MCP-1 = First Metacarpophalangeal joint, ADL = Activities of Daily Life, PRWHE = Patiënt Rated Wrist & Hand Evaluation, MHQ = Michigan Hand outcomes Questionnaire, DASH = Disabilities of Arm, Shoulder and Hand, AIMS2 = Arthritis Impact Measurement Scales 2, JHFT = Jebsen Hand Function Test, AHFT = Arthritis Hand Function Test, SMD = distance between base of first metacarpal and distal end of scaphoid, TMD = distance between base of first metacarpal and radial border of trapezoid

Postoperative exercises/therapy

Large variations were observed in postoperative exercises/therapy regimens of the included studies. One comparative study[28] investigated the added value of hand therapy compared to a home program only in postoperative rehabilitation. No significant differences were found between the groups due to a small sample size, although higher improvements were found for pain intensity, limitations in ADL and grip & pinch six months postoperatively in the group that received hand therapy (Table 5). Effect sizes on pain intensity, limitations in ADL, grip & pinch strength and quality of life range from 0.33 to 0.95, indicating superior treatment effects of hand therapy compared to a home program only.

Five studies[19,26,32,34,43] did not describe the content of postoperative exercises/therapy. When the other 23 studies are summarized, three phases can be identified on postoperative exercises/therapy: (1) the 'acute postoperative phase' (range: zero to six weeks postoperatively); (2) the 'unloaded phase' (range: one to twelve weeks postoperatively) and (3) the 'functional phase' (range: three weeks to six months postoperatively). Table 6 provides a summary of the phases and the physical therapy content per phase as used in the included studies and Table 7 provides an overview of the phases per study. In general in postoperative exercises/therapy emphasis is placed on MCP-1 flexion and CMC palmar abduction and extension, while CMC flexion, adduction and opposition is avoided.

Table 5 provides the outcomes for studies initiating ROM or strengthening exercises respectively ≤4 weeks postoperatively. Thirteen studies[17,20,24,25,27-31,33,36,40,41] initiated ROM exercises and four studies[17,20,28,33] initiated strengthening exercises ≤4 weeks. No comparative studies on different regimens of ROM or strengthening exercises were found. We did not find more complications or worse outcomes in studies that initiated ROM or strengthening exercises ≤4 weeks compared to studies that initiated ROM or strengthening exercises ≥4 weeks.

Table 5. *Overview of studies investigating benefits of postoperative exercises/therapy and of studies initiating thumb range of motion or strengthening exercises ≤4 weeks. Exercises of other joints (i.e. fingers, wrist) are not described.*

Studies on benefits of postoperative exercises/therapy	Methods	Measures at	Measurements & instruments	Outcomes
Poole et al.[28] 2011	Home program group: 4 weeks: 1 consult initiating ROM exercises Hand therapy group: ROM exercises, one therapy session every week	To (pre-op) and T1 (6 months postoperatively).	1) Pain intensity (Boston Questionnaire) 2) Limitations in ADL, (JHFT, AHFT) 3) Grip & pinch strength 4) Quality of life (AIMS 2)	1) Improvements in pain intensity in both groups, although no significant within group differences due to small sample size. No significant differences between groups, although a larger decrease in symptom severity was found in the hand therapy group (ES = 0.53) 2) Higher improvements in limitations in ADL in the hand therapy group for both the JHFT (ES = 0.52) as the AHFT (ES = 0.33), although not significant due to sample size. 3) Improvements in grip (+13%) & 3-point pinch strength (+27%) were only found in the hand therapy group, while grip (-8%) & 3-point pinch strength (-6%) decreased in the home program group (ES grip strength = 0.77, ES 3-point pinch = 0.95). 4) Significant improvements in several subscales of the Arthritis Impact Measurement Scales 2 for both groups, no between group differences.

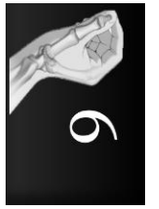


Table 5 *(continued)*

Studies initiating CMC ROM ≤4 weeks	Description of ROM exercises initiated ≤4 weeks	Measures at	Measurements & instruments	Outcomes
Ataker et al.[38] 2012	4 weeks: AROM exercises for CMC1 and MCP1 supervised by a PT, no CMC flexion/adduction, opposition	To (preoperative) T1 (12 weeks) T2 (31.5 months, range: 12-57 months)	1) Pain intensity (VAS) 2) Limitations in ADL (DASH) 3) ROM 4) Grip & pinch strength	1) VAS at To: 8, T1: 3, T2: 3 ($p<0.001$). 2) DASH at To: 56, T1: 29, T2: 24 ($p<0.001$). 3) Increase in palmar and radial abduction, Kapandji score ($p<0.001$). 4) Grip strength (kg) at To: 12, T1: 18 ($p<0.001$), T2: 13, Lateral pinch at To: 3, T1: 5, T2: 4 ($p<0.001$).
Burton et al.[24] 1986	4 weeks: 1) Active abduction and extension while avoiding flexion and adduction, 2) AROM flexion of the MCP and IP joints with MC1 supported in abduction by the patient's opposite hand	To (preoperative) T1 (2 years, range 1-4.5 years).	1) Pain relief (self designed, only measured at T1) 2) Grip & pinch strength 3) Joint imaging	1) Pain relief: 92% of patients enjoyed excellent pain relief and were satisfied with the thumb 2) T1 showed an overall improvement in grip and pinch strength of 19% compared with To values (no significance mentioned). 3) Average loss of 11% of the initial postoperative arthroplasty space
Eaton et al.[36] 1985	4 weeks: extension and circumduction of the CMC joint is emphasized	To (preoperative) T1 (37,5 months, range 14-60 months)	1) Pinch strength 2) Clinical results were graded as excellent, good, fair or failure	1) Pinch strength at To: 5.5 kg, T1: 6.1 kg (no significance reported) 2) All patients had 'relief of pain' at T1. 55% reported no pain whatsoever, and 44% described 'an occasional twinge or rare mild ache'. No patient had postoperative pain, even those whose clinical results were graded as fair. According to the grading system, 41.7% of the cases were graded as excellent, 50% were good, and 8.3% were fair
Horlock et al.[25] 2002	Early group, 1 week: Light use of the hand allowed and active exercises for the thumb Late group, 2 weeks: Gentle use and mobilization were allowed out of the splint	To (preoperative) T1 (6-8 months)	1) Pain intensity, Hand function, Opinion about rehabilitation regimen, Satisfaction with operation (VAS 0-100) 2) ROM 3) Grip & pinch strength.	1) No significant difference in pain intensity decrease, although ES = -0.66 due to preoperative group differences, but VAS score at T1: Late group = 30, Early group = 28. The early group experienced more convenience compared to the late group (ES = 0.66, $p<0.05$). 2) Significant decrease in MCP-1 ROM was found in the late mobilization group but not in de early group (ES = 0.19, within group $p<0.02$). 3) No significant difference in grip & pinch strength, although the early group performed slightly better

				when pooling effect sizes of grip, pulp pinch and key pinch strength (ES = 0.05).
Lins et al.[40] 1996	4 weeks: gentle ROM exercises	To (preoperative) T1 (42-43 months, range 14-88 months)	1) Pain intensity (self designed) 2) Functional status / satisfaction (self designed) 3) ROM (web space) 4) Grip & pinch strength 5) Joint imaging (SMD)	1) At T1, 85% patients considered the frequency of pain 'improved a lot or resolved completely' compared to To and 89% considered the duration and severity as 'improved a lot or completely' at T1, compared to To. 2) At T1, 89% of the patients were satisfied with the 'relief of pain' 3) Web space increased with 1.09 cm ($p<0.02$) 4) Grip strength increased with 5.9 kg ($p<0.001$) and pinch strength increased with 1.4 kg ($p<0.01$) 5) SMD decreased with 30% ($p>0.05$)
Mo et al.[27] 2004	4 weeks: exercises with emphasis on extension/abduction, on maintaining MCP-1 joint flexion and avoiding hyperextension	To (preoperative) T1 (20 months, range 12-44 months	1) Limitations in ADL (DASH) 2) ROM 3) Grip & pinch strength	1) DASH outcomes associated with strength, no results over time reported 2) The distance from thumb tip to the base of the small finger during maximum flexion decreased with 0.4 cm ($p=0.02$) 3) Grip strength improved with 26% at T1 compared to To ($p=0.01$), pinch strength improved 11% ($p=0.11$).
Poole et al.[28] 2011	Home program group, 4 weeks: 1 consult initiating ROM exercises Hand therapy group: ROM exercises, one therapy session every week	To (pre-op) and T1 (6 months postoperatively).	1) Pain intensity (Boston Questionnaire) 2) Limitations in ADL (JHFT, AHFT) 3) Grip & pinch strength	1) Improvements in pain intensity in both groups, although no significant within group differences due to small sample size. No significant differences between groups, although a larger decrease in symptom severity was found in the hand therapy group (ES = 0.53) 2) Higher improvements in limitations in ADL in the hand therapy group for both the JHFT (ES = 0.52) as the AHFT (ES = 0.33), although not significant due to sample size. 3) Improvements in grip (+13%) & 3-point pinch strength (+27%) were only found in the hand therapy group, while grip (-8%) & 3-point pinch strength (-6%) decreased in the home program group (ES grip strength = 0.77, ES 3-point pinch = 0.95).

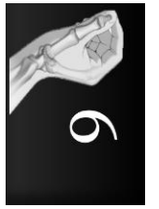


Table 5 *(continued)*

Studies initiating CMC ROM ≤4 weeks	Description of ROM exercises initiated ≤4 weeks	Measures at	Measurements & instruments	Outcomes
Prosser et al.[29] 2014	Rigid vs. Semi-rigid immobilization. Both groups at 4 weeks: abduction exercises	To (preoperative) T1 (6 weeks) T2 (3 months) T3 (1 year)	1) Pain intensity and limitations in ADL (PRWHE, MHQ) 2) Pinch strength 3) Complications	1) No significant differences in pain intensity and limitations in ADL. Insufficient data was provided to calculate ES. 2) No significant differences in pinch strength. Insufficient data was provided to calculate ES. 3) Complications were observed in 14% of the participants in the rigid group compared to 7% in the semi-rigid group.
Roberts et al.[30] 2001	3 weeks: thumb ROM exercises	To (preoperative) T1 (median 1 year and 11 months, range 3 months-11 years, Q1 1 year, Q3 3 years 4 months)	1) Pain intensity (VAS 0-10), measured retrospectively 2) Limitations in ADL (self designed: 15-item daily living checklist), measured retrospectively 3) Grip & pinch strength	4) VAS scores decreased with 8 points (p=0.04) 5) Limitations in ADL showed 60% improvement (p=0.4) 6) Significant improvements in grip & pinch strength in group with hemi-resections, except in groups with full-trapezium resections
Rocchi et al.[31] 2011	4 weeks: exercises to regain full ability; i.e. opposition exercises which gradually progressed from aiming at the tip of the fifth finger, then towards reaching its base	To (preoperative) T1 (3 months) T2 (6 months) T3 (12 months)	6) Pain intensity (VAS mentioned, but results expressed as no pain and restriction, mild pain with use and some restriction, pain at rest and some restriction and pain at rest and severe restriction) 7) Satisfaction (VAS) 8) Limitations in ADL (DASH) 9) Grip & key pinch strength. 10) Joint imaging (SMD)	6) At T3, zero patients had any pain at rest, only 1 occasional mild pain. No significance mentioned. 7) Satisfaction 9.6, time point unknown. 8) DASH at To: 43.3, T1: 25.5, T2: 19.1 T3: 14.5, no significance mentioned. 9) Grip strength at To: 16.0 kg, at T3: 19.2 kg, key pinch at To: 3.7 kg and at T3: 5.6 kg, no significance mentioned. 10) At T3, SMD averaged 6.4 mm
Sirotakova et al.[41] 2007	2 weeks: opposition exercises	To (preoperative), T1 (6 months) T2 (12 months)	1) Pain intensity, stiffness, weakness of the hand, functional disability (self designed) 2) ROM 3) Grip & pinch strength 4) Joint imaging (SMD)	5) 'Excellent' results in terms of pain relief were achieved in 91% 6) Improvements in all ROM measures at T2 (not statistically tested) 7) Grip & pinch strength improved in all measures at T2 (not statistically tested) 8) SMD decreased with 29% at T2

Soejima et al.[33] 2006	2 weeks: ROM exercises were initiated	To (preoperative) T1 (33 months, range 12-71 months)	5) Pain intensity (self designed) 6) ROM 7) Grip & pinch strength 8) Joint imaging (SMD)	5) At T1, 61% had no pain, 24% had mild pain with strenuous activities and 14% had mild pain with light work 6) ROM radial and palmar abduction increased with 14° (p=0.09) and 8° (p=0.07) degrees respectively 7) Grip and the pinch strength increased with 2 kg (p=0.18) and from 1.3 kg (p=0.23), respectively 8) SMD decreased with 15% (p<0.05)
Vermeulen et al.[20] 2014	4 weeks: standardized hand therapy focused on regaining functionality by increasing mobility	To (preoperative) T1 (3 months) T2 (12 months)	1) Pain intensity and limitations in ADL (PRWHE, DASH) 2) ROM 3) Grip & pinch strength 4) Complications 5) Joint imaging (SMD)	5) Pain intensity (PRWHE) decreased significantly for both types of surgery at T2 (Weilby: -17 points vs. Burton-Pellegrini: -18 points (score range 0-50)). DASH: significant improvements for both types of surgery (Weilby: -16 points vs. Burton-Pellegrini: -20 points (score range 0-100)). 6) No differences between different types of surgery, except in CMC extension (decrease in Burton-Pellegrini group) 7) Increase in grip strength for both types of surgery (Weilby: +3 kg vs. Burton-Pellegrini: +4 kg). Key pinch decreased 0.1 kg for both types of surgery, Tip-pinch increased 0.4 kg for both types of surgery and 3-point pinch increased for both types of surgery (Weilby: +0.3 kg vs. Burton-Pellegrini: +0.5 kg). Statistical testing for group differences was not reported 8) In total, complications were observed in 27,8% of the participants (Weilby: 23,1% vs. Burton-Pellegrini: 32,5%, difference not significant) 9) SMD at T2 during rest in Weilby group decreased with 33%, in Burton-Pellegrini group with 48%, during pinch in Weilby group: 66%, Burton-Pellegrini group: 57%
Yao et al.[17] 2014	10 days: Active ROM exercises	To (preoperative) T1 (11 months)	1) Limitations in ADL (DASH)	1) DASH at To: 63, at T1: 10 (single case)

Table 5 *(continued)*

Studies initiating strengthening exercises ≤4 weeks	Description of strengthening exercises initiated ≤4 weeks	Measures at	Measurements & instruments	Outcomes
Poole et al.[56] 2011	Hand therapy group, 4 weeks: strength exercises	To (pre-op) and T1 (6 months postoperatively).	1) Pain intensity (Boston Questionnaire) 2) Limitations in ADL, (JHFT, AHFT) 3) Grip & pinch strength	1) Improvements in pain intensity in both groups, although no significant within group differences due to small sample size. No significant differences between groups, although a larger decrease in symptom severity was found in the hand therapy group (ES = 0.53) 2) Higher improvements in limitations in ADL in the hand therapy group for both the JHFT (ES = 0.52) as the AHFT (ES = 0.33), although not significant due to sample size. 3) Improvements in grip (+13%) & 3-point pinch strength (+27%) were only found in the hand therapy group, while grip (-8%) & 3-point pinch strength (-6%) decreased in the home program group (ES grip strength = 0.77, ES 3-point pinch = 0.95).
Soejima et al.[33] 2006	2 weeks: strength exercises	To (preoperative) T1 (33 months, range 12-71 months)	1) Pain intensity (self designed) 2) ROM 3) Grip & pinch strength 4) Joint imaging (SMD)	1) At T1, 61% had no pain, 24% had mild pain with strenuous activities and 14% had mild pain with light work 2) ROM radial and palmar abduction increased with 14° (p=0.09) and 8° (p=0.07) degrees respectively 3) Grip and the pinch strength increased with 2 kg (p=0.18) and from 1.3 kg (p=0.23), respectively 4) SMD decreased with 15% (p<0.05)
Vermeulen et al.[20] 2014	4 weeks: standardized hand therapy focused on regaining functionality by increasing strength	To (preoperative) T1 (3 months) T2 (12 months)	1) Pain intensity and limitations in ADL (PRWHE, DASH) 2) ROM 3) Grip & pinch strength 4) Complications	1) Pain intensity (PRWHE) decreased significantly for both types of surgery at T2 (Weilby: -17 points vs. Burton-Pellegrini: -18 points (score range 0-50)). DASH: significant improvements for both types of surgery (Weilby: -16 points vs. Burton-Pellegrini: -20 points (score range 0-100)). 2) No differences between different types of surgery, except in CMC extension (decrease in Burton-Pellegrini group) 3) Increase in grip strength for both types of surgery (Weilby: +3 kg vs. Burton-Pellegrini: +4 kg). Key

				pinch decreased 0.1 kg for both types of surgery, Tip-pinch increased 0.4 kg for both types of surgery and 3-point pinch increased for both types of surgery (Weilby: +0.3 kg vs. Burton-Pellegrini: +0.5 kg). Statistical testing for group differences was not reported 4) In total, complications were observed in 27,8% of the participants (Weilby: 23,1% vs. Burton-Pellegrini: 32,5%, difference not significant)
J. Yao et al.[17] 2014	18 days: isometric exercises lateral pinch strength exercises	To (preoperative) T1 (11 months)	1) Limitations in ADL (DASH)	1) DASH at To: 63, at T1: 10 (single case)

Note: VAS = Visual Analogue Scale, ROM = Range of Motion, ES = Effect Size (positive scores indicate better performance of experimental treatment compared to control treatment), MCP-1 = First Metacarpophalangeal joint, ADL = Activities of Daily Life, PRWHE = Patiënt Rated Wrist & Hand Evaluation, MHQ = Michigan Hand outcomes Questionnaire, DASH = Disabilities of Arm, Shoulder and Hand, AIMS2 = Arthritis Impact Measurement Scales 2, JHFT = Jebsen Hand Function Test, AHFT = Arthritis Hand Function Test, IP = Interphalangeal joint, SMD = distance between base of first metacarpal and distal end of scaphoid, TMD = distance between base of first metacarpal and radial border of trapezoid

Table 6. *Summary of the phases and content of postoperative rehabilitation following thumb base arthroplasty as used in the literature. The displayed time frames indicate the range from start to end (minimum – maximum period) of the used period in the literature.*

Phase	Weeks postoperative	Physical therapy content
1. 'Acute'	Range: 0 – 6 weeks postoperatively	Composite finger flexion/extension, thumb IP-1 flexion/extension, wrist/elbow/shoulder movement is emphasized and no CMC or MCP-1 movement is encouraged
2. 'Unloaded'	Range: 1 – 12 weeks postoperatively	ROM-exercises for MCP-1 and CMC are initiated. In general, emphasis is placed on MCP-1 flexion and CMC palmar abduction and extension, while CMC flexion, adduction and opposition is avoided. The exercises are supplemented with scar management and edema control
3. 'Functional'	Range: 3 weeks – 6 months postoperatively	Progressive ROM of the CMC and MCP-1 is allowed and strength exercises are initiated.

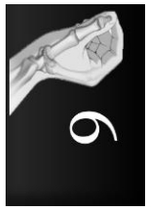
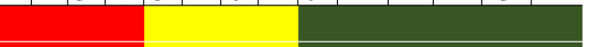
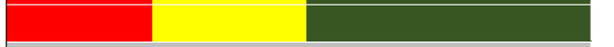
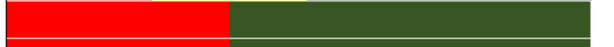
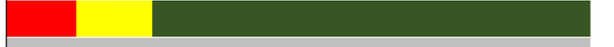
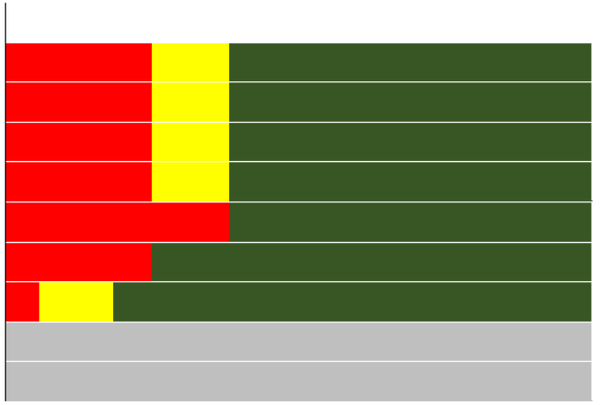


Table 7: *An overview of the phases on postoperative exercises/therapy per week for the individual studies.*

YEAR	AUTHOR	N	TYPE SURGERY / TENDON PLASTY	WEEK
1985	Eaton et al.[36]	25	***FCR***	
1986	Burton et al.[24]	25	***FCR***	
1993	Nylen et al.[43]	102	***FCR***	
1996	Lins et al.[40]	30	***FCR***	
2000	Varitimidis et al.[42]	62	***FCR***	
2001	Roberts et al.[30]	25	***FCR***	
2002	Saehle et al.[32]	55	***APL***	
2002	Horlock et al.[25]	40		
	Late group	*20*	***Simple Trapeziectomy***	
	Early group	*20*	***Simple Trapeziectomy***	
2003	Kuhns et al.[39]	26	***Simple Trapeziectomy***	
2004	Mo et al.[27]	14	***FCR***	
2004	Kriegs-Au et al.[21]	52	***FCR***	
2004	Davis et al.[37]	62	***FCR***	
		59	***PL***	
		62	***Simple Trapeziectomy***	
2006	Soejima et al.[33]	21	***APL***	
2007	Sirotakova et al.[41]	104	***APL***	
2009	Vermeulen et al.[19]	20	***FCR***	
2009	Wong et al.[18]	22	***FCR + PL***	
2011	Rocchi et al.[31]	50	***APL***	
2011	Poole et al.[28]	9		
	Home program group	*5*	***PL***	
	Occupational therapy group	*4*	***PL***	
2012	Ataker et al.[38]	27	***FCR***	
2012	Başar et al.[22]	19	***FCR***	
2012	Abbas et al. [23]	10	***FCR + PL***	
				

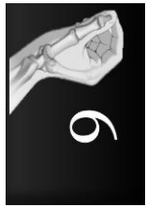
2014	Prosser et al.[29]	53		
	Rigid group	*27*	***FCR***	
	*Semi-rigid group**	*26*	***FCR***	
	Rigid group	*1*	***Simple Trapeziectomy***	
	*Semi-rigid group**	*2*	***Simple Trapeziectomy***	
2014	Yang et al.[35]	21	***FCR***	
2014	Vermeulen et al.[20]	72	***FCR***	
2014	Yao et al.[17]	1	***Tightrope***	
2015	Lee et al.[26]	19	***APL***	
2016	Werthel et al.[34]	49	*FCR*	



Note: FCR = Flexor Carpi Radialis, APL = Abductor Pollicis Longus, PL = Palmaris Longus
Abbreviations: IP-1 = thumb interphalangeal joint

Legend Table 7

Acute phase	=	
Unloaded phase	=	
Functional phase	=	
Content unknown	=	



Discussion

The aim of this systematic review was to describe the different components of postoperative rehabilitation protocols for patients who underwent CMC arthroplasty and several components of rehabilitation protocols were specifically investigated. Twenty-seven studies were included with a total of 1015 participants in whom 1118 procedures were performed. This systematic review presents a summary of the used postoperative rehabilitation for different surgical interventions. We found positive outcomes of partial instead of complete immobilization until 6 weeks, a total immobilization period 4-6 or ≤4 weeks and the initiation of ROM or strengthening exercises ≤4 weeks, but too few comparative studies are available in order to draw firm conclusions on relative effectiveness. Additionally, we identified three phases on postoperative exercises/therapy as used in the included studies: the 'acute phase', the 'unloaded phase' and the 'functional phase' (Table 6-7).

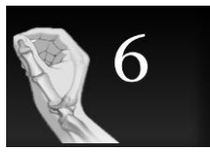
In general in this review, postoperative exercises/therapy emphasizes on positioning the CMC in extension and abduction, while flexion and adduction is avoided during rehabilitation.[44,45] Furthermore, MCP-1 hyperextension should be avoided while MCP-1 flexion is encouraged to prevent the development of a z-deformity.[44] Despite the fact that no conclusions regarding effectiveness can be drawn, the presented summary for different surgical interventions and the identification of the aforementioned phases may provide guidance in clinical decision making for hand therapists and surgeons in the postoperative rehabilitation for patients who underwent CMC arthroplasty. However, there is considerable variation in time frames of the individual phases, possibly since the phases are carried out more quickly over the years in literature (Table 7). Hence, further exploration of these phases is needed in future research. Furthermore, these phases should be identified for different surgical procedures specifically.

Wolfe et al. concluded that there was too much variation in the literature in order to formulate recommendations on postoperative immobilization and exercises.[9] In the present systematic review, we also conclude that there are insufficient comparative studies to draw conclusions regarding the effectiveness of postoperative rehabilitation. However, we do present a more extensive overview of the postoperative rehabilitation as used in the literature compared to the results by Wolfe et al.[9] All the nineteen studies included by Wolfe et al.[9] were identified in the literature search of the present study, but only four were included in the present review. For example, Wolfe et al. also included several types of joint prostheses while we excluded joint prostheses. The inclusion of other studies than included by Wolfe et al. may have resulted in a

different representation of postoperative rehabilitation for patients who underwent CMC arthroplasty.

Two comparative studies[25,29] on postoperative immobilization were included in this review (Table 4). Similar or better outcomes were found when partial instead of complete immobilization was used in the first six weeks postoperatively. Horlock et al., where partial instead of complete immobilization was used following simple trapeziectomy, found an effect size of -0.66 on pain intensity, indicating worse outcomes in the early mobilization group. However, the difference was not statistically significant and mostly due to a mean difference at baseline between both groups. Furthermore, Visual Analogue Scale score for pain intensity at follow-up were comparable with previously reported outcomes following simple trapeziectomy.[8] Therefore, the effect size of -0.66 on pain intensity should be interpreted with caution.

On MCP-1 flexion and experienced convenience by the participants, the early mobilization group performed significantly better than the late mobilization group with effect sizes 0.19 and 0.66 respectively, indicating small to large treatment effects.[16] Hence, these studies suggest that partial instead of complete immobilization demonstrates good outcomes but more randomized controlled trials on postoperative immobilization are needed to confirm this.



The study by Poole et al.[28] was the sole study that compared rehabilitation including a home program only with a more extensive rehabilitation program including hand therapy following CMC arthroplasty. No significant between-group differences were found postoperatively, probably due to a small sample size (n=9) although more within-group improvements were found on pain intensity, limitations in ADL and grip & pinch strength in the group that received hand therapy with effect sizes between 0.33 and 0.95, indicating small to large treatment effects.[16] For example, improvements were found in postoperative grip strength (+13%) & pinch strength (+27%) in the hand therapy group, while a decrease in grip strength (-8%) and pinch strength (-6%) was found in the group that did not receive hand therapy. These findings suggest that additional hand therapy is beneficial in reducing pain intensity and limitations in ADL and improving grip & pinch strength after CMC arthroplasty, but randomized controlled trials with larger sample sizes are needed.

Several studies investigated the concept of 'early active recovery', which includes short immobilization and allows patients to exercise in an early postoperative phase.[25,28,29] A trend is identifiable indicating that early active recovery (including short immobilization, early initiation of ROM and strength exercises) provides positive outcomes on pain, limitations in ADL and grip & pinch strength, but no conclusions on effectiveness can be drawn since comparative studies are lacking. Additionally, Table 7 indicates a trend that, over the years, early active rehabilitation

is applied more often in literature. This accelerated type of rehabilitation does not lead to worse outcomes or more complications. Faster recovery may result in faster return to work, which could be beneficial for patients with CMC OA considering the fact that ageing populations need to participate longer in working life. Hence, future high quality studies are needed in order to determine the effectiveness of early active recovery.

Historically, determining of postoperative scaphometacarpal distance (SMD) by joint imaging has been a particular outcome of interest in many studies on CMC arthroplasty, since the hypothesis is that maintenance of SMD after surgery results in better function and less pain.[8] The sole comparative study on evaluating SMD was by Horlock et al.[25], in which no difference in SMD was found between the early and late mobilization group. Additionally, Wajon et al.[8] reported that there is no clinically relevant correlation between SMD and pinch strength and all of the studies included in the present review did not find a correlation between SMD and clinical outcomes. Therefore, the influence of different types of postoperative rehabilitation on SMD and the predictive value of SMD on clinical outcomes remains unclear and should be addressed in future research.

Study limitations

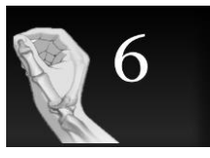
A weakness of this systematic review is the large amount of low quality studies included (Supplementary Table 2, Appendix 2). Despite that findings of the individual studies are in line with each other, no conclusions on effectiveness of postoperative rehabilitation following CMC arthroplasty can be drawn since comparative studies are lacking and large heterogeneity in outcome measures and measurement instruments is present. Therefore, we recommend, predominantly in line with Vermeulen et al.[7] and Wajon et al.[8] that future studies report homogenous outcome measures, preferably measured with validated measurement instruments. Additionally, confounding may be present regarding the fulfillment of the different components of rehabilitation. The outcomes of studies without group comparisons are based on an interaction between type of surgery, immobilization type, immobilization period and postoperative exercises/therapy. Hence, no conclusions can be drawn on the specific effects of one of the aforementioned components of treatment. Therefore, future research should explore different postoperative regimes within the same surgical procedure, which allows researchers to study the effectiveness of specific rehabilitation protocols for individual surgical techniques.

Another limitation is that many studies regarding CMC arthroplasty provide very little or no information on postoperative rehabilitation.[6,8] This may have resulted in a biased reflection of the actual postoperative regime for CMC arthroplasty.

Therefore, it is strictly recommended that future studies on CMC arthroplasty provide an adequate description of the postoperative regime, including an adequate description of postoperative immobilization and postoperative exercises/therapy.

Conclusions

In conclusion, this review presents an overview of postoperative rehabilitation for different surgical interventions on CMC OA. Furthermore, three postoperative phases were identified with regard to postoperative exercises/therapy: the 'acute phase', the 'unloaded phase' and the 'functional phase'. In addition, we found that early active recovery (including short immobilization, early initiation of ROM and strength exercises) provides positive outcomes for patients who underwent CMC arthroplasty and is used more often in literature, but more high quality studies comparing different postoperative rehabilitation protocols are needed to get more insight in the effectiveness of postoperative rehabilitation. Additionally, it is strongly recommended that future studies regarding CMC arthroplasty provide adequate descriptions of their postoperative regime.



References

1. Bijlsma JWJ, Berenbaum F, Lafeber FPJG. Osteoarthritis: An update with relevance for clinical practice. The Lancet. 2011;377(9783):2115-2126.

2. Dahaghin S, Bierma-Zeinstra SMA, Ginai AZ, Pols HAP, Hazes JMW, Koes BW. Prevalence and pattern of radiographic hand osteoarthritis and association with pain and disability (the Rotterdam study). Ann Rheum Dis. 2005;64(5):682-687.

3. Haugen IK, Englund M, Aliabadi P, et al. Prevalence, incidence and progression of hand osteoarthritis in the general population: the Framingham Osteoarthritis Study. Ann Rheum Dis. 2011;70(9):1581-1586.

4. Centraal Bureau voor Statistiek. Vol http://www.cbs.nl2013.

5. Zhang Y, Niu J, Kelly-Hayes M, Chaisson CE, Aliabadi P, Felson DT. Prevalence of symptomatic hand osteoarthritis and its impact on functional status among the elderly: The framingham study. Am J Epidemiol. 2002;156(11):1021-1027.

6. Handchirurgie NVv. Richtlijn Conservatieve en Chirurgische Behandeling van Primaire Artrose van de Duimbasis. 2014.

7. Vermeulen G, Slijper H, Feitz R, Hovius SER, Moojen T, Selles R. Surgical management of primary thumb carpometacarpal osteoarthritis: a systematic review. The Journal of hand surgery. 2011;36(1):157-169.

8. Wajon A, Vinycomb T, Carr E, Edmunds I, Ada L. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. Cochrane Database Syst Rev. 2015;2:Cd004631.

9. Wolfe T, Chu JY, Woods T, Lubahn JD. A systematic review of postoperative hand therapy management of basal joint arthritis. Clin Orthop Relat Res. 2014;472(4):1190-1197.

10. Ireton JE, Unger JG, Rohrich RJ. The role of wound healing and its everyday application in plastic surgery: a practical perspective and systematic review. Plast Reconstr Surg Glob Open. 2013;1(1).

11. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol. 2009;62(10):1006-1012.

12. Thomas H. Quality assessment tool for quantitative studies. Effective public health practice project. Toronto: McMaster University. 2003.

13. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. Phys Ther. 2003;83(8):713-721.

14. Landis JR, Koch GG. An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. Biometrics. 1977;33(2):363-374.

15. Morris SB. Estimating Effect Sizes From Pretest-Posttest-Control Group Designs. Organizational Research Methods. 2008;11(2):364-386.

16. Cohen J. Statistical power analysis for the behavioral sciences. Hillsdale, N.J.: L. Erlbaum Associates; 1988.

17. Yao J, Lashgari D. Thumb basal joint: Utilizing new technology for the treatment of a common problem. J Hand Ther. 2014;27(2):127-132; quiz 133.

18. Wong TC, Ip FK. A modified technique of interpositional arthroplasty in treating the Basal joint arthritis of the thumb in a Chinese population. Hand surgery : an international journal devoted to hand and upper limb surgery and related research : journal of the Asia-Pacific Federation of Societies for Surgery of the Hand. 2009;14(2-3):83-87.

19. Vermeulen GM, Brink SM, Sluiter J, Elias SG, Hovius SE, Moojen TM. Ligament reconstruction arthroplasty for primary thumb carpometacarpal osteoarthritis (weilby technique): prospective cohort study. J Hand Surg Am. 2009;34(8):1393-1401.

20. Vermeulen GM, Spekreijse KR, Slijper H, Feitz R, Hovius SER, Selles RW. Comparison of arthroplasties with or without bone tunnel creation for thumb basal joint arthritis: A randomized controlled trial. J Hand Surg Am. 2014;39(9):1692-1698.

21. Kriegs-Au G, Petje G, Fojtl E, Ganger R, Zachs I. Ligament reconstruction with or without tendon interposition to treat primary thumb carpometacarpal osteoarthritis. A prospective randomized study. J Bone Joint Surg Am. 2004;86-a(2):209-218.

22. Başar H, Başar B, Erol B, Tetik C. Ligament reconstruction and tendon interposition arthroplasty of the trapeziometacarpal joint with the use of the full

thickness of the flexor carpi radialis tendon. Chirurgie de la Main. 2012;31(6):331-336.

23. Abbas K, Hashmi P, Raza H. Short term results of ligament reconstruction and tendon interposition resection arthroplasty for basal joint arthritis. J Pak Med Assoc. 2012;62(4):398-401.

24. Burton RI, Pellegrini VD, Jr. Surgical management of basal joint arthritis of the thumb. Part II. Ligament reconstruction with tendon interposition arthroplasty. J Hand Surg Am. 1986;11(3):324-332.

25. Horlock N, Belcher HJ. Early versus late mobilisation after simple excision of the trapezium. J Bone Joint Surg Br. 2002;84(8):1111-1115.

26. Lee HJ, Kim PT, Deslivia MF, Jeon IH, Lee SJ, Nam SJ. Results of abductor pollicis longus suspension ligamentoplasty for treatment of advanced first carpometacarpal arthritis. CiOS Clinics in Orthopedic Surgery. 2015;7(3):372-376.

27. Mo JH, Gelberman RH. Ligament reconstruction with trapezium retention arthroplasty for carpometacarpal arthritis. J Hand Surg Am. 2004;29(2):240-246.

28. Poole JL, Walenta MH, Alonzo V, Coe A, Moneim M. A Pilot Study Comparing of Two Therapy Regimens Following Carpometacarpal Joint Arthroplasty. Physical & Occupational Therapy in Geriatrics. 2011;29(4):327-336.

29. Prosser R, Hancock MJ, Nicholson L, Merry C, Thorley F, Wheen D. Rigid versus semi-rigid orthotic use following TMC arthroplasty: a randomized controlled trial. J Hand Ther. 2014;27(4):265-270; quiz 271.

30. Roberts RA, Jabaley ME, Nick TG. Results following trapeziometacarpal arthroplasty of the thumb. J Hand Ther. 2001;14(3):202-207.

31. Rocchi L, Merolli A, Cotroneo C, Morini A, Brunelli F, Catalano F. Abductor pollicis longus hemitendon looping around the first intermetacarpal ligament as interposition following trapeziectomy: a one-year follow-up study. Orthop Traumatol Surg Res. 2011;97(7):726-733.

32. Saehle T, Sande S, Finsen V. Abductor pollicis longus tendon interposition for arthrosis in the first carpometacarpal joint: 55 thumbs reviewed after 3 (1-5) years. Acta Orthop Scand. 2002;73(6):674-677.

33. Soejima O, Hanamura T, Kikuta T, Iida H, Naito M. Suspensionplasty with the abductor pollicis longus tendon for osteoarthritis in the carpometacarpal joint of the thumb. J Hand Surg Am. 2006;31(3):425-428.

34. Werthel JD, Dubert T. Use of the entire flexor carpi radialis tendon for basal thumb ligament reconstruction interposition arthroplasty. Hand Surgery and Rehabilitation. 2016;35(2):107-113.

35. Yang Y, Tien HY, Kumar KK, et al. Ligament reconstruction with tendon interposition arthroplasty for first carpometacarpal joint osteoarthritis. Chinese Medical Journal. 2014;127(22):3921-3925.

36. Eaton RG, Glickel SZ, Littler JW. Tendon interposition arthroplasty for degenerative arthritis of the trapeziometacarpal joint of the thumb. J Hand Surg Am. 1985;10(5):645-654.

37. Davis TRC, Brady O, Dias JJ. Excision of the trapezium for osteoarthritis of the trapeziometacarpal joint: A study of the benefit of ligament reconstruction or tendon interposition. Journal of Hand Surgery. 2004;29(6):1069-1077.

38. Ataker Y, Gudemez E, Ece SC, Canbulat N, Gulgonen A. Rehabilitation protocol after suspension arthroplasty of thumb carpometacarpal joint osteoarthritis. J Hand Ther. 2012;25(4):374-382; quiz 383.

39. Kuhns CA, Emerson ET, Meals RA. Hematoma and distraction arthroplasty for thumb basal joint osteoarthritis: a prospective, single-surgeon study including outcomes measures. J Hand Surg Am. 2003;28(3):381-389.

40. Lins RE, Gelberman RH, McKeown L, Katz JN, Kadiyala RK. Basal joint arthritis: trapeziectomy with ligament reconstruction and tendon interposition arthroplasty. J Hand Surg Am. 1996;21(2):202-209.

41. Sirotakova M, Figus A, Elliot D. A new abductor pollicis longus suspension arthroplasty. J Hand Surg Am. 2007;32(1):12-22.

42. Varitimidis SE, Fox RJ, King JA, Taras J, Sotereanos DG. Trapeziometacarpal arthroplasty using the entire flexor carpi radialis tendon. Clin Orthop Relat Res. 2000(370):164-170.

43. Nylen S, Johnson A, Rosenquist AM. Trapeziectomy and ligament reconstruction for osteoarthrosis of the base of the thumb. A prospective study of 100 operations. J Hand Surg Br. 1993;18(5):616-619.

44. Neumann DBT. The carpometacarpal joint of the thumb: stability, deformity, and therapeutic intervention. The Journal of orthopaedic and sports physical therapy. 2003;33(7):386-399.

45. Valdes K, Von Der Heyde R. An exercise program for carpometacarpal osteoarthritis based on biomechanical principles. J Hand Ther. 2012;25(3):251-262.

Appendix

Final search strings:

Pubmed (MEDLINE) → 227 hits
(((CMC OR carpometacarp* OR (“basal joint”) OR (“basilar joint”) OR basal OR basilar OR thumb OR (“thumb base”) OR (“Carpometacarpal Joints”) OR trapez* OR trapeziometacarp*) AND (arthroplasty OR "Arthroplasty"[Mesh] OR hemiarthroplasty OR suspen* OR (ligament AND reconstruction) OR (tendon AND interposition) OR stabilization OR prosth* OR arthrodesis OR implant) OR "Trapezium Bone/surgery"[Mesh] OR "Carpometacarpal Joints/surgery"[Mesh] OR Weilby[tiab] OR Burton[tiab] OR “Burton Pellegrini”[tiab] OR LRTI OR (Ligament AND reconstruction AND tendon AND Interposition) OR “Ligament reconstruction tendon Interposition” OR Trapeziectomy OR Sardella OR pyrodisk OR “Pyrocarbon interposition” OR (Eaton AND (littler OR Glickel)))) AND ("Rehabilitation"[Mesh] OR “Physical and Rehabilitation Medicine”[Mesh] OR physioth* OR kinesiotherap* OR "Postoperative Care/rehabilitation"[Mesh] OR "Osteoarthritis/rehabilitation"[Mesh] OR "Physical Therapy Modalities"[Mesh] OR “hand therapy” OR "Occupational therapy"[Mesh] OR "Therapeutics/therapy"[Mesh])*

Cinahl → 58 hits
((CMC* OR carpometacarp*l OR (“basal joint”) OR (“basilar joint”) OR basal OR basilar OR thumb OR (“thumb base”) OR (“Carpometacarpal Joints”) OR trapez* OR trapeziometacarp*) AND ((MM "Arthroplasty+")OR hemiarthroplasty OR suspen* OR (ligament AND reconstruction) OR (TI weilby) OR (AB weilby) OR (TI Burton) OR (AB Burton) OR (tendon AND interposition) OR stabilization OR prosth* OR arthrodesis OR implant) OR LRTI OR (Ligament AND reconstruction AND tendon AND Interposition) OR “Ligament reconstruction tendon Interposition” OR Trapeziectomy OR Sardella OR pyrodisk OR “Pyrocarbon interposition” OR (Eaton AND (littler OR Glickel))) AND ((MM "Arthroplasty+/RH") OR (MM "Rehabilitation+") OR (MM "Postoperative Care+/RH") OR (MM "Osteoarthritis+/RH") OR (MM "Physical Therapy+") OR (MM "Hand Therapy") OR (MM "Occupational Therapy+"))

Embase → 1075 hits
(('carpometacarpal joint'/exp OR carpometacarp* OR CMC* OR ‘basal joint’ OR ‘basilar joint’ OR basal OR basilar OR thumb OR ‘thumb base’ OR trapez* OR (“carpometacarpal joint”) OR trapeziometacarp*) AND ('arthroplasty'/exp OR hemiarthroplasty OR suspen* OR (ligament AND reconstruction) OR (tendon AND interposition) OR stabilization OR prosth* OR arthrodesis OR implant OR Weilby:ab,ti OR Burton:ab,ti OR “Burton Pellegrini”:ab,ti OR LRTI OR (Ligament AND reconstruction AND tendon AND Interposition) OR ‘Ligament reconstruction tendon Interposition’ OR Trapeziectomy OR Sardella OR pyrodisk OR ‘Pyrocarbon interposition’ OR (Eaton AND (littler OR Glickel)))) AND ('physiotherapy'/exp OR 'postoperative care'/exp OR ‘Hand therapy’ OR 'occupational therapy'/exp OR

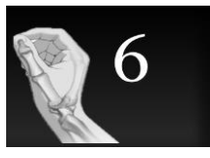
rehabilita*)

Cochrane → 37 hits

#1: (CMC* or carpometacarp*l or ("basal joint") or ("basilar joint") or basilar or basal or (“carpometacarpal joint”) or thumb or ("thumb base") or trapez* or trapeziometacarp*)
#2: (arthroplasty or suspen* or (ligament and reconstruction) or (tendon and interposition) or stabilization or prosth* or arthrodesis or hemiarthroplasty or implant or Weilby:ti,ab or Burton:ti,ab or "Burton Pellegrini":ti,ab or LRTI or (Ligament and reconstruction and tendon and Interposition) or "Ligament reconstruction tendon Interposition" or Trapeziectomy or Sardella or pyrodisk or "Pyrocarbon interposition" or (Eaton and (littler or Glickel)))
#3: “hand therapy”
#4: MeSH descriptor: [Physical Therapy Modalities] explode all trees
#5: MeSH descriptor: [Rehabilitation] explode all trees
#6: MeSH descriptor: [Postoperative Care] explode all trees
#7: MeSH descriptor: [Occupational Therapy] explode all trees
#8: #1 and #2 and (#3 or #4 or #5 or #6 or #7)
Total: **1397**

Supplementary Table 1. *Types of surgical co-interventions performed in the included studies.*

Surgical co-intervention	**N**	**Reference(s)**
Carpal tunnel release	76	[37-42]
MCP-1 stabilization	22	[36-39]
Temporary Kirschner-wire fixation for MCP-1	22	[37,43]
MCP-1 arthrodesis	13	[37,42,43]
Trigger finger release	12	[37-39,42]
Quervain's release	6	[37,38]
Advancement or plication of a somewhat lax APL tendon	6	[36]
Trigger thumb release	5	[37]
Unknown procedure	4	[43]
IP-1 arthrodesis	3	[40,42]
Ganglion excision	1	[39]
Lipoma excision	1	[39]
Total	171	

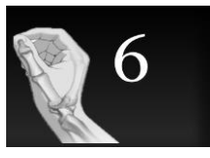


Supplementary Table 2. *Methodological quality (risk of bias), scored using the EPHPP, supplemented with the PEDro scale in randomized studies*

Author, year	A: Selection Bias	B: Study design	C: Confounders	D: Blinding	E: Data collection methods	F: Withdrawal and dropouts	Global Rating	PEDro
Abbas et al.[23] 2012	Moderate	Moderate	Weak	Moderate	Strong	Weak	Weak	N/A
Ataker et al.[38] 2012	Moderate-strong	Moderate	Weak	Moderate	Strong	Weak	Weak	N/A
Başar et al.[22] 2012	Moderate	Moderate	Weak	Moderate	Moderate	Weak	Weak	N/A
Burton et al.[24] 1986	Moderate	Moderate	Weak	Moderate	Weak	Weak	Weak	N/A
Davis et al.[37] 2004	Moderate	Strong	Strong	Moderate	Weak	Strong	Moderate	8/10
Eaton et al.[36] 1985	Weak	Moderate	Weak	Moderate	Weak	Weak	Weak	N/A
Horlock et al.[25] 2002	Weak	Strong	Weak	Moderate	Strong	Weak	Weak	4/10
Kriegs-Au et al.[21] 2004	Moderate	Strong	Strong	Moderate	Moderate	Weak	Moderate	4/10
Kuhns et al.[39] 2003	Moderate	Moderate	Weak	Moderate	Moderate	Weak	Weak	N/A
Lee et al.[26] 2015	Moderate	Moderate	Weak	Moderate	Strong	Weak	Weak	N/A

Lins et al.[40] 1996	Moderate	Moderate	Weak	Moderate	Weak	Moderate	Weak	N/A
Mo et al.[27] 2004	Moderate	Moderate	Weak	Moderate	Strong	Weak	Weak	N/A
Nylen et al.[43] 1993	Moderate	Moderate	Moderate-Weak	Moderate	Weak	Strong	Weak	N/A
Poole et al.[28] 2011	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong	7/10
Prosser et al.[29] 2014	Strong	Strong	Strong	Moderate	Strong	Strong	Strong	8/10
Roberts et al.[30] 2001	Weak	Moderate	Weak	Moderate	Weak	Weak	Weak	N/A
Rocchi et al.[31] 2011	Weak	Moderate	Weak	Moderate	Moderate	Strong	Weak	N/A
Saehle et al.[32] 2002	Moderate	Moderate	Weak	Moderate	Strong	Weak	Weak	N/A
Sirotakova et al.[41] 2007	Moderate	Moderate	Weak	Weak	Weak	Weak	Weak	N/A
Soejima et al.[33] 2006	Moderate	Moderate	Weak	Moderate	Weak	Weak	Weak	N/A
Varitimidis et al.[42] 2000	Moderate	Moderate	Weak	Moderate	Moderate	Weak	Weak	N/A
Vermeulen et al.[19] 2009	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong	9/10
Vermeulen et al.[20] 2014	Moderate	Moderate	Weak	Moderate	Moderate	Weak	Weak	N/A
Werthel et al.[34] 2016	Moderate-Strong	Moderate	Weak	Moderate	Moderate	Strong	Moderate	N/A

Wong et al.[18] 2009	Moderate	Moderate	Weak	Moderate-Weak	Moderate	Moderate	Moderate	N/A
Yang et al.[19,20,28,35,39,40,42,43] 2014	Moderate	Moderate	Weak	Moderate	Strong	Strong	Moderate	N/A
J. Yao et al.[17] 2014	Weak	Weak	Weak	Moderate	Strong	Strong	Weak	N/A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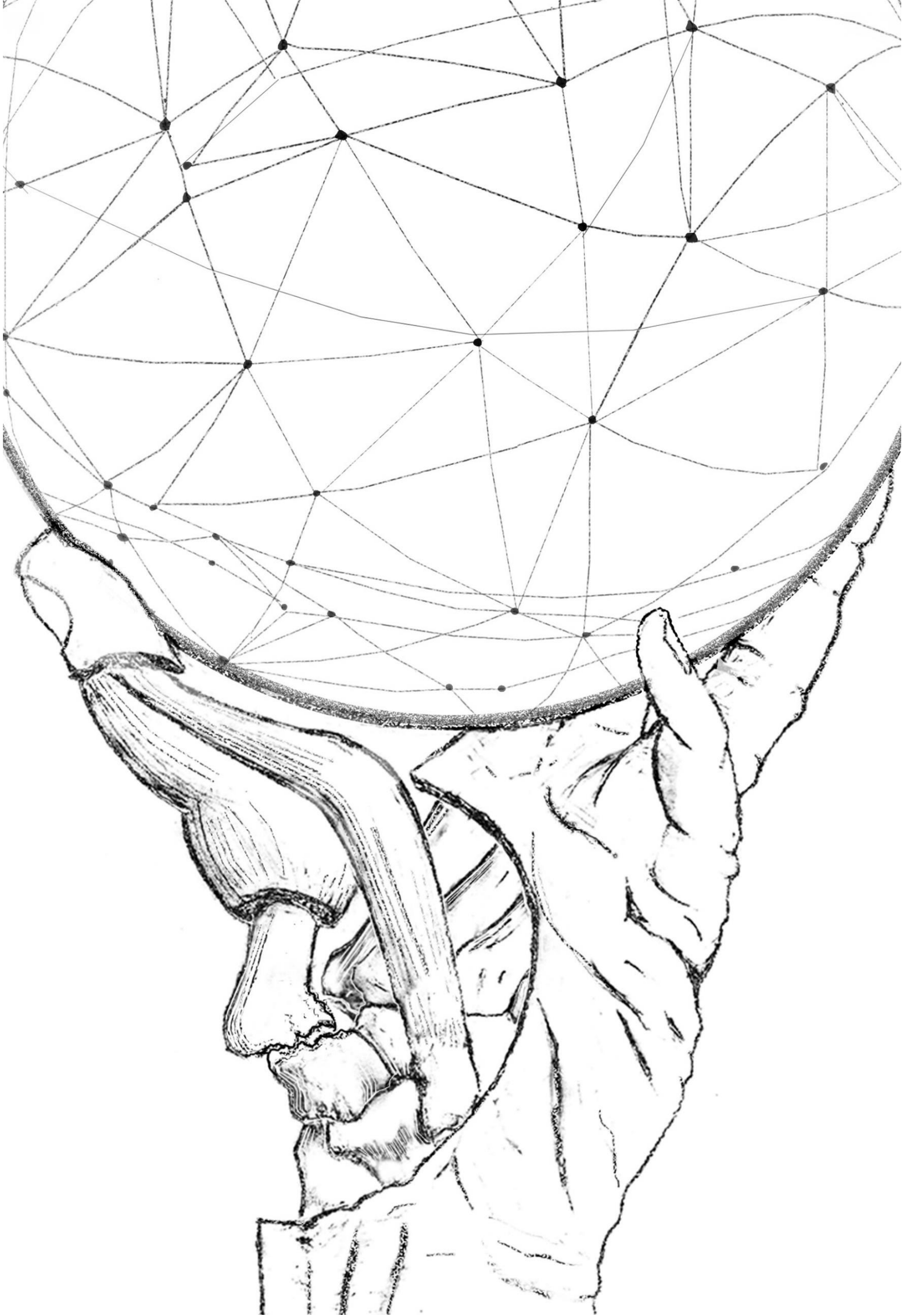


SHORTER VERSUS LONGER IMMOBILIZATION AFTER SURGERY FOR THUMB CARPOMETACARPAL OSTEOARTHRITIS: A PROPENSITY SCORE MATCHED STUDY

Tsehaie J
Wouters RM
Feitz R
Slijper HP
Hovius SER
Selles RW
The Hand-Wrist Study Group

Arch Phys Med Rehabil. 2019 Apr 23.
Pii: S0003-9993(19)30259-X.
Doi: 10.1016/j.apmr.2019.02.016. [Epub ahead of print]

7

Abstract

Objective: To investigate if shorter immobilization is non-inferior to longer immobilization after Weilby procedure for thumb carpometacarpal osteoarthritis

Methods: In this prospective cohort study, shorter immobilization (3-5 days plaster cast followed by a thumb spica orthosis including wrist until 4 weeks postoperatively) was compared with longer immobilization (10-14 days plaster cast followed by a thumb spica orthosis including wrist until 6 weeks postoperatively) after Weilby procedure for CMC osteoarthritis. Propensity Score Matching (PSM) was used to control for confounders. Data collection took place in sixteen outpatient clinics for hand surgery and hand therapy. Outcomes were pain measured with a Visual Analogue Scale (VAS) and hand function measured with the Michigan Hand outcomes Questionnaire (MHQ) at three and twelve months. Secondary outcomes were complications, range of motion, grip and pinch strength, satisfaction with treatment and return to work.

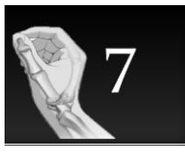
Results: We matched 131 participants with shorter immobilization and 131 participants with longer immobilization. No significant differences were found in VAS pain (effect size 0.03, 95% C.I. -0.21-0.27) or the MHQ (effect size 0.01, 95% C.I. -0.23-0.25) between the groups at three months or at twelve months. Furthermore, no differences were found in complication rate or in other secondary outcomes.

Conclusion: In conclusion, shorter immobilization of 3-5 days of a plaster cast after Weilby procedure is equal compared to longer immobilization for outcomes on pain, hand function and our secondary outcomes. These results indicate that shorter immobilization is safe and can be recommended, since discomfort of longer immobilization may be prevented and patients may be able to recover sooner which may lead to reduced loss of productivity. Future studies need to investigate effectiveness of early active and more progressive hand therapy following CMC arthroplasty.

Introduction

Osteoarthritis (OA) of the thumb base joint (CMC) is a common disorder in the elderly, with a radiologically diagnosed prevalence of 33-40% amongst females aged ≥50 years.[1-3] CMC osteoarthritis can occur in both thumbs, and patients often experience pain, reduced pinch- or grip strength and limitations in activities of daily life (ADL).[1,4] There is an overall weakened hand strength due to muscular atrophy, incorrect thumb position, and by avoiding painful movements or activities.[4] Limitations in activity of daily living usually comprises of pinch movements with the thumb, such as turning a key, opening a jar or gripping a pen.[1,4] When non-operative treatment modalities (i.e. orthosis, hand therapy, steroid injections, analgesics or patient education) fail to provide sufficient pain relieve or functional improvement, CMC arthroplasty may be indicated.[5]

Several studies emphasize the importance of postoperative rehabilitation for patients who underwent CMC arthroplasty to reduce postoperative pain and improve function, limitations in ADL, satisfaction, range of motion (ROM) and grip & pinch strength.[6-8] Recently, we published a systematic review on postoperative rehabilitation following CMC arthroplasty, which indicated, based on very limited evidence, that early active rehabilitation (including shorter immobilization and early initiation of exercises/hand therapy) is increasingly used in literature without worse outcomes or more complications.[7] Theoretically, early active recovery would be beneficial by preventing longer patient discomfort and reducing postoperative complications due to longer immobilization. In addition, a shorter immobilization period allows the patient to return to daily activities more quickly during rehabilitation.



Various time frames on postoperative immobilization after CMC arthroplasty have been reported in literature, with cast immobilization varying from zero to five weeks, while the total immobilization period even varies between two to twelve weeks postoperatively.[7] However, no evidence is available whether a long period of immobilization is necessary and if shorter immobilization will lead to similar results. Therefore, more insight in the effectiveness of shorter immobilization following CMC arthroplasty is needed to ensure that it is safe, does not lead to more complications and has at least similar outcome in terms of pain and hand function.

The aim of this prospective cohort study is to investigate if shorter immobilization is non-inferior to longer immobilization after CMC arthroplasty (Weilby procedure) in terms of hand function and pain intensity postoperatively. Shorter immobilization comprises a 3-5 days plaster cast followed by a thermoplastic thumb spica orthosis immobilization until 4 weeks, while longer immobilization comprises 10-14 days plaster cast followed by a thermoplastic thumb spica orthosis immobilization until 6 weeks.

Methods

Study design

This is a prospective cohort study with propensity score matching (PSM), reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[9] We compared short versus longer immobilization by comparing patients that were treated in two different time periods, in which different postoperative regimes were used and matched the participants using propensity score matching.

This study was performed in sixteen outpatient clinics of a specialized treatment center for hand surgery and hand therapy in The Netherlands and data collection was part of usual care. The Medical Research Ethical Committee of the Erasmus MC Rotterdam approved this study and written informed consent was obtained from all participants. Certified hand surgeons diagnosed patients with CMC OA by physical examination and radiographic evaluation to determine Eaton stage.10 Following the treatment protocol, all the participants received three months of non-operative treatment first, regardless of the disease severity or duration of symptoms.[5] The decision to proceed to surgery was made when patients had insufficient pain relieve or insufficient functional improvement.

Participants

Participants were eligible for inclusion when they were: 1) adult and diagnosed with stage I-IV[10] CMC OA by a certified hand surgeon and 2) underwent a Weilby-sling procedure. Exclusion criteria included: 1) secondary CMC OA (i.e. due Bennett's fracture); 2) occurrence of a co-intervention (i.e. carpal tunnel release); 3) patient history of surgery interfering with treatment or outcome (i.e. due to Bennett's fracture); or 4) steroid injections given within 6 weeks in hand or wrist prior to surgery due to 1) it was not part of the treatment protocol and 2) to keep the studied population as homogenous as possible.

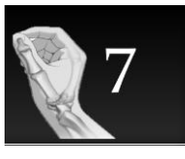
Surgical treatment

The surgical treatment consisted of a Weilby procedure: after a Wagner incision over the radial side of the CMC1 joint and preservation of the radial superficial nerve, the trapezium was fully removed. Subsequently, either a Flexor Carpi Radialis (FCR) or Abductor Pollicis Longus (APL) tendon graft was intertwined in a figure-of-eight-reconstruction between the remaining half of the its own insertion and the APL/FCR insertion. The remaining tendon split was stored in the trapezial cavity.[11,12]

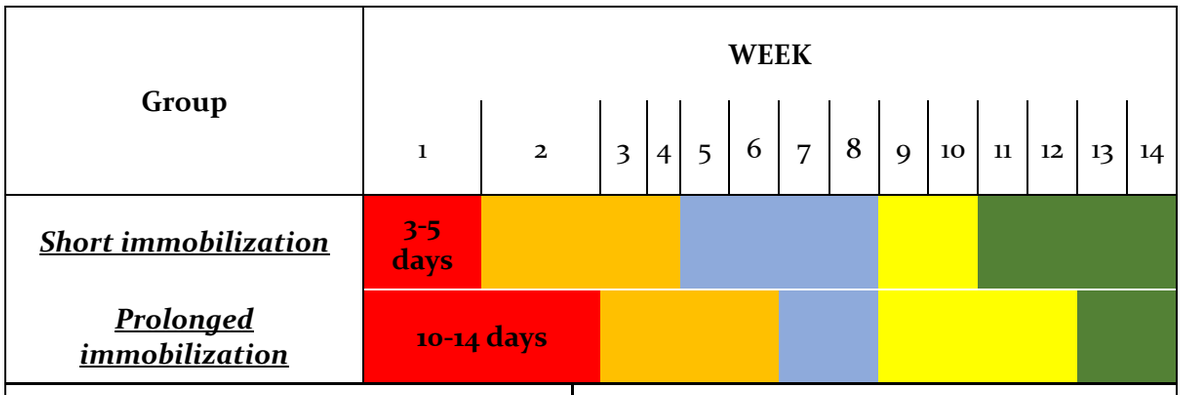
Postoperative treatment

Due to the observational design of this study, the postoperative treatment was not completely standardized such as in most randomized controlled trials. However, the hand therapists of all treatment locations carried out the same, protocolized postoperative regime following strict guidelines developed by Handtherapie Nederland, which is based on the Dutch national guideline and recent literature.[7,13] Naturally, all hand therapists were informed when the new postoperative regime was introduced and compliance was randomly checked internally by auditing patient charts. To further ensure that all therapists had adjusted to the new protocol and did not (partly) used the previous protocol, we created a half year inclusion gap for this study. More specifically, all patients treated between January 2012 and April 2015 were included in the longer immobilization group and all patients treated between October 2015 and April 2017 were included in the shorter immobilization group.

The patients in the longer immobilization group were primarily immobilized in a plaster cast for 10-14 days. After this period, the hand therapist removed the cast and a thermoplastic thumb spica orthosis including wrist immobilization (Supplementary Figure 1) was applied until 6 weeks postoperatively. Patients were instructed to wear the thermoplastic thumb spica orthosis 24 hours/day, except during exercises. Afterwards, a butterfly orthosis (Supplementary Figure 2) was applied 24 hours/day until 8 weeks (except during exercises), which was phased out until 3 months postoperatively.



The patients in the shorter immobilization group were primarily immobilized in a plaster cast for 3-5 days. The hand therapist removed the cast and a thermoplastic thumb spica orthosis including wrist immobilization was applied until 4 weeks postoperatively. Patients were instructed to wear the thermoplastic thumb spica orthosis 24 hours/day, except during exercises. Afterwards, a butterfly orthosis was applied until 8 weeks 24 hours/day, except during exercises, which was phased out until 10 weeks postoperatively. Figure 1 provides a graphic overview of the immobilization periods for both groups.



	Short Immobilization	Prolonged Immobilization
Plaster cast immobilization:	3-5 days	10-14 days
Thumb spica splint incl. wrist immobilization:	Until 4 weeks	Until 6 weeks
Thumb butterfly splint:	Until 8 weeks	Until 8 weeks
Orthosis phased out	Until 10 weeks	Until 3 months
Orthosis completely discontinued	>10 weeks	> 3 months

Figure 1. *Timeline and Legend for postoperative immobilization periods*

The rationale for selecting these orthotic devices was to provide enough protection and stability for these specific postoperative phases, while allowing range of motion exercises when safe and preventing excessive joint stiffness. All orthotic devices were fabricated by experienced and trained hand therapists to assure consistency and quality of application.

In both groups, the hand therapy exercises directly postoperatively (acute phase) included tendon-gliding exercises of the fingers and the thumb interphalangeal joint. After 10-14 days, sutures were removed. Hand therapy and home exercises in the unloaded phase (2-6 weeks) focused on active wrist flexion/extension, CMC palmar and radial abduction and metacarpophalangeal (MCP-1) flexion (with support to the

first metacarpal), along with scar management. In this phase, no flexion/adduction and thumb opposition was allowed. The functional phase included the initiation of static pinch exercises by 6 weeks, after which increased grip & pinch exercises were performed, usually until three months postoperatively.

Primary outcomes

The primary outcomes in this study were hand function, measured with the Michigan Hand outcomes Questionnaire (MHQ) and pain, measured with a Visual Analogue Scale (VAS) at baseline, six weeks, three months and twelve months. The rationale behind measuring pain and function is that the decision to proceed to surgery is usually based on persistent pain and limited hand function and outcomes on these domains are highly relevant for this particular group of patients.[13]

The MHQ (range: 0–100, higher scores indicate better performance except for the subscale pain) is a validated questionnaire with a high internal consistency, high internal validity, acceptable reliability and is particularly applicable for patients with hand OA. The minimal clinical important difference (MCID) for the MHQ is 8-13 (3-23 for the subscales).[14-16] The MHQ subscales were secondary outcomes.

For pain, we measured VAS pain at rest (range: 0-100, higher scores indicate more pain) and VAS pain during physical load. The VAS is a reliable and valid instrument to measure pain intensity in patients with rheumatic diseases and has a minimal detectable change (MDC) of eleven points.[17]

For this article, we decided to report VAS pain and MHQ at three months as primary outcome, since we assumed that three months after surgery is the first relevant moment to experience improvement in pain and function due to the surgery and the different immobilization periods.[5,6] However, outcome in VAS pain at six weeks and twelve months are also reported as well as outcome in MHQ at twelve months, to study both early recovery as well as long-term recovery.

Secondary outcomes

Secondary outcomes were complications, ROM, grip & pinch strength, return to work and an additional satisfaction with treatment questionnaire. Complications of surgery were scored by authors JT & RW by reviewing patient charts. The following events were scored as a complication: tenovaginitis stenosans of the thumb, Quervain tenosynovitis, FCR tendinitis, FCR rupture, carpal tunnel syndrome, complex regional pain syndrome (CRPS), presence of neuroma, infection, clinically and radiologically diagnosed metacarpal abutment with the scaphoid, radial superficial nerve injury or revision surgery.

ROM measurements were performed at baseline and three months using the recommendations of the American Society of Hand Therapists.[18] Grip & key pinch

strength was measured at baseline and three months using the Biometric E-Link© following Mathiowetz et al.[19-21] Return to work and patient satisfaction was assessed at three months using self-designed questionnaires on the patient's ability to work and the experienced treatment effect respectively.

Study size

In non-inferiority studies, a priori power analysis is different from the more commonly used superiority studies. It has been described that defining the non-inferiority margin should be based on clinical judgment and statistical reasoning.[22] We used a conventional small to medium effect size of .35, defined by Cohen et al.[23] as a non-inferiority margin, resulting in a total sample of 204 participants for a power of .80 (α=0.05).

Due to the nature of propensity score matching, a number of participants will not be matched to other participants and will therefore be excluded from the analysis. In a study by Zhou et al. on Dupuytren's disease, propensity score matching was also used and 60% of the total sample was included in the final analysis.[24] To account for this, we decided to enlarge the total sample to >400 participants.

Statistical methods

Usually, comparing groups in observational studies is difficult due to the presence of covariates.[25] propensity score matching involves the use of a propensity score, which is the probability for an individual to be assigned to a particular treatment given a vector of observed covariates.[26,27] propensity score matching allows researchers to compare matched individuals without introducing bias, the only difference being whether the individual is treated with the intervention of interest or not, assuming that all relevant covariates are included in the model estimating the propensity score.[25,27]

The propensity scores were estimated using logistic regression, in which treatment status is regressed on baseline characteristics.[26-28] The following baseline characteristics were used as covariates for estimating the propensity score: age, gender, type of work, duration of symptoms, dominant side treated, the MHQ subscales, VAS pain at rest, VAS pain during physical load, grip strength, key pinch strength, CMC palmar abduction angle, CMC radial abduction angle, MCP-1 flexion angle and MCP-1 extension angle. The propensity scores were subsequently used to match participants on a one-to-one basis using a nearest-neighbor algorithm with a matching tolerance width of 0.2 SD of the logit of the propensity score.[26-28]

Since the matched samples were dependent, the between-group differences in demographic characteristics were analyzed using Standard Error of Mean Difference (SEMD). A SEMD of greater than 10 percent was suggested as substantial imbalance in a certain variable between groups.[29] Propensity score matching was performed using

the MatchIt package. Between group differences were tested with Whitney tests. We performed Chi-square tests to study both differences in total number of complications as well as individual complications between both groups.

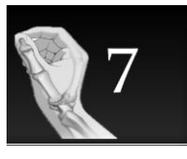
As described earlier, a conventional small to medium effect size of .35 was used as a non-inferiority margin. Following Hahn et al.[22], equality was considered if the 95% CIs lie within both the negative and positive non-inferiority margin, whereas non-inferiority was considered if one bound of the 95% CI lies outside the non-inferiority margin but an effect size of zero lies within the other bound.[22] All analyses were performed in R, version 3.4.1.

Results

Patient characteristics

Between 2011 and 2017, a total of 648 patients underwent a Weilby procedure in one of our clinics. After applying the eligibility criteria, 489 patients were included in the initial cohort. After surgery, 70% underwent longer immobilization and 30% shorter immobilization, reflecting the shorter inclusion period for the shorter immobilization. After propensity score matching, each group contained 131 patients (Figure 2).

Table 1 shows the baseline characteristics of the patients before and after propensity score matching. Before propensity score matching, the shorter immobilization group had on average a slightly shorter duration of symptoms, higher pain during physical load, larger MCP-1 extension and less range of motion during MCP-1 flexion at baseline. After propensity score matching, the standardized error mean difference between the groups were within the margin of ten percent for all variables except some small imbalance in age, RAB angle and moderate workload (Table 1).



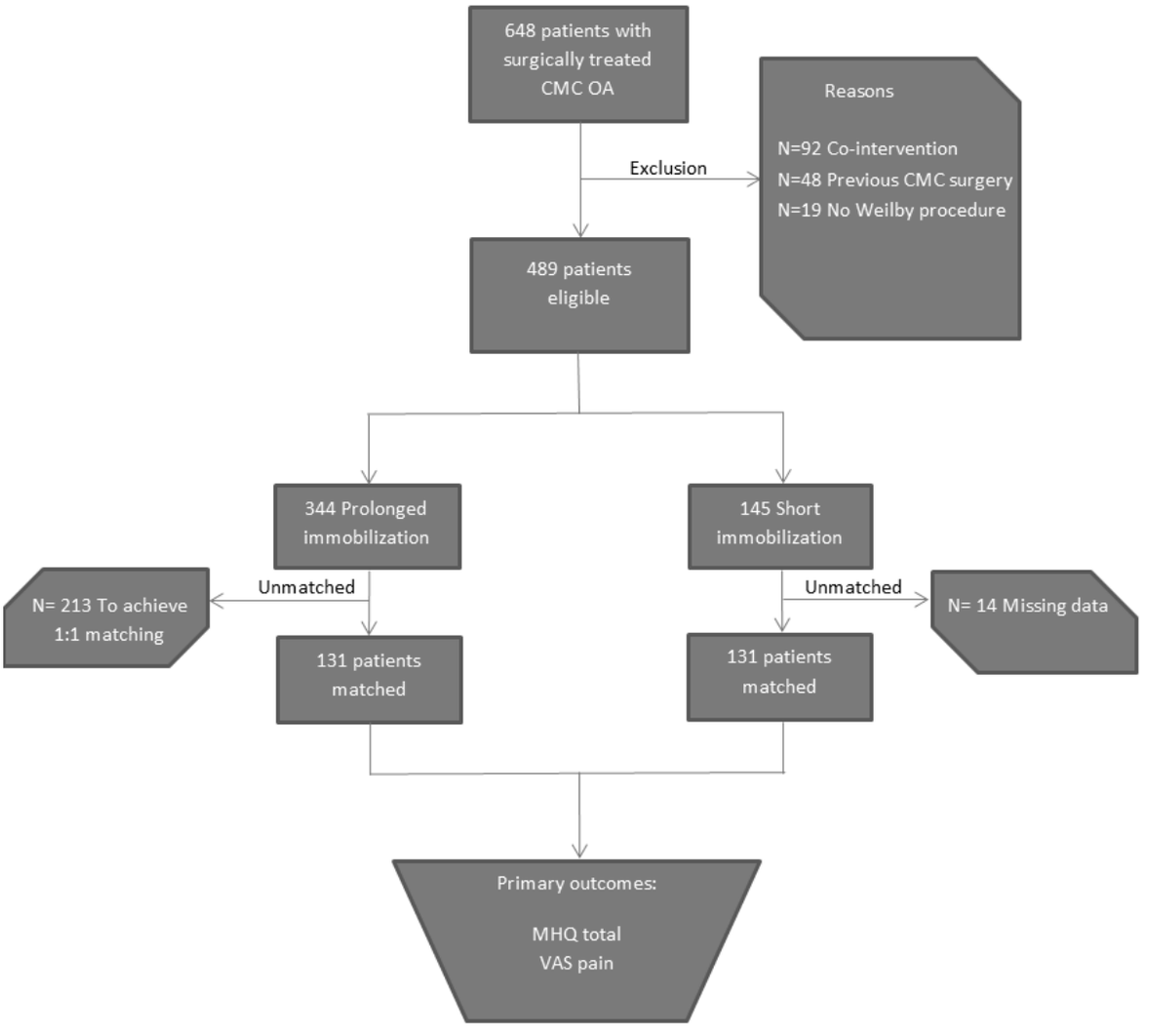
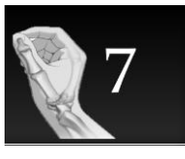


Figure 2. *Flowchart of the study*

Table 1. *Baseline characteristics before and after propensity score matching*

	All patients		Matched patients		
Continuous variables	Longer immobilization group (N= 344)	Shorter immobilization group (N= 145)	Longer immobilization group (N= 131)	Shorter immobilization group (N= 131)	Standard error of mean difference (%)
Age	60 ± 8	60 ± 9	61 ± 8	60 ± 8	12,5
Duration complaints (months)	44 ± 51	38 ± 41	39 ± 49	39 ± 42	0
MHQ function	49 ± 15	51 ± 19	51 ± 16	52 ± 19	5,7
MHQ ADL	52 ± 22	55 ± 21	55 ± 22	55 ± 22	0
MHQ work	49 ± 24	49 ± 26	49 ± 25	49 ± 26	0
MHQ pain	35 ± 14	35 ± 14	35 ± 14	35 ± 14	0
MHQ esthetics	80 ± 19	79 ± 21	79 ± 20	80 ± 21	4,9
MHQ satisfaction	31 ± 18	32 ± 20	33 ± 20	32 ± 20	5,0
VAS pain during rest	49 ± 22	51 ± 23	52 ± 22	50 ± 18	9,5
VAS pain during physical load	73 ±19	75 ± 17	74 ± 17	75 ± 17	9,9
PAB angle	46 ± 10	46 ± 11	46 ± 9	46 ± 11	0
RAB angle	47 ± 28	52 ± 46	47 ± 10	53 ± 47	18
MCP extension	-14 ± 15	-16 ± 12	-16 ± 15	-16 ± 12	0
MCP flexion	67 ±13	64 ± 14	64 ± 13	64 ± 14	0
Categorical variables					
Gender, female (%)	80	75	70	74	8,9
Treated side dominant (%)	48	48	45	48	6,0
Workload					
Not working (%)	46	51	52	50	4,0
Light work (%)	21	16	18	17	2,6
Moderate work (%)	23	23	18	23	12,4
Heavy work (%)	10	10	12	10	6,4

Abbreviations: MHQ: Michigan hand questionnaire, VAS: Visual Analogue Scale, SEMD: Standard error of mean difference, MCP: Metacarpophalangeal, PAB: Palmar abduction, RAB: Radial abduction



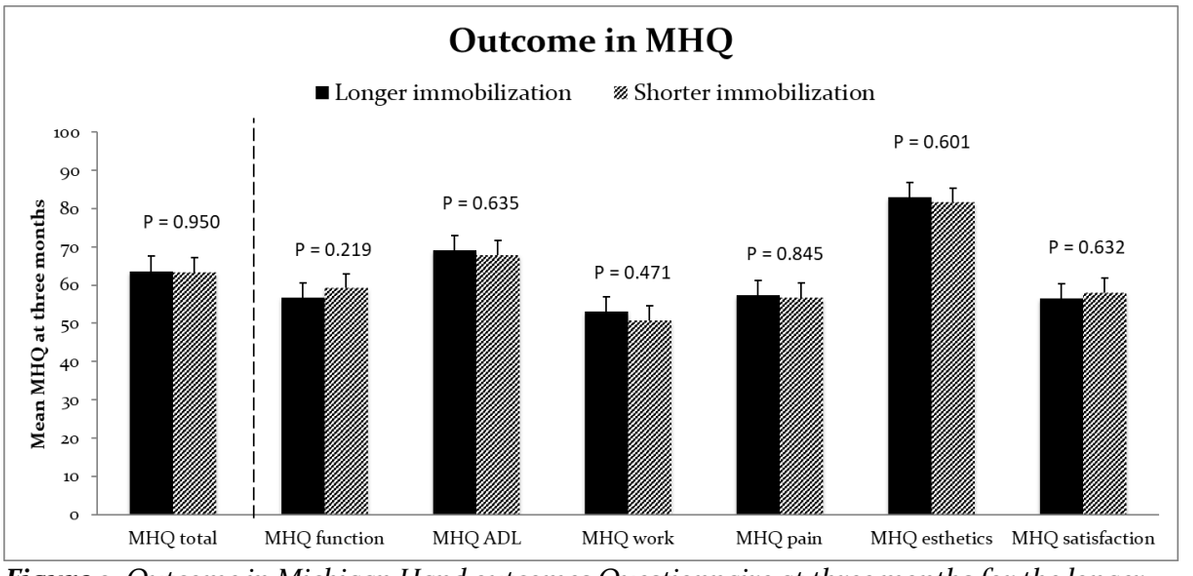


Figure 3. *Outcome in Michigan Hand outcomes Questionnaire at three months for the longer and shorter immobilization group. Error bars indicate standard errors. Abbreviations; MHQ: Michigan Hand Questionnaire*

Outcome of MHQ total and MHQ subscales are displayed in Figure 3. Both the MHQ total (effect size 0.01, 95% C.I. -0.23 - 0.25) as well as the MHQ subscales at three months did not show any significant differences between both groups. Outcome in MHQ total and subscales at twelve months was similar to the three months outcome, with no significant differences between both groups (Supplementary Figure 3).

In addition, both groups showed highly similar improvements in pain during physical load and pain during rest compared to preoperative measures (Figure 4). Moreover, outcome in pain during physical load and pain during rest showed no significant differences between both groups at three months; effect size 0.11, 95% C.I. -0.12 - 0.35 for VAS pain during physical load at three months and effect size 0.03, 95% C.I. -0.21 - 0.27 for VAS pain during rest at three months (Figure 4). The magnitude of the effect sizes for the MHQ and VAS and their confidence intervals (lying within non-inferiority margin of 0.35) indicate equality for the MHQ and VAS pain during rest and non-inferiority for VAS during physical load. In addition, outcome in pain during physical load and pain during rest compared at six weeks and twelve months was similar to the three months outcome, with no significant differences between both groups (Figure 4).

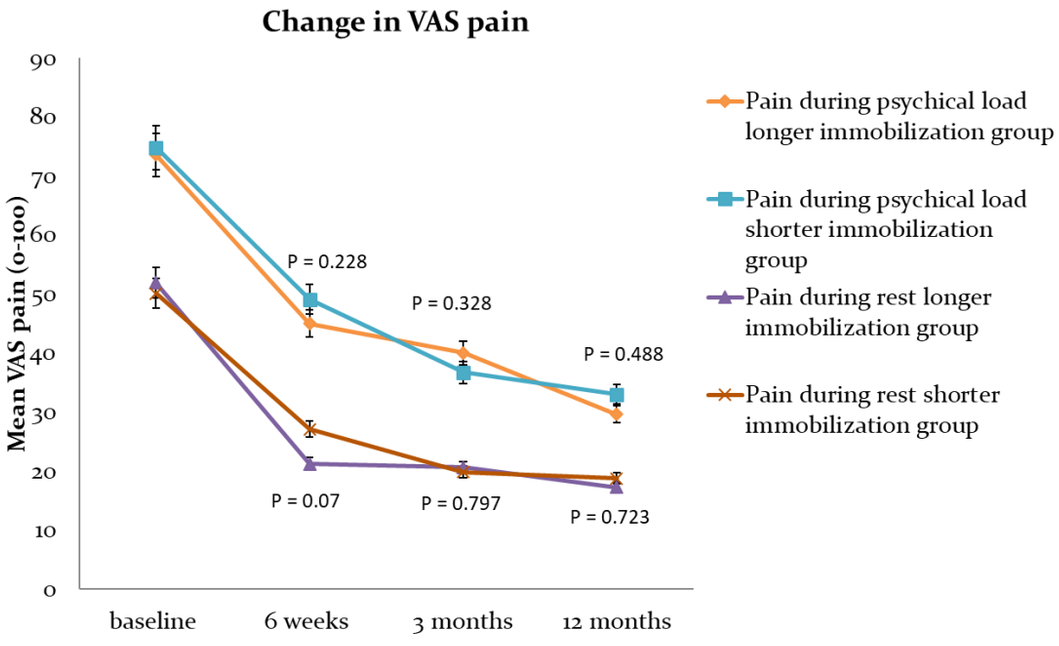


Figure 4. *Change in Visual Analogue Scale pain at baseline, six weeks, three months and twelve months postoperatively for the longer and shorter immobilization group. P-values correspond to the comparisons between groups at follow-up.*
Abbreviations: VAS = Visual Analogue Scale

Figure 5 shows the satisfaction with treatment of the patients at three months, where both groups expressed similar satisfaction with treatment (p=0.274). In addition, 80% of the patients in the shorter immobilization group would chose the same operation again, versus 82% of the longer immobilization group (p=0.706). Table 2 displays the number of complications in the longer and the shorter immobilization group. No significant differences in complication rate were present in the longer immobilization group compared to the shorter immobilization group (p= 0.102). At baseline, 50-52% of the patients were unemployed or retired. Of the people that were mployed, no significant differences in return to work after three months were found between the groups (Table 3).

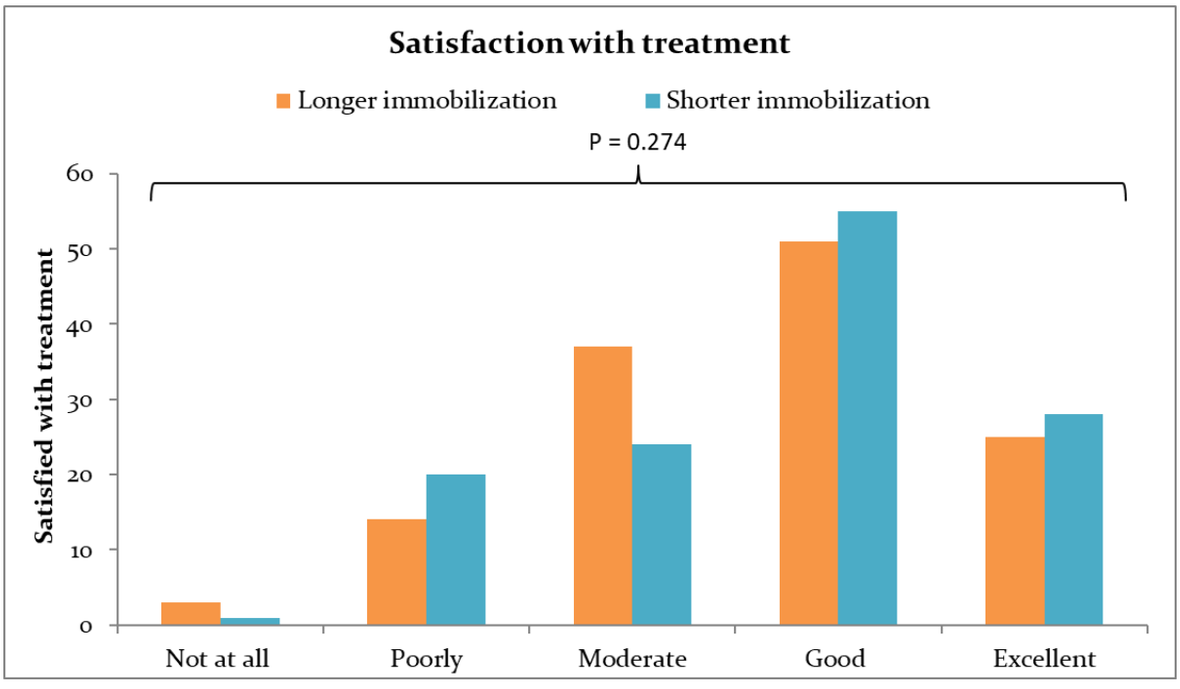
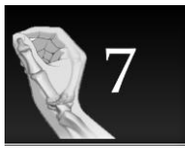


Figure 5. *Outcome in overall treatment satisfaction at three months in the longer and shorter immobilization group*

Table 2. *Complications in the prolonged and short immobilization group*

	Longed immobilization group (N= 131)	Shorter immobilization group (N= 131)	p-value
Total No. complications	27	23	0.102
Tenovaginitis Stenosans	4	9	
Carpal tunnel syndrome	3	1	
Tendinitis	9	3	
Neuroma	0	0	
Quervain	8	4	
FCR rupture	0	2	
CRPS	3	1	
Infection	0	1	
Sensory changes	0	1	
MC abutment	0	1	

Abbreviations: FCR = Flexor carpi radialis, CRPS = Complex regional pain syndrome, MC = Metacarpal



Furthermore, range of motion and grip & pinch strength (Table 3) were not significantly different between groups, except for radial abduction with 3 degrees in favor of the longer immobilization group (p=0.040). However, this difference lies within the generally accepted measurement error in goniometry measurements, which is more than 5 degrees.[30]

Table 3. *Outcome in work and objective measures. Since more than 50% was not currently working, only data of patients that were working was collected. This resulted in a lower number of patients.*

Outcome at 3 months	Longer immobilization group (N= 46)	Shorter immobilization group (N= 38)	p-value
Work			
Currently working			1.0
Yes (%)	96	79	
No, due to thumb complaints (%)	0	0	
No, due to other reasons (%)	4	21	
Performing original working activities (%)	61	53	0.655
Current number of hours Working / week	26 ± 12	23 ± 10	0.191
	Longer immobilization group (N= 131)	Shorter immobilization group (N= 131)	p-value
Strength			
Key pinch (kg)	3.3 ± 1.4	3.3 ± 1.5	0.824
JAMAR (two-position) (kg)	17.4 ± 1.2	17.6 ± 1.3	0.839
Goniometry			
PAB (º)	45 ± 8	44 ± 8	0.267
RAB (º)	47 ± 9	44 ± 14	0.040
MCP extension (º)	-10 ± 12	-8 ± 19	0.430
MCP flexion (º)	60 ± 13	61 ± 18	0.749

Abbreviations: MCP: Metacarpophalangeal, PAB: Palmar abduction, RAB: Radial abduction

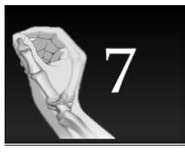
Discussion

The aim of this study was to investigate if shorter immobilization is non-inferior compared to longer immobilization after CMC arthroplasty for outcomes on hand function and pain intensity postoperatively. We found that shorter immobilization was equal to longer immobilization in our primary outcomes in terms of MHQ function and VAS pain. In addition, no significant differences between groups were found in our secondary outcomes in terms of complications, return to work, range of motion, satisfaction with treatment, grip and pinch strength.

The results of our study are in line with several other studies. For example, Horlock et al.[31] compared early with late mobilization in patients after simple trapeziectomy and found no significant differences between both groups in terms of pain, hand function,

satisfaction, range of motion and pinch strength. However, patients in the early group experienced significantly more convenience with the post-operative treatment. In addition, Prosser et al.[32] compared rigid with semi-rigid immobilization following trapeziectomy with or without ligament reconstruction and tendon interposition and also found no difference in pain, hand function and pinch strength. Furthermore, when comparing our results with a study by Davis et al.[33] that used a 6-week period of plaster cast immobilization, again, very similar outcomes are found. For example, 15 out of 62 patients had pain during use at three months, while we found in our study that the mean pain during physical load was 37 on a 0-100 scale. In addition, mean key pinch was 3.1 kg at three months in the study of Davis et al., while our mean key pinch was 3.3 kg at three months. Moreover, both study of Davis et al. and our study showed very low infection rates (<1%).

As mentioned above, our study found equal outcomes on pain and function. These findings suggest that shorter cast immobilization may lead to the same functional outcomes and an even more convenient treatment experience for individual patients. We postulate that shorter cast immobilization will lead to faster recovery of the patient with similar outcomes, which in turn will lead to reduced loss of productivity in working life. A study of Marks et al.[34] showed that the average sick leave in patients treated with a LRTI was 10 weeks, with an average costs due to loss of productivity of €7500. We hypothesize that by applying shorter immobilization, patients will be able to start recovering more quickly while returning earlier to work and daily activities. Hence further cost effectiveness studies on this subject are needed to confirm this hypothesis.



Our study showed that shorter immobilization is safe and will not lead to more complications or worse outcome for patients following Weilby procedure for CMC OA. Conventionally, patients were immobilized for a substantial amount of time after surgery, without sufficient evidence showing that this long period of immobilization was necessary.[7] This study suggests that shorter immobilization may be beneficial by preventing longer patient discomfort. In this study, we only investigated the effect of shorter immobilization, but not of early active and more progressive hand therapy, including early initiation of ROM and strengthening exercises. Future research should investigate the feasibility and possible beneficial effects of early active hand therapy in addition to shorter immobilization. Early active hand therapy may be preferable, since less postoperative stiffness and muscle atrophy will occur. Therefore, longer patient discomfort may be prevented and again, patients will recover more quickly while returning earlier to work and daily activities. Hence, future studies are needed in order to determine the effectiveness of early active and more progressive hand therapy.

Study Limitations

Our study has a number of strengths and limitations. The main strength of this study is the large sample size of 262 patients that were included after propensity score matching. To our knowledge, this is the largest study comparing different time frames of immobilization. While the observational character of this study may be a limitation, it is also a strength due to the pragmatic nature; since our data is collected in daily practice it represents the outcomes of actual daily clinical care.

Another limitation of this study is that patients were included in two different time periods, resulting in therapists knowing which treatment patients were receiving. However, therapists treating the patients were not aware of the present research question at the time of treatment. Furthermore, we used propensity score matching to correct for potential bias, the only risk being that selection bias still might have occurred if not all relevant covariates were measured at baseline. Furthermore, a limitation of this study is that deviations of the postoperative treatment protocol may have occurred. However, the therapists were extensively trained in using the treatment guidelines and several checks were randomly performed to monitor adherence.

Another limitation of this study is that we investigated shorter cast immobilization and earlier transition to an orthosis without wrist immobilization, but only small differences were present in total immobilization period. For example, we did not study potential differences in outcome following 6 weeks or 10 weeks of total immobilization. Therefore, the effect of different time frames in total immobilization periods remains partially unclear and future studies should address this.

Furthermore, a limitation of this study is that we only report outcomes following Weilby procedure. Hence, it is unclear if this postoperative treatment is feasible as well for other surgical procedures on CMC OA, thus future studies should investigate different types of postoperative immobilization for different surgical procedures.

Conclusion

In conclusion, the present study shows that shorter immobilization provides equal outcomes compared to longer immobilization after Weilby procedure for CMC OA. Hence, we conclude that shorter immobilization is safe and can be recommended due to its potential benefits compared to longer immobilization. More high-quality studies on early active rehabilitation are needed in order to understand which factors improve patient comfort and return to functional activities.

References

1. Bijlsma JWJ, Berenbaum F, Lafeber FPJG. Osteoarthritis: An update with relevance for clinical practice. The Lancet. 2011;377(9783):2115-2126.

2. Haugen IK, Englund M, Aliabadi P, et al. Prevalence, incidence and progression of hand osteoarthritis in the general population: the Framingham Osteoarthritis Study. Ann Rheum Dis. 2011;70(9):1581-1586.

3. Dahaghin S, Bierma-Zeinstra SMA, Ginai AZ, Pols HAP, Hazes JMW, Koes BW. Prevalence and pattern of radiographic hand osteoarthritis and association with pain and disability (the Rotterdam study). Ann Rheum Dis. 2005;64(5):682-687.

4. Zhang Y, Niu J, Kelly-Hayes M, Chaisson CE, Aliabadi P, Felson DT. Prevalence of symptomatic hand osteoarthritis and its impact on functional status among the elderly: The framingham study. Am J Epidemiol. 2002;156(11):1021-1027.

5. Handchirurgie NVv. Richtlijn Conservatieve en Chirurgische Behandeling van Primaire Artrose van de Duimbasis. 2014.

6. Wajon A, Vinycomb T, Carr E, Edmunds I, Ada L. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. The Cochrane database of systematic reviews. 2015;2:Cd004631.

7. Wouters RM, Tsehaie J, Hovius SER, Dilek B, Selles RW. Postoperative rehabilitation following thumb base surgery: a systematic review of the literature. Arch Phys Med Rehabil. 2017.

8. Vermeulen G, Slijper H, Feitz R, Hovius SER, Moojen T, Selles R. Surgical management of primary thumb carpometacarpal osteoarthritis: a systematic review. The Journal of hand surgery. 2011;36(1):157-169.

9. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453-1457.

10. Eaton RG, Glickel SZ, Littler JW. Tendon interposition arthroplasty for degenerative arthritis of the trapeziometacarpal joint of the thumb. J Hand Surg Am. 1985;10(5):645-654.

11. Weilby A. Tendon interposition arthroplasty of the first carpo-metacarpal joint. J Hand Surg Br. 1988;13(4):421-425.

12. Vermeulen GM, Spekreijse KR, Slijper H, Feitz R, Hovius SER, Selles RW. Comparison of arthroplasties with or without bone tunnel creation for thumb basal joint arthritis: A randomized controlled trial. J Hand Surg Am. 2014;39(9):1692-1698.

13. Handtherapie Nederland. Guideline thumb base osteoarthritis (Richtlijn duimbasisartrose/duimprogramma), Handtherapie Nederland. 2014.

14. Poole J. Measures of hand function: Arthritis Hand Function Test (AHFT), Australian Canadian Osteoarthritis Hand Index (AUSCAN), Cochin Hand Function Scale, Functional Index for Hand Osteoarthritis (FIHOA), Grip Ability Test (GAT), Jebsen Hand Function Test (JHFT), and Michigan Hand Outcomes Questionnaire (MHQ). Arthritis Care Res (Hoboken). 2011;63 Suppl 11:S189-S199.

15. Shauver MJ, Chung KC. The minimal clinically important difference of the Michigan hand outcomes questionnaire. J Hand Surg Am. 2009;34(3):509-514.

16. London DA, Stepan Jg Fau - Calfee RP, Calfee RP. Determining the Michigan Hand Outcomes Questionnaire minimal clinically important difference by means of three methods. 2014(1529-4242 (Electronic)).

17. Hawker GMSKTFM. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). Arthritis Care Res (Hoboken). 2011;63 Suppl 11:S240-S252.

18. American Society for Hand T. Clinical Assessment Recommendations, 2nd edition. 1992.

19. Mathiowetz VKNVGWKDMRS. Grip and pinch strength: normative data for adults. Arch Phys Med Rehabil. 1985;66(2):69-74.

20. Allen D, Barnett F. Reliability and validity of an electronic dynamometer for measuring grip strength. International Journal of Therapy and Rehabilitation. 2011;18(5):258-264.

21. Mathiowetz VWKVGKN. Reliability and validity of grip and pinch strength evaluations. The Journal of hand surgery. 1984;9(2):222-226.

22. Hahn S. Understanding noninferiority trials. Korean J Pediatr. 2012;55(11):403-407.

23. Cohen J. Statistical power analysis for the behavioral sciences, second edition. 1988.

24. Zhou C, Hovius SE, Slijper HP, Feitz R, Van Nieuwenhoven CA, Pieters AJ, Selles RW. Collagenase Clostridium Histolyticum versus Limited Fasciectomy for Dupuytren's Contracture: Outcomes from a Multicenter Propensity Score Matched Study. Plast Reconstr Surg. 2015;136(1):87-97.

25. Rubin DB. The design versus the analysis of observational studies for causal effects: parallels with the design of randomized trials. Stat Med. 2007;26(1):20-36.

26. Freemantle N, Marston L, Walters K, Wood J, Reynolds MR, Petersen I. Making inferences on treatment effects from real world data: propensity scores, confounding by indication, and other perils for the unwary in observational research. BMJ. 2013;347:f6409.

27. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. Biometrika. 1983;70(1):41-55.

28. Austin PC. An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies. Multivariate Behav Res. 2011;46(3):399-424.

29. Austin PC, Grootendorst P, Anderson GM. A comparison of the ability of different propensity score models to balance measured variables between treated and untreated subjects: A Monte Carlo study. Stat Med. 2007;26:734-53.

30. van Kooij YE, Fink A, Nijhuis-van der Sanden MW, Speksnijder CM. The reliability and measurement error of protractor-based goniometry of the fingers: A systematic review. J Hand Ther. 2017;30(4):457-467.

31. Horlock N, Belcher HJ. Early versus late mobilisation after simple excision of the trapezium. J Bone Joint Surg Br. 2002;84(8):1111-1115.

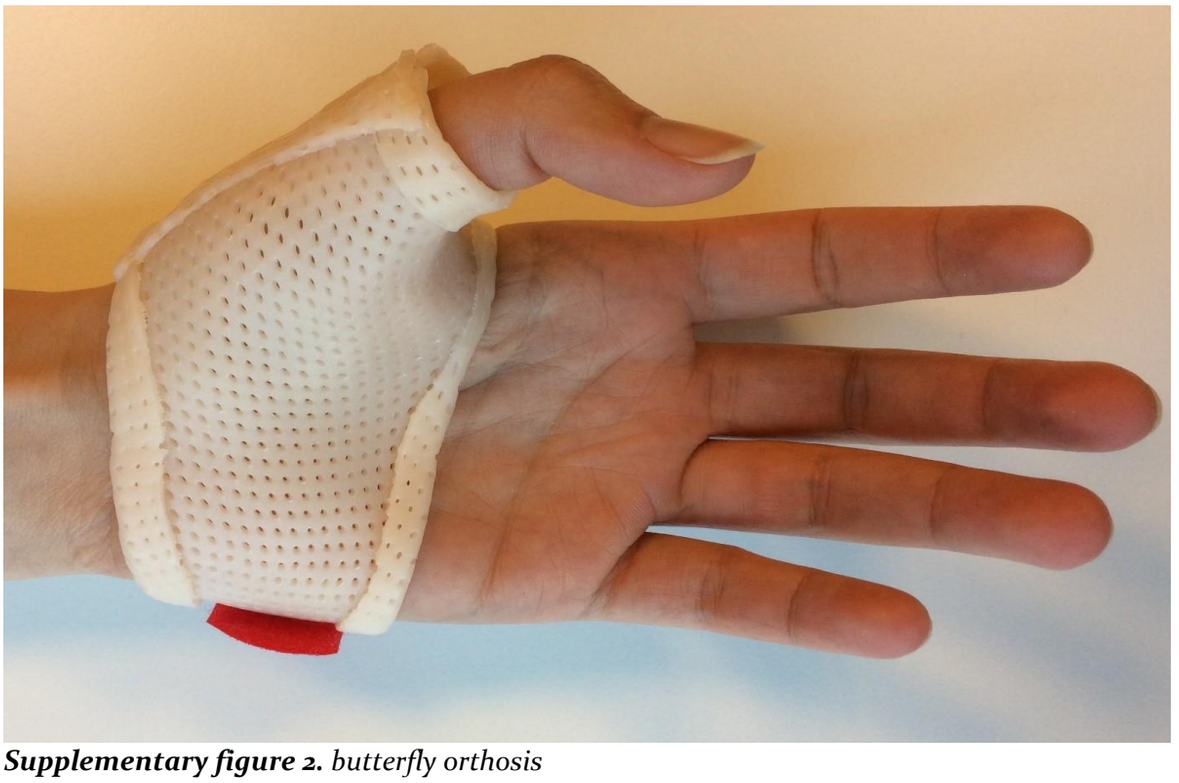
32. Prosser R, Hancock MJ, Nicholson L, Merry C, Thorley F, Wheen D. Rigid versus semi-rigid orthotic use following TMC arthroplasty: a randomized controlled trial. J Hand Ther. 2014;27(4):265-270; quiz 271.

33. Davis TRC, Brady O, Dias JJ. Excision of the trapezium for osteoarthritis of the trapeziometacarpal joint: A study of the benefit of ligament reconstruction or tendon interposition. Journal of Hand Surgery. 2004;29(6):1069-1077.

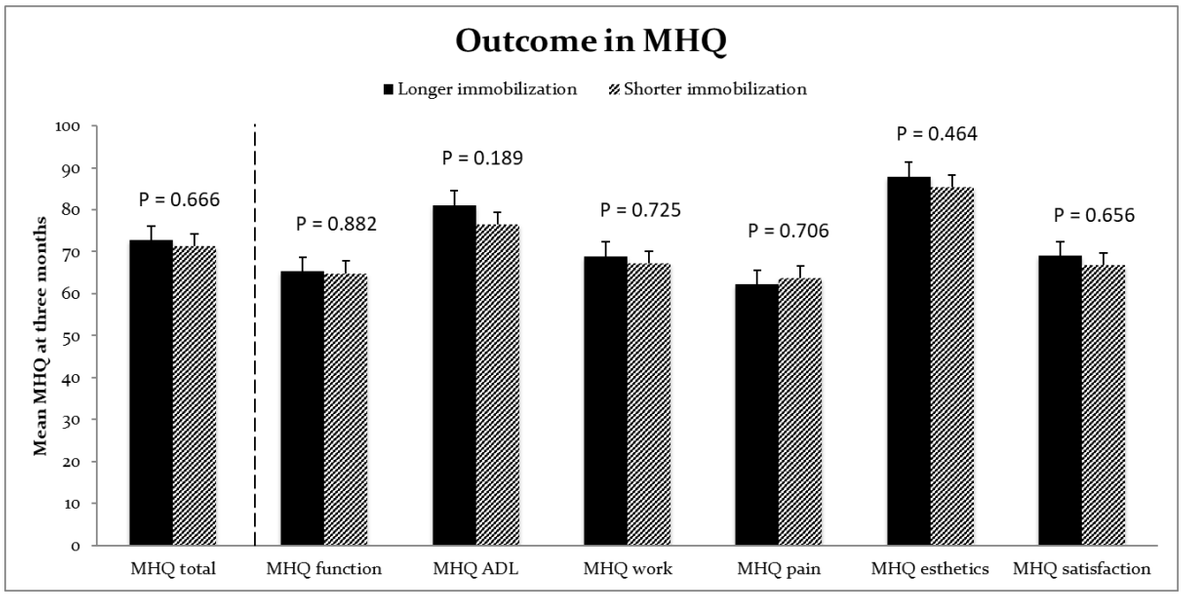
34. Marks M, Vliet Vlieland TP, Audige L, Herren DB, Nelissen RG, van den Hout WB. Healthcare costs and loss of productivity in patients with trapeziometacarpal osteoarthritis. J Hand Surg Eur Vol. 2015;40(9):927-934.

Appendix

Supplementary figure 1. *thermoplastic thumb spica orthosis including wrist immobilization*



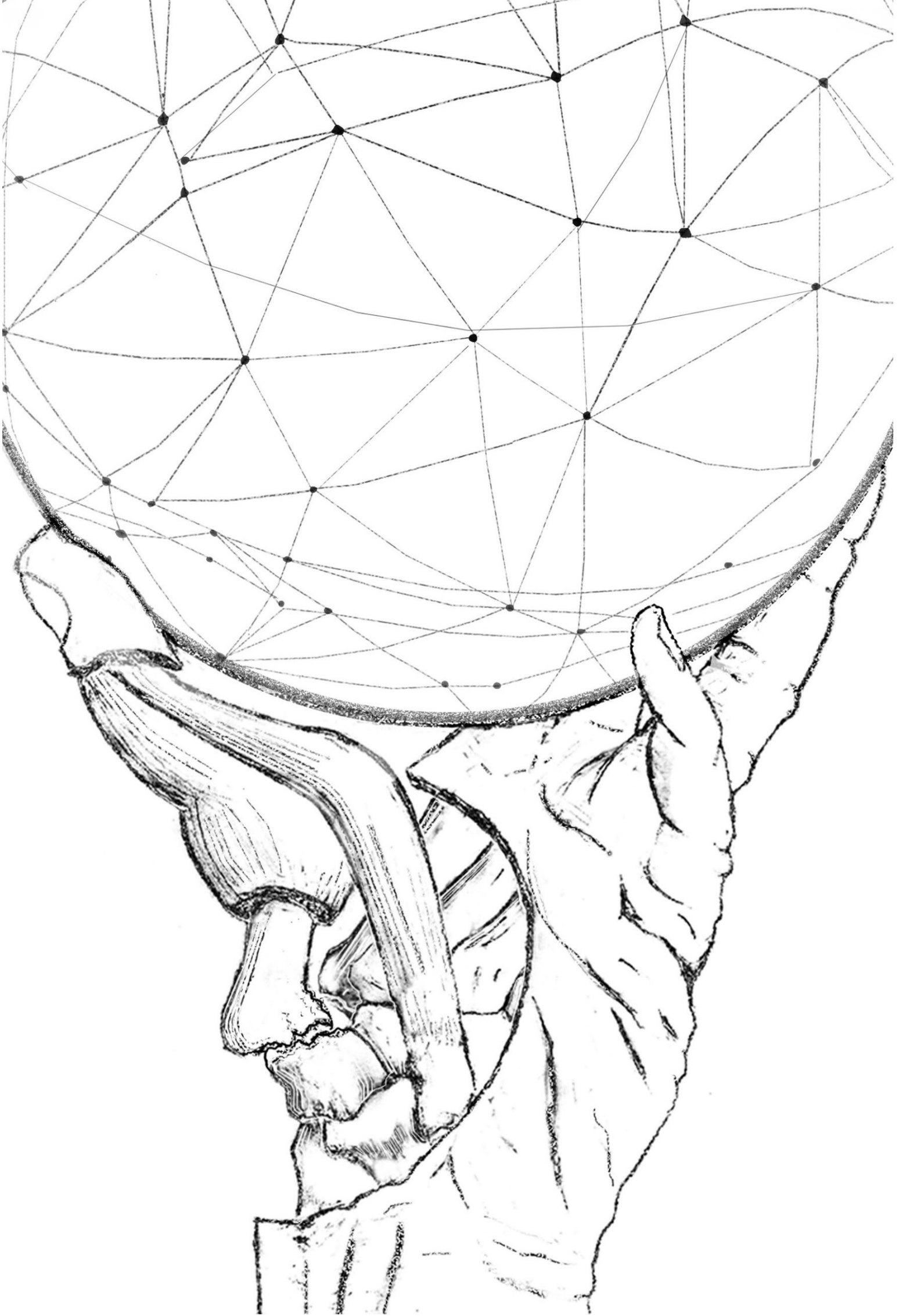
Supplementary figure 2. *butterfly orthosis*



Supplementary figure 3. *Outcome in MHQ total and subscales at twelve months*

PART 3

PSYCHOLOGICAL FACTORS AND CONTEXTUAL EFFECTS IN THUMB CMC OSTEOARTHRITIS



THE ROLE OF PSYCHOLOGICAL FACTORS AND RADIOGRAPHIC SEVERITY OF OSTEOARTHRITIS IN PRE-TREATMENT PAIN OF NON-INVASIVELY TREATED PATIENTS WITH THUMB CARPOMETACARPAL OSTEOARTHRITIS.

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8

Abstract

Introduction: The aim of this study is to investigate to what extent psychological factors are related to pain levels prior to non-invasive treatment in patients with osteoarthritis of the first carpometacarpal joint (CMC OA).

Methods: In this cross-sectional study performed at Xpert Clinic between September 2017 and July 2018, we included 255 patients at the start of non-invasive treatment for CMC OA. Main outcome measures were: 1) pain levels prior to treatment (MHQ), Psychological distress measured with the Patient Health Questionnaire-4 (PHQ), pain catastrophizing behavior was measured with the Pain Catastrophizing Scale (PCS) and illness perception measured with the Brief Illness Perception Questionnaire (B-IPQ). X-rays were scored on presence of scaphotrapeziotrapezoid (STT) osteoarthritis. We used hierarchical linear regression analysis to determine to what extent pain levels could be explained by patient characteristics, X-ray scores and psychological factors.

Results: Patient characteristics and X-ray scores accounted for only 6% of the variation in pre-treatment pain levels. After adding the psychological factors to our model, 47% of the variance could be explained.

Conclusions: Our results show that psychological factors are more strongly related to pain levels prior to non-invasive treatment in patients with CMC osteoarthritis than patient characteristics and X-ray scores, which implies the important role of these factors in the reporting of symptoms. More research is needed to determine whether psychological factors will also affect treatment outcomes for patients treated non-invasively for CMC OA.

Introduction

Osteoarthritis (OA) of the first carpometacarpal joint (CMC) is a degenerative disease that causes pain and loss of function.[1]. Patients are initially treated non-invasively with hand therapy, occupational therapy, an orthosis, or a combination of treatment modalities.[2,3] While previous studies demonstrated that non-invasive treatment may prevent the need for surgical treatment and effectively reduces pain in a selection of patients, not all patients respond well to non-invasive treatment.[4,5]

At present, the outcome of non-invasive treatment of CMC OA cannot accurately be predicted.[5] Traditional patient and disease attributes, e.g. age, grip strength and X-ray scores, only explain a small amount of the variation in reported symptoms, which suggests other factors are at play.[6,7]

Studies looking at surgical treatment of OA, including total knee or hip replacement[8-11] and surgery for CMC OA[12,13] suggest that psychological factors (e.g. depression, pain catastrophizing behavior and illness perception) are associated with worse patient reported outcomes, both before and after treatment. Moreover, recent studies suggested that interventions improving catastrophizing behavior and negative illness perception have a beneficial effect on symptoms caused by OA.[14,15]

Although there is evidence that psychological factors are associated with symptom severity in knee and hip OA, for patients with CMC OA there is limited evidence regarding the association between pain and psychological factors, in particular for patients who receive non-invasive treatment.[12,16-18] Moreover, no studies have investigated to what extent illness perception is associated with pain in this patient population. Therefore, the aim of this study is to investigate to what extent psychological distress, pain catastrophizing behavior and illness perception relate to pain levels prior to non-invasive treatment in patients with osteoarthritis of the first carpometacarpal joint.

Methods

Setting and study population

This cross-sectional study was performed at Xpert Clinic in The Netherlands. Xpert Clinic is a specialized private treatment center for hand and wrist conditions. Xpert Clinic has 20 different locations, with 20 European Board certified (FESSH) hand surgeons and over 150 hand therapists.

All patients who received non-invasive treatment, consisting of orthosis and/or hand therapy, for CMC OA at Xpert Clinic between September 2017 and July 2018 were invited to complete several questionnaires as part of routine clinical care to measure symptom severity, psychological status, understanding of disease and quality of life prior to treatment. These questionnaires were e-mailed after the first consultation and

before non-invasive treatment started. Three reminders were e-mailed to non-responders. Furthermore, baseline demographics, including age, sex, hand dominance and occupational intensity were collected. All patients provided written informed consent.

Michigan Hand Outcomes Questionnaire

The Michigan Hand Outcomes Questionnaire (MHQ)[19] is a patient reported outcome measure with six domains (pain, aesthetics, hand function, performance of activities of daily living, work performance and satisfaction) with good validity, reliability and responsiveness in CMC OA patients.[20] Scores range from 0-100 (0 = poorest function, 100 = ideal function). In the present study the pain scores were reversed (0 = no pain, 100 = extreme pain). We only used the pain subscale as outcome measure.

Patient Health Questionnaire-4

The Patient Health Questionnaire-4 (PHQ)[21] is a generic depression- and anxiety-screening tool and was used to measure psychological distress. This questionnaire is a combination of two brief screening tools (Patient Health Questionnaire-2 and Generalized Anxiety Disorder-2). The PHQ contains two domains (anxiety and depression) with two questions each. The total score ranges from 0-12 (0 = no indication for psychological distress; 12 = strong indication for psychological distress). It has a good reliability and validity.[22]

Pain Catastrophizing Scale

The Pain Catastrophizing Scale (PCS)[23] was used to assess catastrophizing behavior in response to pain. This questionnaire consists of 13 questions and 3 domains (helplessness, magnification and rumination). It has been demonstrated to have good validity, reliability and responsiveness.[24,25] The total score ranges from 0-52 (0 = no catastrophizing behavior; 52 = severe catastrophizing behavior).

Brief Illness Perception Questionnaire

The Brief Illness Perception Questionnaires (B-IPQ)[26] was used to assess the patients' perceptions of illness. This questionnaire is a short version of the Revised Illness perception Questionnaire (IPQ-R).[27] In the B-IPQ each subscale of the IPQ-R is summarized by one question. Five questions assess cognitive illness representation, two questions assess emotional representations, one question assesses understanding of disease and in the final question patients are asked to list the factors they believe to have caused their illness. This last question was not part of our questionnaire. Reliability and validity has been demonstrated for multiple conditions.[28]

CMC joint X-rays

The patients' records were searched for X-rays of the first carpometacarpal joint. If multiple X-rays were present, we selected the X-ray in which both the CMC joint and the scaphotrapeziotrapezoid joint (STT) were most clearly visible. The Eaton-Glickel classification ranges from stage I to stage IV.[29] Stage III is defined as excessive CMC degeneration and subluxation. Stage IV is defined as stage III with additional presence of STT OA. According to this classification, presence of STT OA indicates the most advanced stage of structural damage. Therefore, we used this feature as indication of radiographic severity of disease. The first 100 X-rays were independently scored by both a FESSH certified hand surgeon (G.V.) and a junior scientist (L.H.). The Intraclass Correlation Coefficient was 0.58 (95% CI 0.49-0.65). This is in agreement with the study by Dela Rosa et al.[30], who reported fair to moderate inter-observer agreement for the Eaton-Glickel classification, with similar agreement rates for stage I, III and IV. The scores of the junior scientist were used for all patients. Patients without an X-ray of the CMC joint were excluded.

Statistical analyses

A complete case analysis was performed with patients who completed all previously mentioned questionnaires. To see whether patients with missing data differed from patients with complete data, two non-responder analyses were performed; both for patients who completed the MHQ but did not complete the psychological questionnaires and for patients who completed all questionnaires, but without X-ray of the CMC joint. For these analyses, T-tests were used for normally distributed continuous data and Mann-Whitney-Wilcoxon tests were used for continuous data that was not normally distributed. Chi square statistics were used for categorical data. We calculated Pearson correlation coefficients to determine to what extent the psychological variables were correlated.

Data were analyzed using hierarchical linear regression analyses with baseline MHQ-pain levels as a dependent variable. In the first step of the analysis, age, sex and occupational intensity were entered into the model. Presence of STT OA was added in the second step of analysis. In the third step, we entered the total PHQ score, as well as the total PCS score. In the fourth step, all B-IPQ subscales were added in order to determine the effect of illness perception on pain, after correcting for psychological distress and pain catastrophizing behavior.

For all variables, the regression coefficients (B) are reported. In order to compare the relative contribution of each explanatory variable on the outcome, the standardized beta coefficients (β) are also reported. For categorical explanatory variables, only the outcome was standardized. For all models both the multiple explained variance (R2) and the explained variance adjusted for number of variables in the model (adjusted R2) is calculated.

All analyses were performed using R statistical computing, version 3.4.1. For all tests a p-value smaller than 0.05 was considered statistically significant.

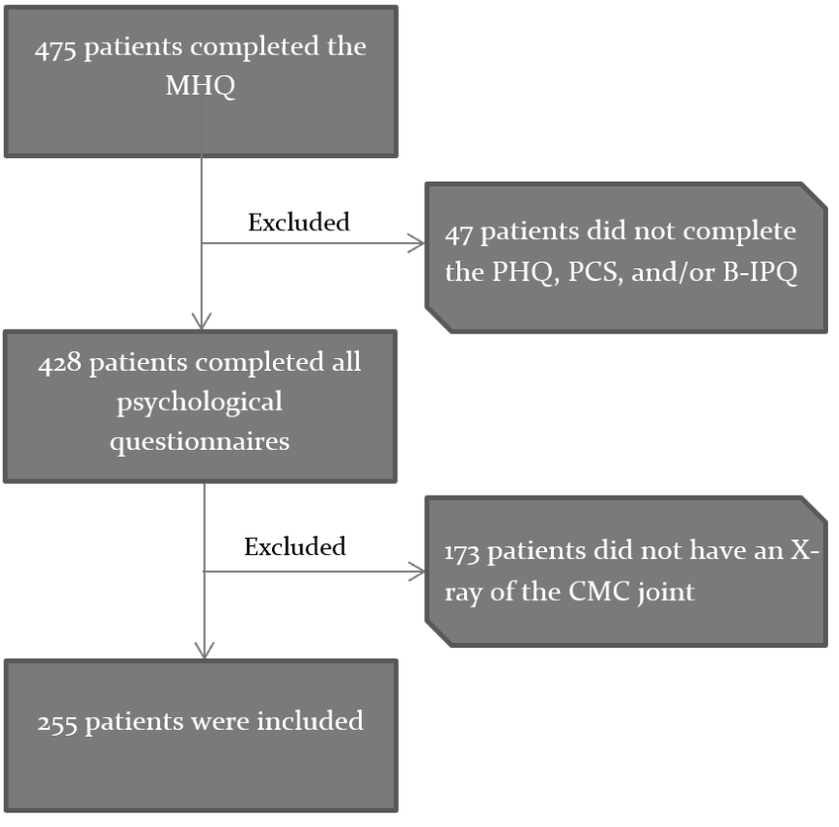


Figure 1. *Flowchart of the study*

Results

Non-responder analysis

We identified 475 patients at the start of non-invasive treatment for CMC OA who had completed the MHQ. 5.2% of these patients did not complete all psychological questionnaires. Of the patients who completed all questionnaires, 40.4% did not have an X-ray of the CMC joint. Supplemental tables 1-2 show demographic characteristics and MHQ scores for responders and non-responders, indicating no significant differences in any patient characteristic or MHQ-pain scores between responders and non-responders.

Patient characteristics

255 patients were included in the analysis (Figure 1). Their mean age was 60 ± 8 years (mean ± SD) and 75% of the patients were female. The mean MHQ-pain score was 52.9 ± 17.3. Table 1 shows baseline characteristics for all included patients. Correlations between the psychological factors ranged from -0.24 to 0.60. (Supplemental table 3).

Table 3. *Demographic characteristics of the patients included for analysis*

Baseline characteristics	Total (n = 255)
Age in years	59.8 (7.8)
Sex (%)	
Female	74.9%
Hand dominance (%)	
Right	91.4%
Left	6.3%
Both	2.4%
Laterality of the affected hand (%)	
Right	47.8%
Left	50.2%
Both	2.0%
Dominant hand affected (%)	51.8%
Duration of symptoms in months (median, interquartile range)	12 (6-24)
Occupational intensity (%)	
Not employed	40.0%
Light	21.6%
Moderate	27.5%
Severe	11.0%
STT OA present (%)	13.3%
PHQ score	1.6 (2.6)
PCS score	12.2 (10.0)
B-IPQ Consequences	6.4 (2.3)
B-IPQ Timeline	7.8 (2.3)
B-IPQ Personal control	5.3 (2.3)
B-IPQ Treatment control	6.8 (1.8)
B-IPQ Identity	6.1 (2.5)
B-IPQ Concern	6.1 (2.7)
B-IPQ Understanding	8.4 (2.0)
B-IPQ Emotional response	4.3 (2.8)
MHQ-pain	52.9 (17.3)

** Values reported as mean (SD) unless otherwise stated.*

Hierarchical linear regression

Table 2 shows the outcomes of the hierarchical regression analysis. In model 1 and 2, female sex was significantly associated with higher MHQ-pain scores. However, after adding psychological distress and catastrophizing behavior to the model, sex was no longer significantly related to pain, while higher PHQ and PCS scores were significantly associated with higher MHQ-pain scores. After adding the B-IPQ subscales to the model, B-IPQ subscales 'consequences' and 'identity' were, in addition to PHQ score and PCS score, also significantly associated with pain. Figure 2 shows the increase in explained variance per model. Model 1 and 2 had an explained variance of 5% and 6% respectively. After adding psychological distress and catastrophizing behavior, the explained variance increased to 35%, and after adding illness perception, the explained variance increased to 47%. In this model, more psychological distress (PHQ score, $\beta = 0.12$), more pain catastrophizing behavior (PCS score, $\beta = 0.27$), experiencing more consequences (B-IPQ 'consequences', $\beta = 0.19$) and more symptoms (B-IPQ 'identity', $\beta = 0.16$) were significantly associated with higher MHQ-pain scores. Total PCS score had the largest standardized coefficient ($\beta = 0.27$) in this model, which indicates that pain catastrophizing behavior has the largest effect on pre-treatment pain of all variables investigated in this study.

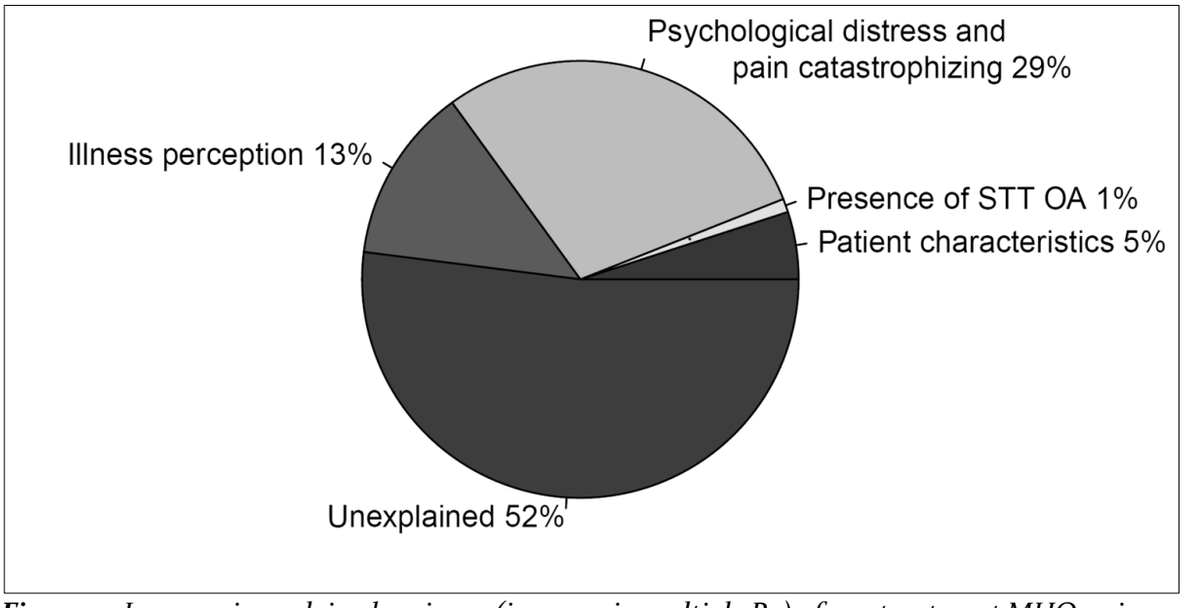


Figure 2. *Increase in explained variance (increase in multiple R2) of pre-treatment MHQ-pain per step in the hierarchical linear regression model*

Table 2. *Beta coefficients and explained variance (R2) for hierarchical linear regression models explaining pre-treatment pain levels. In each additional model, more variables potentially explaining pre-treatment pain levels are included. Standardized (β) beta coefficients are reported.*

	Model 1 (Patient characteristics)	Model 2 (Model 1+ Presence of STT OA)	Model 3 (Model 2+ Psychological distress and pain catastrophizing)	Model 4 (Model 3 + Illness perception)	Univariable models
Explanatory variables	**β**	**β**	**β**	**β**	**β**
Age	-0.04	-0.03	-0.001	-0.005	-0.07
Sex, male	-0.49***	-0.48**	-0.30*	-0.19	-0.47
Physical activity at work (ref = no work)					
Light	-0.11	-0.11	0.02	0.10	0.005
Moderate	-0.12	-0.12	-0.09	-0.11	-0.02
Severe	0.18	0.23	0.15	0.07	0.18
STT OA, present		-0.28	-0.21	-0.15	-0.26
PHQ score			0.16*	0.12*	0.43
PCS score			0.44***	0.27***	0.55
B-IPQ Consequences				0.19**	0.52
B-IPQ Timeline				-0.10	0.09
B-IPQ Personal control				-0.08	-0.17
B-IPQ Treatment control				0.03	-0.05
B-IPQ Identity				0.16**	0.41
B-IPQ Concern				0.06	0.47
B-IPQ Understanding				0.03	0.04
B-IPQ Emotional response				0.12	0.51
Multiple R^2	**0.051**	**0.060**	**0.346**	**0.474**	
Adjusted R^2	**0.032**	**0.037**	**0.325**	**0.439**	

** $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$*

Discussion

The aim of this study was to investigate to what extent psychological factors are related to pre-treatment pain levels in patients receiving non-invasive treatment for CMC OA. We found that higher psychological distress, more pain catastrophizing behavior and experiencing more consequences and symptoms from the illness were independently associated with higher pre-treatment pain levels. Pain catastrophizing behavior has the strongest association with pre-treatment pain. Patient characteristics and radiographic severity of the disease had no clear association with pre-treatment pain.

Several previous studies focused on the association between X-ray scores and pain in patients with CMC OA. However, different methods are available to score X-rays[31] and the available literature is conflicting.[6,7,32-35] Several radiographic OA features including erosions and sclerosis have been linked to pain levels, while Dahaghin et al. in a large population study (n=3906) reported that radiographic OA was poorly correlated with pain.[7,32,35] In our study, we found that presence of STT osteoarthritis could only explain a limited amount of variance in pain scores. While X-rays may still have an important role in clinical practice, our study indicates that their value for understanding symptom severity is limited.

To our knowledge this is the first study that assessed pre-treatment pain in CMC OA patients that included both radiographic severity and psychological factors in the analysis. Murphy et al.[36] performed a similar study for women with knee OA. They found that fatigue, sleep quality and depression explained additional variance in pain severity after correcting for age and X-ray scores. This is in line with our findings that psychological factors explained additional variance in pre-treatment pain. However, in our study we found that psychological factors explained an additional variance of 40% compared to 10% in Murphy et al., which may be explained by use of different definitions of psychological variables in both studies.

Becker et al.[17] reported that symptom severity could largely be explained by whether or not the patients sought treatment for his symptoms and by pain catastrophizing behavior. This is in agreement with our finding that pain catastrophizing behavior has the strongest association with pre-treatment pain of all variables included in our study. While no studies reported the association between pain and illness perception for patients with CMC OA, Hill et al.[37] found that higher pain levels were associated with reporting more frustration, experiencing more consequences and expecting a chronic timeline in people with musculoskeletal hand problems.

The strength of this study is the large population where we combined psychological distress, pain catastrophizing as well as illness perception in explaining pre-treatment pain in non-invasively treated CMC OA. Moreover, we included presence of STT OA in our analyses as measure for structural damage to the CMC joint. To our knowledge this is the first study that combined psychological factors and radiographic severity of disease to explain pre-treatment pain levels of CMC OA patients.

A limitation of our study is the quality of the X-rays that we used to score presence of STT OA. These X-rays were taken as part of daily clinical practice and therefore not taken in a standardized way, making it difficult to score all radiographic OA features. For that reason we only scored presence of STT OA, because presence of STT OA is an indication that radiologically the disease has reached an advanced stage.[29] Still our study clearly demonstrates that presence of STT OA, on X-rays taken as part of routine care, is not related to pre-treatment pain, whereas psychological factors show a strong association with pre-treatment pain.

Future research

Due to the design of our study we were not able to draw any causal implications from our research findings and a large prospective study may provide more valuable knowledge of the longitudinal association between psychological factors and pain. Based on the strong association between pre-treatment pain and treatment outcomes in our study and in previous studies, the question arises whether psychological factors will affect treatment outcomes and consequently, whether treatment results will improve when patients receive psychological support in addition to usual care. More research is needed to answer these questions.[17,23,31]

Moreover, future studies have to demonstrate what type of psychological intervention would improve pain levels most in non-invasively treated CMC OA patients, while also being feasible to offer in addition to usual care. This study suggests that pain catastrophizing behavior is the most important factor to target with a psychological intervention, but psychological distress and/or negative illness perception may be relevant targets for intervention as well.

In conclusion, the present study demonstrates that patient characteristics and X-rays have limited value for understanding symptom severity in patients with carpometacarpal osteoarthritis of the thumb base. In contrast, we found a strong association between psychological factors and pain levels prior to non-invasive treatment. Clinicians should be aware of the strong relation between pain and psychological factors and should look beyond X-ray scores to judge symptom severity in patients with carpometacarpal osteoarthritis.

References

1. Anakwe RE, Middleton SD. Osteoarthritis at the base of the thumb. BMJ. 2011;343:d7122.

2. van Uchelen J, Beumer A, Brink SM, Hoogvliet P, Moojen TM, Spaans AJ, et al. Richtlijn Conservatieve en Chirurgische Behandeling van Primaire Artrose van de Duimbasis [Dutch]: Nederlandse Vereniging voor Plastische Chirurgie (NVPC); 2014 [Available from: https://www.nvpc.nl/uploads/stand/150416DOC-MB-Definitieve_richtlijn_Conservatieve_en_Chirurgische_behandeling_duimbasisartrose_28-10-2014_aangenomen_ALV_14_april_2015149.pdf.

3. Aebischer B, Elsig S, Taeymans J. Effectiveness of physical and occupational therapy on pain, function and quality of life in patients with trapeziometacarpal osteoarthritis - A systematic review and meta-analysis. Hand Ther. 2016;21(1):5-15.

4. Berggren M, Joost-Davidsson A, Lindstrand J, Nylander G, Povlsen B. Reduction in the need for operation after conservative treatment of osteoarthritis of the first carpometacarpal joint: a seven year prospective study. Scand J Plast Reconstr Surg Hand Surg. 2001;35(4):415-7.

5. Tsehaie J, Spekreijse KR, Wouters RM, Slijper HP, Feitz R, Hovius SER, et al. Outcome of a Hand Orthosis and Hand Therapy for Carpometacarpal Osteoarthritis in Daily Practice: A Prospective Cohort Study. J Hand Surg Am. 2018.

6. Jones G, Cooley HM, Bellamy N. A cross-sectional study of the association between Heberden's nodes, radiographic osteoarthritis of the hands, grip strength, disability and pain. Osteoarthritis Cartilage. 2001;9(7):606-11.

7. Dahaghin S, Bierma-Zeinstra SM, Ginai AZ, Pols HA, Hazes JM, Koes BW. Prevalence and pattern of radiographic hand osteoarthritis and association with pain and disability (the Rotterdam study). Ann Rheum Dis. 2005;64(5):682-7.

8. Bierke S, Petersen W. Influence of anxiety and pain catastrophizing on the course of pain within the first year after uncomplicated total knee replacement: a prospective study. Arch Orthop Trauma Surg. 2017;137(12):1735-42.

9. Hernandez C, Diaz-Heredia J, Berraquero ML, Crespo P, Loza E, Ruiz Iban MA. Pre-operative Predictive Factors of Post-operative Pain in Patients With Hip or Knee Arthroplasty: A Systematic Review. Reumatol Clin. 2015;11(6):361-80.

10. Lewis GN, Rice DA, McNair PJ, Kluger M. Predictors of persistent pain after total knee arthroplasty: a systematic review and meta-analysis. Br J Anaesth. 2015;114(4):551-61.

11. Hanusch BC, O'Connor DB, Ions P, Scott A, Gregg PJ. Effects of psychological distress and perceptions of illness on recovery from total knee replacement. Bone Joint J. 2014;96-B(2):210-6.

12. London DA, Stepan JG, Boyer MI, Calfee RP. The impact of depression and pain catastrophization on initial presentation and treatment outcomes for atraumatic hand conditions. J Bone Joint Surg Am. 2014;96(10):806-14.

13. Oh Y, Drijkoningen T, Menendez ME, Claessen FM, Ring D. The Influence of Psychological Factors on the Michigan Hand Questionnaire. Hand (N Y). 2017;12(2):197-201.

14. Broderick JE, Keefe FJ, Bruckenthal P, Junghaenel DU, Schneider S, Schwartz JE, et al. Nurse practitioners can effectively deliver pain coping skills training to osteoarthritis patients with chronic pain: A randomized, controlled trial. Pain. 2014;155(9):1743-54.

15. de Raaij EJ, Pool J, Maissan F, Wittink H. Illness perceptions and activity limitations in osteoarthritis of the knee: a case report intervention study. Man Ther. 2014;19(2):169-72.

16. Becker SJ, Bot AG, Curley SE, Jupiter JB, Ring D. A prospective randomized comparison of neoprene vs thermoplast hand-based thumb spica splinting for trapeziometacarpal arthrosis. Osteoarthritis Cartilage. 2013;21(5):668-75.

17. Becker SJ, Makarawung DJ, Spit SA, King JD, Ring D. Disability in patients with trapeziometacarpal joint arthrosis: incidental versus presenting diagnosis. J Hand Surg Am. 2014;39(10):2009-15 e8.

18. Makarawung DJ, Becker SJ, Bekkers S, Ring D. Disability and pain after cortisone versus placebo injection for trapeziometacarpal arthrosis and de Quervain syndrome. Hand (N Y). 2013;8(4):375-81.

19. Chung KC, Pillsbury MS, Walters MR, Hayward RA. Reliability and validity testing of the Michigan Hand Outcomes Questionnaire. J Hand Surg Am. 1998;23(4):575-87.

20. Marks M, Audige L, Herren DB, Schindele S, Nelissen RG, Vliet Vlieland TP. Measurement properties of the German Michigan Hand Outcomes Questionnaire in patients with trapeziometacarpal osteoarthritis. Arthritis Care Res (Hoboken). 2014;66(2):245-52.

21. Kroenke K, Spitzer RL, Williams JB, Lowe B. An ultra-brief screening scale for anxiety and depression: the PHQ-4. Psychosomatics. 2009;50(6):613-21.

22. Lowe B, Wahl I, Rose M, Spitzer C, Glaesmer H, Wingenfeld K, et al. A 4-item measure of depression and anxiety: validation and standardization of the Patient Health Questionnaire-4 (PHQ-4) in the general population. J Affect Disord. 2010;122(1-2):86-95.

23. Sullivan MJL, Bishop SR, Pivik J. The Pain Catastrophizing Scale: Development and validation. Psychol Assessment. 1995;7(4):524-32.

24. Osman A, Barrios FX, Gutierrez PM, Kopper BA, Merrifield T, Grittmann L. The Pain Catastrophizing Scale: Further psychometric evaluation with adult samples. J Behav Med. 2000;23(4):351-65.

25. Osman A, Barrios FX, Kopper BA, Hauptmann W, Jones J, O'Neill E. Factor structure, reliability, and validity of the pain catastrophizing scale. J Behav Med. 1997;20(6):589-605.

26. Broadbent E, Petrie KJ, Main J, Weinman J. The brief illness perception questionnaire. J Psychosom Res. 2006;60(6):631-7.

27. Moss-Morris R, Weinman J, Petrie KJ, Horne R, Cameron LD, Buick D. The revised Illness Perception Questionnaire (IPQ-R). Psychology & Health. 2002;17(1):1-16.

28. Broadbent E, Wilkes C, Koschwanez H, Weinman J, Norton S, Petrie KJ. A systematic review and meta-analysis of the Brief Illness Perception Questionnaire. Psychol Health. 2015;30(11):1361-85.

29. Eaton RG, Glickel SZ. Trapeziometacarpal osteoarthritis. Staging as a rationale for treatment. Hand Clin. 1987;3(4):455-71.

30. Dela Rosa TL, Vance MC, Stern PJ. Radiographic optimization of the Eaton classification. J Hand Surg Br. 2004;29(2):173-7.

31. Visser AW, Boyesen P, Haugen IK, Schoones JW, van der Heijde DM, Rosendaal FR, et al. Radiographic scoring methods in hand osteoarthritis--a systematic literature search and descriptive review. Osteoarthritis Cartilage. 2014;22(10):1710-23.

32. Haugen IK, Slatkowsky-Christensen B, Boyesen P, van der Heijde D, Kvien TK. Cross-sectional and longitudinal associations between radiographic features and measures of pain and physical function in hand osteoarthritis. Osteoarthritis Cartilage. 2013;21(9):1191-8.

33. Hoffler CE, 2nd, Matzon JL, Lutsky KF, Kim N, Beredjiklian PK. Radiographic Stage Does Not Correlate With Symptom Severity in Thumb Basilar Joint Osteoarthritis. J Am Acad Orthop Surg. 2015;23(12):778-82.

34. Kroon FPB, van Beest S, Ermurat S, Kortekaas MC, Bloem JL, Reijnierse M, et al. In thumb base osteoarthritis structural damage is more strongly associated with pain than synovitis. Osteoarthritis Cartilage. 2018;26(9):1196-202.

35. Sonne-Holm S, Jacobsen S. Osteoarthritis of the first carpometacarpal joint: a study of radiology and clinical epidemiology. Results from the Copenhagen Osteoarthritis Study. Osteoarthritis Cartilage. 2006;14(5):496-500.

36. Murphy SL, Lyden AK, Phillips K, Clauw DJ, Williams DA. Association between pain, radiographic severity, and centrally-mediated symptoms in women with knee osteoarthritis. Arthritis Care Res (Hoboken). 2011;63(11):1543-9.

37. Hill S, Dziedzic K, Thomas E, Baker SR, Croft P. The illness perceptions associated with health and behavioural outcomes in people with musculoskeletal hand problems: findings from the North Staffordshire Osteoarthritis Project (NorStOP). Rheumatology (Oxford). 2007;46(6):944-51.

Appendix

Supplemental Table 1. *Non-responder analysis for patients who completed the MHQ, but did not complete the psychological questionnaires*

Variables	**Responder (n=428)**	**Non-responder (n=47)**	**P-value**
Age in years	59.9 (7.7)	61.5 (8.9)	0.23
Female (%)	76.9	76.6	1
Hand dominance (%)			0.29
Right	90.7	89.4	
Left	6.8	4.3	
Both	2.6	6.4	
Dominant hand affected (%)	52.6	42.6	0.25
Duration of symptoms in months (median, interquartile range)	12 (6-24)	12 (6-33)	0.38
MHQ-pain (reversed)	53.7 (17.6)	53.5 (17.0)	0.95
MHQ-aesthetics	82.0 (19.8)	78.3 (21.0)	0.24
MHQ-hand function	58.3 (18.4)	57.3 (16.9)	0.70
MHQ-activities of daily life	66.0 (21.9)	65.2 (15.7)	0.38
MHQ-work performance	61.0 (26.0)	66.3 (25.4)	0.18
MHQ-satisfaction	42.8 (21.7)	44.2 (20.3)	0.67
MHQ-total score	59.4 (14.9)	59.8 (14.4)	0.63

** Values reported as mean (SD) unless otherwise stated.*

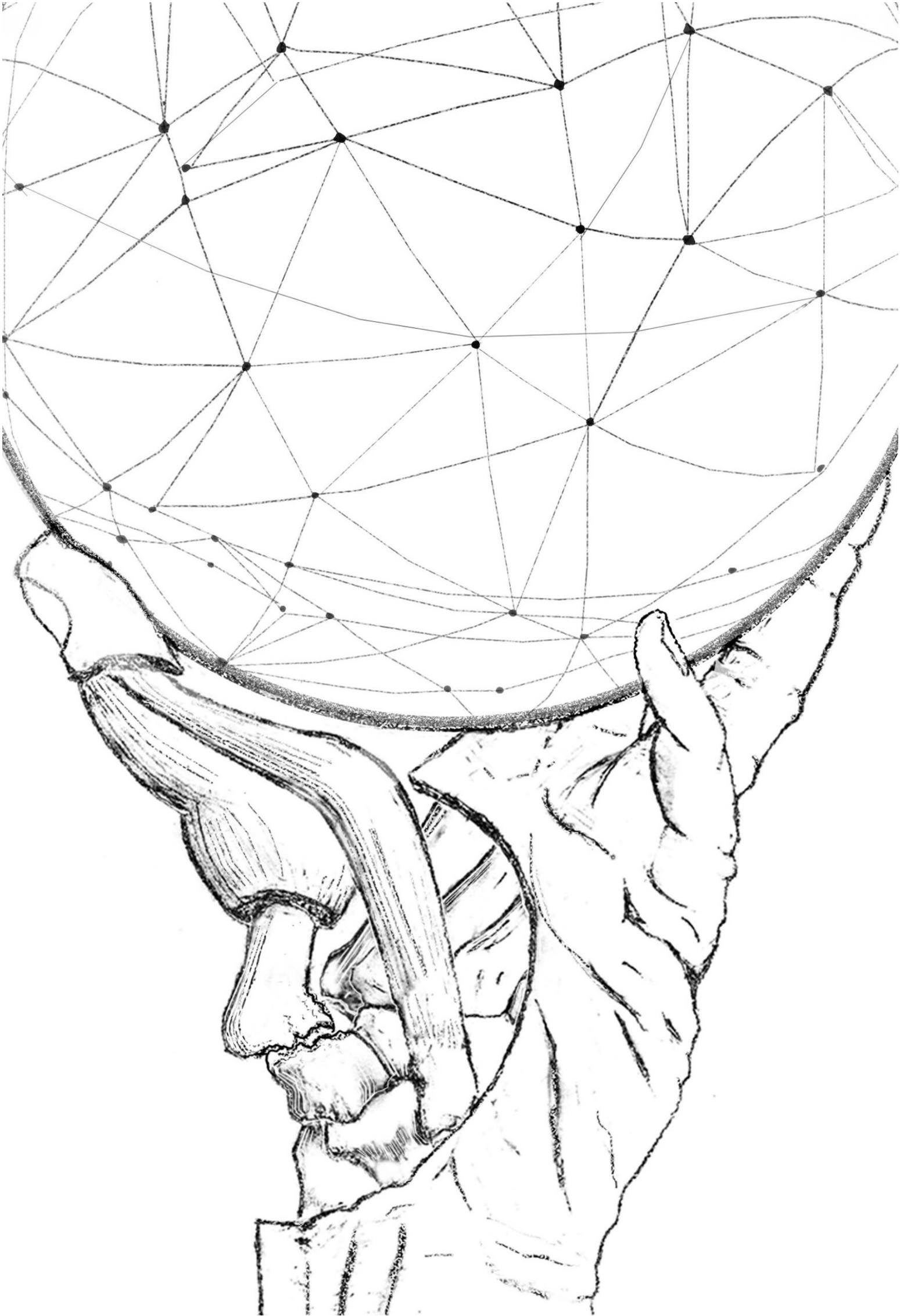
Supplemental Table 2. *Non-responder analysis for patients with complete questionnaires, but without CMC joint X-ray*

	Responder (n=255)	Non-responder (n=173)	P-value
Age in years	59.8 (7.8)	60.1 (7.6)	0.74
Female (%)	74.9	79.8	0.29
Hand dominance (%)			0.82
Right	91.4	89.6	
Left	6.3	7.5	
Both	2.4	2.9	
Dominant hand affected (%)	51. 2	54.4	0.76
Duration of symptoms in months (median, interquartile range)	12 (6-24)	12 (5-24)	0.58
MHQ-pain	52.9 (17.3)	54.8 (18.0)	0.27
MHQ-aesthetics	83.0 (19.5)	80.4 (20.4)	0.12
MHQ-hand function	57.9 (18.0)	59.0 (18.9)	0.54
MHQ-activities of daily life	66.2 (22.2)	65.8 (21.3)	0.79
MHQ-work performance	61.3 (26.4)	60.3 (25.5)	0.81
MHQ-satisfaction	43.2 (22.2)	42.2 (20.8)	0.66
MHQ-total score	59.7 (15.2)	59.1 (14.4)	0.68

** Values reported as mean (SD) unless otherwise stated.*

Supplemental Table 3. *Correlation matrix of the psychological variables*

	1	2	3	4	5	6	7	8	9
1. PHQ total score	___	___	___	___	___	___	___	___	___
2. PCS total score	0.55	___	___	___	___	___	___	___	___
3. B-IPQ Consequences	0.33	0.45	___	___	___	___	___	___	___
4. B-IPQ Timeline	0.09	0.17	0.27	___	___	___	___	___	___
5. B-IPQ Personal control	-0.08	-0.23	-0.06	0.05	___	___	___	___	___
6. B-IPQ Treatment control	-0.12	-0.24	0.02	-0.10	0.31	___	___	___	___
7. B-IPQ Identity	0.17	0.26	0.52	0.24	-0.05	0.02	___	___	___
8. B-IPQ Concern	0.34	0.48	0.60	0.35	-0.11	-0.10	0.50	___	___
9. B-IPQ Understanding	-0.11	-0.22	0.03	0.11	0.13	0.18	0.06	0.003	___
10. B-IPQ Emotional response	0.41	0.53	0.57	0.18	-0.12	-0.08	0.36	0.59	-0.02



THUMB CARPOMETACARPAL OSTEOARTHRITIS: POSITIVE EXPERIENCE WITH TREATMENT IS ASSOCIATED WITH BETTER SURGICAL OUTCOME

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9

Abstract

Introduction: Although patients' experiences with the delivered care can influence treatment outcome, this relationship has not been examined for surgical treatment of thumb carpometacarpal joint (CMC) osteoarthritis. Therefore, the aim of the study was to investigate the association between patients' experiences with CMC arthroplasty and treatment outcomes in terms of patient-reported outcome measures (PROMS).

Methods: Included were eligible patients who received a Weilby procedure for CMC osteoarthritis in 17 outpatient clinics between 2011 and 2017. Before surgery and 12 months postsurgery, patients completed a PROM and the Michigan Hand Outcomes Questionnaire (MHQ) (0-100), and their therapists recorded strength measurements. In addition, at three months post-surgery, a patient-reported experience measure (PREM) (0-10) was completed. Regression analysis was used to examine associations between the different subscales of the PREM and the MHQ change scores, while adjusting for confounders.

Results: A total of 233 patients were included in the analysis. A significant positive association was found between the PROM (the MHQ) and the PREM, with the strongest associations for patients' experiences with i) information provision (B = 4.8, 95% CI 2.5-7.0, $p<0.05$), ii) communication skills of the physician (B = 4.0, 95% CI 1.6-6.4, $p<0.05$), and iii) postoperative care (B = 3.7, 95% CI 1.5 - 5.9, $p<0.05$). No significant associations were found between patient experience and strength measurements. The PREM explained 3.2-8.4% of the variation between patients in the MHQ outcomes.

Conclusion: This study shows a positive association between experiences with healthcare delivery and PROMs in the surgical treatment of CMC osteoarthritis. The results highlight the potential importance of positive experience with the treatment process to improve treatment outcomes in patients undergoing surgery for CMC osteoarthritis.

Introduction

The context in which healthcare is delivered is an important part of a treatment, since the experience with healthcare delivery can contribute to treatment outcomes.[1] Treatment context can be broadly defined as all aspects of the therapeutic context (e.g., treatment rationale, response to treatment) or the healthcare environment (e.g., quality of facilities, hygiene) that may affect patient perceptions across the continuum of care.[2-4] When these aspects have an effect on treatment outcomes which cannot be attributed to the treatment itself, they are called 'contextual effects'.[5,6] In many conditions, influencing the treatment context, e.g. by improving the communication between patient and clinician, can improve patient-reported health status.[7]

To measure these contextual aspects of a treatment, questionnaires are available that can reliably record the patient's experience with the delivered healthcare: such questionnaires are called patient-reported experience measures (PREMs).[8] These questionnaires often focus on different domains of healthcare experience, such as communication with the physician or other healthcare providers, involvement of the patient in the decision-making, delivery of postoperative care, and hygiene of the healthcare facilities. Together with patient-reported outcome measures (PROMs) and therapist-reported outcome measures (TROMs), which are measurements of clinical outcome, PREMs are increasingly used as a measure of quality of care.[9-11]

Observational studies have shown an association between healthcare experience (measured with PREMs) and PROMs in emergency surgery and elective surgery.[12,13] For example, in hip replacement surgery, better experience with the healthcare process was associated with better outcome as measured with the Oxford Hip Score.[14] Another study showed that general practitioners (GPs) who received training in communication and pain evaluation prior to the treatment for osteoarthritis had significantly better outcomes, i.e. their patients experienced significantly less pain compared with patients whose GPs did not receive this training.[15] Moreover, in hand surgery, empathy of the physician was the strongest driver of patient satisfaction, with 66% of the variation in patients satisfaction explained by the empathy of the physician.[16]

Currently, it is unknown why some patients have good outcome after surgery for CMC osteoarthritis, while others have less than optimal outcome and/or residual pain after surgery. Although a relation has been shown between expectations of treatment outcome and patient-reported outcome after treatment of CMC osteoarthritis[17], to our knowledge no study has investigated the effect of the experience of the delivered healthcare on outcome after treatment of CMC osteoarthritis. To elucidate why some patients have good outcomes after CMC arthroplasty while others do not, it is important to take into account the effect of

patient-reported healthcare experiences on postoperative outcome of patients treated for carpometacarpal osteoarthritis of the thumb.

Therefore, this study aimed to investigate which aspects of the experienced healthcare delivery are associated with better treatment outcome after surgery for CMC osteoarthritis in terms of both patient-reported outcomes and therapist-reported outcomes.

Methods

Study design and setting

This cohort study was performed between February 2011 and April 2017 at Xpert clinic in the Netherlands. Xpert clinic is a specialized treatment center for hand and wrist problems. Xpert clinic has 17 different locations, with 16 European Board certified (FESSH) hand surgeons and over 50 hand therapists. The study was approved by the local institutional review board and written informed consent was obtained from all patients.

Included were patients who underwent surgery for their symptomatic CMC osteoarthritis. During the study period, no non-certified hand surgeons or fellows performed the surgical procedure. Patients were invited to fill in a PROM questionnaire prior to surgery and 12 months postoperatively. In addition, 3 months postoperatively, patients were also asked to fill in a PREM questionnaire to rate their experience with the delivered healthcare. To include a homogenous group, patients who underwent a surgical treatment other than the Weilby procedure were excluded from the analysis. Also excluded were patients who did not fill in either the PROM questionnaires or the PREM questionnaires.

Treatment

In the Weilby technique[18], after a Wagner incision, first the trapezium was removed (while preserving the superficial nerve of the radial nerve). Then, the flexor carpi radialis distal pedicled tendon strip was intertwined in a figure of eight reconstruction round the abductor pollicis longus and distal flexor carpi radialis insertion. Lastly, the excessive tendon split was placed in the trapezial cavity as a spacer. Postoperatively, patients received plaster cast immobilization for 3-14 days. Thereafter, the cast was replaced by a custom-made removable splint. Hand therapists provided hand therapy, divided into two phases of six weeks. Phase one included instructions to wear the splint during heavy activities; this consisted of hand therapy to optimize the position of the thumb and to use a full thumb range of motion. In phase two, the splint was slowly phased out; the patient practiced the learned stability during daily activities and also improved thenar muscle strength.[19] Patients performed home exercises 4-6

times a day. The number of prescribed home exercises ranged from 3-6 exercises, with 10-15 repetitions each.

Baseline demographics

Baseline characteristics of all patients (including age, gender, occupational status and hand dominance) were collected before start of treatment.

Patient-reported outcome measures (PROMS)

To evaluate treatment outcome, patients were invited to fill in the Michigan Hand Questionnaire[20-22] (MHQ, Dutch Language Version, MHQ; 0 = poorest function, 100 = ideal function) before surgery and at 12 months postoperatively. The MHQ is a self-reported questionnaire with six domains (pain, esthetics, hand function, performance of activities of daily living, work performance and satisfaction) and 37 items. For non-traumatic hand conditions, minimal clinically important difference (MCID) for the total MHQ ranges from 9-13 points.[23] Furthermore, all subdomains have excellent internal consistency, with Cronbach's alpha ranging from 0.86-0.97 for the subscales.[20]

Patient-reported experience measures (PREMS)

To rate patients' perceived experience with the provided healthcare, patients completed a PREM questionnaire that is widely used in private practice clinics in the Netherlands.[24] The PREM questionnaire consists of 25 items divided into six subscales to rate patients' perceived experience. The six subscales were: quality of facilities (6 items), physician communication and competence (6 items), perioperative care (4 items), postoperative care (4 items), treatment information (3 items), and general information (2 items). Each item was graded on a 10-point scale, where 1 represents 'very poor experience', and 10 'excellent experience'. The full questionnaire is published in the study of Poelstra et al.[24]

Therapist-reported outcome measures (TROMS)

Using a Jamar-type hydraulic hand dynamometer, tip pinch and key pinch were measured by the hand therapist at baseline and at 12 months postoperatively. All strength measurements were recorded as the mean of three consecutive measurements[25] in accordance with the Dutch treatment guideline for CMC osteoarthritis.[19] The MCID was 0.33 kg for tip pinch and 0.84 kg for key pinch.[26]

Statistical methods

Data for this study was collected during daily clinical practice, which led to some attrition at follow-up (Fig. 1). Because of this non-response, a thorough non-responder analysis was performed to compare patients that did and those that did not fill in the questionnaires at 3 months, using Chi-square statistics or t-tests for all variables measured at baseline based on the response at 3 months.

Paired t-tests were performed to investigate whether the change in outcome measured in both PROMS and TROMS at 12 months post-surgery was significant. Linear regression analysis was used to examine the univariable relationship between PREMS and the change in outcome after surgery (PROMS + TROMS) and were reported as beta coefficients.

To examine the extent to which the variation in treatment outcomes between patients could be explained by the experience of the delivered healthcare, explained variance (R2) was calculated for treatment outcomes when all PREM subscales were entered simultaneously in a multiple linear regression model. All analyses were done using R statistical computing, version 3.3.3. For all tests, a p-value ≤0.05 was considered statistically significant.

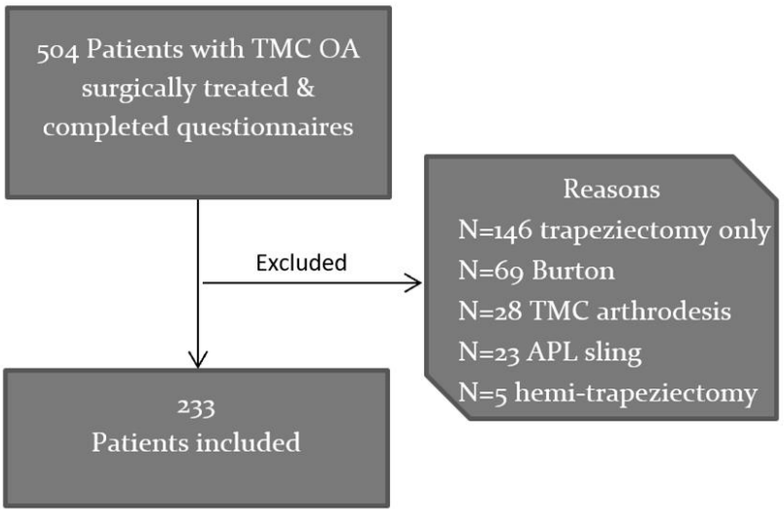


Figure 1. *Flowchart showing the selection of patients and the reasons for exclusion. Of the 504 identified patients, 233 were included for the analyses.*
Abbreviations: CMC OA = Carpometacarpal osteoarthritis; APL = Abductor Pollicis longus; PROM = Patient- Reported Outcome Measure; PREM = Patient-Reported Experience Measure.

Results

Between 2011 and 2017, a total of 504 patients with CMC osteoarthritis were operated. After applying the exclusion criteria, 233 patients were included for a complete case analysis (Fig. 1). At baseline, no significant differences were found between patients that filled in all the questionnaires and those that did not fill in all the questionnaires at follow-up, except for a small but significant difference in MHQ work (see Supplementary Table 2). The mean age of the patients was 59.3 (SD ±7.9) years, and 82% of the patients were female. Furthermore, 48% was either unemployed or retired, and 48% had surgery on their dominant hand. At 12 months post-surgery, all

improvements in MHQ total and MHQ subscales were significant and clinically important (i.e. they exceeded the MCID described in Methods), except for the MHQ subscale 'esthetics' (Table 1). Change in the therapist-reported outcomes key pinch strength at 12 months post-surgery was not significant, whereas the improvement in tip pinch strength was significant and clinically important (Table 1). Lastly, on average, patients had very high satisfaction with the whole treatment experience, with all subscales of the PREMS scoring ≥8.0 on a 1-10 scale.

Table 1. *Preoperative and postoperative outcome scores.*

	Preoperative	Postoperative
PREM scores: median (IQR)		
Physician: communication & competence		8.3 (7.8-9.0)
Perioperative care		8.5 (8.0-9.0)
Postoperative care		8.4 (8.0-9.0)
General information		8.2 (8.0-9.0)
Treatment information		8.3 (7.7-9.0)
Quality of facilities		8.4 (7.8-9.0)
PROM scores: mean (SD)		
Total	48 (13)	69 (19)*
General function	47 (16)	63 (18)*
ADL	49 (21)	76 (22)*
Pain	33 (13)	60 (23)*
Esthetics	79 (21)	85 (20)*
Satisfaction	28 (17)	65 (28)*
Work	44 (23)	64 (28)*
Objective outcome scores (SD)		
Key pinch	4.4 (2)	4.8 (2)
Tip pinch	18.9 (9)	24.8 (9)*

** p<0.05. Abbreviations: IQR = Interquartile range, ADL = Activity of daily living*

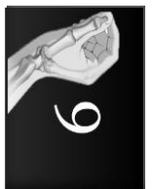
Regression analysis showed a positive association between PREM subscales and PROM subscales, with the 'general information' subscale of the PREM having the highest association with the change in PROM subscales (Table 2). Beta coefficients of the regression analysis are presented in Table 2 and show, for instance, that each 1-point improvement in PREM subscale general information (1-10) resulted in an 8.1-point increase on the MHQ satisfaction subscale (0-100). In contrast to the PROMS, no significant association was found between the PREM subscales and change in key pinch or tip pinch strength.

Multiple regression analysis showed that, when combining all the individual PREM subscales into one model to match the PROM, the PREM subscales explained 3-8% of the variation in patient-reported outcome between patients (Table 2. bottom

row). The PREM subscales had the strongest association with the total score of the MHQ, with 8.4% of the variance explained by the subscales of the PREM. Again, no associations were found between PREM subscales and change in key pinch or tip pinch strength.

Table 2. *Univariable regression analysis of the association between experience with the delivered healthcare (PREM) and outcome after surgery (PROM + TROM), displayed as beta-coefficients (with 95% confidence interval). Bottom row presents the results of the multiple regression analysis and shows how much of the variation in the subscales of the PROMS are explained by the PREM, when the PREM subscales are combined in one model to reflect the different subscales of the PROM and TROM.*

	Change in PROM							Change in TROM	
PREM	**Total**	**General function**	**ADL**	**Pain**	**Esthetics**	**Satisfaction**	**Work**	**Key pinch**	**Tip pinch**
Physician communication & competence	4.0 (1.6 - 6.4)*	1.2 (-1.7 - 4.0)	4.7 (1.1 - 8.2)*	5.5 (2.3 - 8.7)*	3.5 (-0.1 - 7.0)	5.9 (1.8 - 9.9)*	5.4 (1.5 - 9.3)*	0.1 (-0.3 - 0.6)	-0.3 (-2.3- 1.8)
Perioperative care	2.5 (0.0 - 5.0)*	1.0 (-1.9 - 3.9)	2.8 (-0.8 - 6.5)	3.1 (-0.3 - 6.4)	0.9 (-2.6 - 4.6)	5.3 (1.1 - 9.4)*	3.4 (-0.6 - 7.4)	0.2 (-0.2 - 0.6)	-0.3 (-2.2-1.5)
Postoperative care	3.7 (1.5 - 5.9)*	1.7 (-0.8 - 4.3)	4.6 (1.4 - 7.8)*	4.1 (1.1 - 7.0)*	3.0 (-0.2 - 6.3)	5.0 (1.3 - 8.7)*	5.0 (1.4 - 8.5)*	-0.2 (-0.5 - 0.2)	-0.3 (-2.3 - 1.6)
General information	4.8 (2.5 - 7.0)*	3.2 (0.5 - 5.9)*	5.7 (2.3 - 9.0)*	5.3 (2.2 - 8.3)*	4.0 (0.6 - 7.3)*	8.1 (4.3 - 11.8)*	4.4 (0.7 - 8.1)*	0.1 (-0.3 - 0.6)	-0.2 (-2.1 – 1.7)
Treatment information	3.6 (1.3 - 5.9)*	0.7 (-2.0 - 3.3)	3.0 (-0.3 - 6.4)	3.9 (0.8 - 6.9)*	4.7 (1.4 - 8.0)*	6.2 (2.4 - 10.0)*	3.8 (0.1 - 7.5)*	0.0 (-0.4 - 0.4)	-0.6 (-2.5 – 1.3)
Quality of facilities	4.5 (1.7 - 7.3)*	1.9 (-1.3 - 5.2)	3.6 (-0.5 - 7.7)	5.8 (2.1 - 9.5)*	5.0 (0.9 - 9.1)*	6.1 (1.4 - 10.8) *	6.5 (2.0 - 11.0)*	0.2 (-0.3 - 0.7)	-0.3 (-2.5- 1.9)
Explained variance (R^2)	8.4 %*	3.2 %	6.7 %*	7.1 %*	4.7 %	7.8 %*	5.0 %	4.4 %	0.0 %



Discussion

The main objective of this study was to investigate which aspects of experienced healthcare delivery are associated with treatment outcomes after surgery for carpometacarpal osteoarthritis of the thumb. It was found that patients who reported a more positive experience with the delivered healthcare had better self-reported outcomes in terms of pain and function. Patient experiences with i) general information provided to patients and ii) better postoperative care delivery, were most strongly associated with a positive change in treatment outcomes. In contrast, no association was found between the experience of the delivered care and therapist-reported outcomes of hand strength. Lastly, PREMs explained 3-8% of the variance in the change in therapist-reported outcome.

Our findings are in line with similar studies, but with different patient populations. For example, in patients undergoing knee or hip replacement, Black et al.[14] found that communication and trust in their doctor had the highest association with patient-reported outcome. We found similar results, with strong univariate associations between physician's communication and patient-reported outcome in terms of pain and satisfaction.

Since the role of treatment context on outcomes in hand surgery has not yet been thoroughly studied, it is difficult to compare our results with other studies. However, Poelstra et al.[24] who examined the association between treatment context and treatment outcome after Dupuytren's disease, showed that treatment context was also positively associated with PROMS. More specifically, they found that the subscales 'physician communication', 'postoperative care' and 'treatment information' were most strongly associated with outcome. We found very similar results, with a strong association between the subscales 'physician communication' and 'general information' and patient-reported outcomes.

In addition, Menendez et al.[16] showed that one aspect of treatment context, i.e. the perceived empathy of their physician, was correlated with higher overall satisfaction with their provider. Our study showed that also other aspects of treatment context, e.g. perioperative and postoperative care, are associated with treatment outcomes in terms of pain, function and satisfaction.

Although our study had an observational design, an intervention study by Basch et al.[27], examining the effects of symptom monitoring during routine cancer care, showed that patients who received symptom monitoring during their cancer treatment had less decline in quality of life compared to patients who received usual care (1.4-point v 7.1-point drop; $p < 0.001$). More interventional research is required to assess whether improving various aspects of healthcare delivery in surgical treatments for CMC osteoarthritis leads to better treatment outcomes.

There are many reasons why the experience of healthcare delivery is associated with patient-reported outcomes. For example, we found that the general information provided on the website and the brochure had the highest association with outcomes after surgical treatment for CMC1 osteoarthritis. As we designed and produced a video for our website showing which steps are performed during surgery and what the entire treatment will consist of (including the postoperative rehabilitation process), patients may have felt they knew what to expect, which may have resulted in better postoperative exercise adherence, which may have led to better treatment outcomes.

Another explanation is that providing adequate information on general treatment, and good communication with the patient, may lead to altered expectations of outcome. It is becoming clearer that treatment expectations are a cornerstone in context effects[28] and can be adjusted by either discussing treatment beliefs[29], using an empathetic communication style[30], or by performing short psychological interventions in forms of therapy.[12,31] In addition, a trustful caregiver-caretaker relationship where patients feel understood and taken seriously may lead to better postoperative rehabilitation treatment adherence which may lead to better patient-reported treatment outcome.[32] The present study did not find a positive association between treatment context and strength measurements, possibly because no marked improvements were seen in strength post-surgery.

Our study has a several strengths and limitations. The main strength is the large sample population and the observational study design. Another strength is the relatively high level of generalizability, since our data were collected in daily clinical practice instead of the more controlled setting of a randomized controlled trial. In addition, the collection of data took place in 17 outpatient clinics throughout the Netherlands, providing a representative sample of the population of patients with CMC osteoarthritis. Furthermore, the well-validated and tested MHQ was used to measure the PROMs.

A limitation of the study is that the PREM questionnaire has not yet been thoroughly tested and may have omitted other important aspects of treatment context. For example, the validated OAS-CAHPS questionnaire includes questions on the recovery period after surgery, which our PREM questionnaire did not include.[33]

Furthermore, an important part of contextual effects is the expectations of the patient regarding the treatment. Patients who have more positive or optimistic expectations may have reported more positive experiences with the delivered healthcare, irrespective of the actual delivered care; this may be a confounder and warrants more research.

A critical note is that it is impossible to know whether the associations found are causal, i.e. it remains unclear whether patients have a better outcome because of the better experience, or whether they have better experience because of a better

outcome. Future studies with an appropriate design should further investigate this topic.

Finally, we could only include 233 of the initial 504 patients in our complete case analysis. However, our analysis of the patients who did not complete all questionnaires showed only a slight significant difference on the work subscale of the MHQ.

In conclusion, the present study shows that experience with the delivered care of patients with CMC osteoarthritis is positively associated with patient-reported outcomes, whereas no association was found between experience with the delivered care and therapist-reported outcomes. This study highlights the potential importance of positive experiences with the treatment process for improving treatment outcomes in patients treated for CMC osteoarthritis. Educating surgeons and other healthcare providers about such contextual effects may be a valuable addition to their skillset.

References

1. Curran J. The Doctor, his Patient and the Illness. BMJ. 2007;335:941.

2. Arnold MH, Finniss DG, Kerridge I. Medicine's inconvenient truth: The placebo and nocebo effect. Intern. Med. J. 2014;44:398–405.

3. Connor-Greene PA. The therapeutic context: Preconditions for change in psychotherapy. Psychotherapy. 1993;30:375–382.

4. Wolf J, Niederhauser V, Marshburn D, Lavela SL. Defining patient experience. Patient Exp. J. 2014;1:7–19.

5. Miller FG, Kaptchuk TJ. The power of context: Reconceptualizing the placebo effect. J. R. Soc. Med. 2008;101:222–225.

6. Moerman DE, Jonas WB. Deconstructing the placebo effect and finding the meaning response. Ann. Intern. Med. 2002;136:471–476.

7. Di Blasi Z, Harkness E, Ernst E, Georgiou A, Kleijnen J. Influence of context effects on health outcomes: a systematic review. Lancet. 2001;357:757–762.

8. Manary MP, Boulding W, Staelin R, Glickman SW. The Patient Experience and Health Outcomes. N. Engl. J. Med. 2013;368:201–203. Available at: http://www.nejm.org/doi/10.1056/NEJMp1211775.

9. Anon. Hospital Value-Based Purchasing. Available at: https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/hospital-value-based-purchasing/index.html?redirect=/Hospital-Value-Based-Purchasing/.

10. Nilsson E, Orwelius L, Kristenson M. Patient-reported outcomes in the Swedish National Quality Registers. J. Intern. Med. 2016;279:141–153.

11. Roland M. Linking Physicians' Pay to the Quality of Care — A Major Experiment in the United Kingdom. N. Engl. J. Med. 2004;351:1448–1454. Available at: http://www.nejm.org/doi/abs/10.1056/NEJMhpr041294.

12. Howe LC, Goyer JP, Crum AJ. Harnessing the placebo effect: Exploring the influence of physician characteristics on placebo response. Heal. Psychol. 2017;36:1074–1082.

13. Jones CH, O'Neill S, McLean KA, Wigmore SJ, Harrison EM. Patient experience and overall satisfaction after emergency abdominal surgery. BMC Surg. 2017;17.

14. Black N, Varaganum M, Hutchings A. Relationship between patient reported experience (PREMs) and patient reported outcomes (PROMs) in elective surgery. BMJ Qual. Saf. 2014;23:534–543.

15. Chassany O, Boureau F, Liard F, Bertin P, Serrie A, Ferran P, Keddad K, Jolivet-Landreau I, Marchand S. Effects of training on general practitioners' management of pain in osteoarthritis: a randomized multicenter study. J. Rheumatol. 2006;33:1827–1834.

16. Menendez ME, Chen NC, Mudgal CS, Jupiter JB, Ring D. Physician Empathy as a Driver of Hand Surgery Patient Satisfaction. J. Hand Surg. Am. 2015;40:1860–1865.

17. Frouzakis R, Herren DB, Marks M. Evaluation of expectations and expectation fulfillment in patients treated for trapeziometacarpal osteoarthritis. J. Hand Surg. Am. 2015;40:483–490.

18. Weilby A. Tendon interposition arthroplast of the first carpo-metacarpal joint. J. Hand Surg. Am. 1988;13:421–425.

19. Van Uchelen, J, Beumer A, Brink SM, Hoogvliet P, Moojen TM, Spaans AJ VG. Dutch guideline for conservative and surgical treatment for primary thumb base osteoarhtritis. Amsterdam, Netherlands NVPC, NVVH, NOV, VRA, VvBN. 2014.

20. Chung, KC, Pillsbury MS, Walter MR HR. Reliability and validity testing of the Michigan Hand Outcome Questionnaire. J. Hand Surg. Am. 1998;23:575–587.

21. van der Giesen FJ, Nelissen RG, Arendzen JH, de Jong Z, Wolterbeek R, Vliet Vlieland TP. Responsiveness of the Michigan Hand Outcomes Questionnaire-Dutch Language Version in Patients With Rheumatoid Arthritis. Arch. Phys. Med. Rehabil. 2008;89:1121–1126.

22. Marks M, Audige L, Herren DB, Schindele S, Nelissen RGHH, Vliet Vlieland TPM. Measurement properties of the German Michigan Hand Outcomes Questionnaire in patients with trapeziometacarpal osteoarthritis. Arthritis Care Res. (Hoboken). 2014;66:245–252.

23. London DA, Stepan JG, Calfee RP. Determining the Michigan Hand Outcomes Questionnaire minimal clinically important difference by means of three methods. Plast. Reconstr. Surg. 2014;133:616–625. Available at: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=medl&NEWS=N&AN=24572853.

24. Poelstra R, Selles RW, Slijper HP, van der Oest MJW, Feitz R, Hovius SER, et al. Better patients' treatment experiences are associated with better postoperative results in Dupuytren's disease. J Hand Surg Eur Vol. 2018;43(8):848-54.

25. Mathiowetz V, Weber K, Volland G, Kashman N. Reliability and validity of grip and pinch strength evaluations. J. Hand Surg. Am. 1984;9:222–226.

26. Villafañe JH, Valdes K, Bertozzi L, Negrini S. Minimal clinically important difference of grip and pinch strength in women with thumb carpometacarpal osteoarthritis when compared to healthy subjects. Rehabil. Nurs. 2015.

27. Basch E, Deal AM, Kris MG, Scher HI, Hudis CA, Sabbatini P, Rogak L, Bennett A V., Dueck AC, Atkinson TM, Chou JF, Dulko D, Sit L, Barz A, Novotny P, Fruscione M, Sloan JA, Schrag D. Symptom monitoring with patient-reported outcomes during routine cancer treatment: A randomized controlled trial. J. Clin. Oncol. 2016;34:557–565.

28. Crow R, Gage H, Hampson S, Hart J, Kimber A, Thomas H. The role of expectancies in the placebo effect and their use in the delivery of health care: A systematic review. Health Technol. Assess. (Rockv). 1999;3.

29. Laferton JAC, Auer CJ, Shedden-Mora MC, Moosdorf R, Rief W. Optimizing preoperative expectations in cardiac surgery patients is moderated by level of disability: The successful development of a brief psychological intervention. Psychol. Heal. Med. 2016;21:272–285.

30. Kaptchuk TJ, Kelley JM, Conboy LA, Davis RB, Kerr CE, Jacobson EE, Kirsch I, Schyner RN, Nam BH, Nguyen LT, Park M, Rivers AL, McManus C, Kokkotou E, Drossman DA, Goldman P, Lembo AJ. Components of placebo effect: randomised controlled trial in patients with irritable bowel syndrome. BMJ. 2008;336:999–1003. Available at: http://www.bmj.com/cgi/doi/10.1136/bmj.39524.439618.25.

31. Rief W, Shedden-Mora MC, Laferton JAC, Auer C, Petrie KJ, Salzmann S, Schedlowski M, Moosdorf R. Preoperative optimization of patient expectations improves long-term outcome in heart surgery patients: results of the randomized controlled PSY-HEART trial. BMC Med. 2017;15:4. Available at: http://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-016-0767-3.

32. Street RL, Makoul G, Arora NK, Epstein RM. How does communication heal? Pathways linking clinician-patient communication to health outcomes. Patient Educ. Couns. 2009;74:295–301.

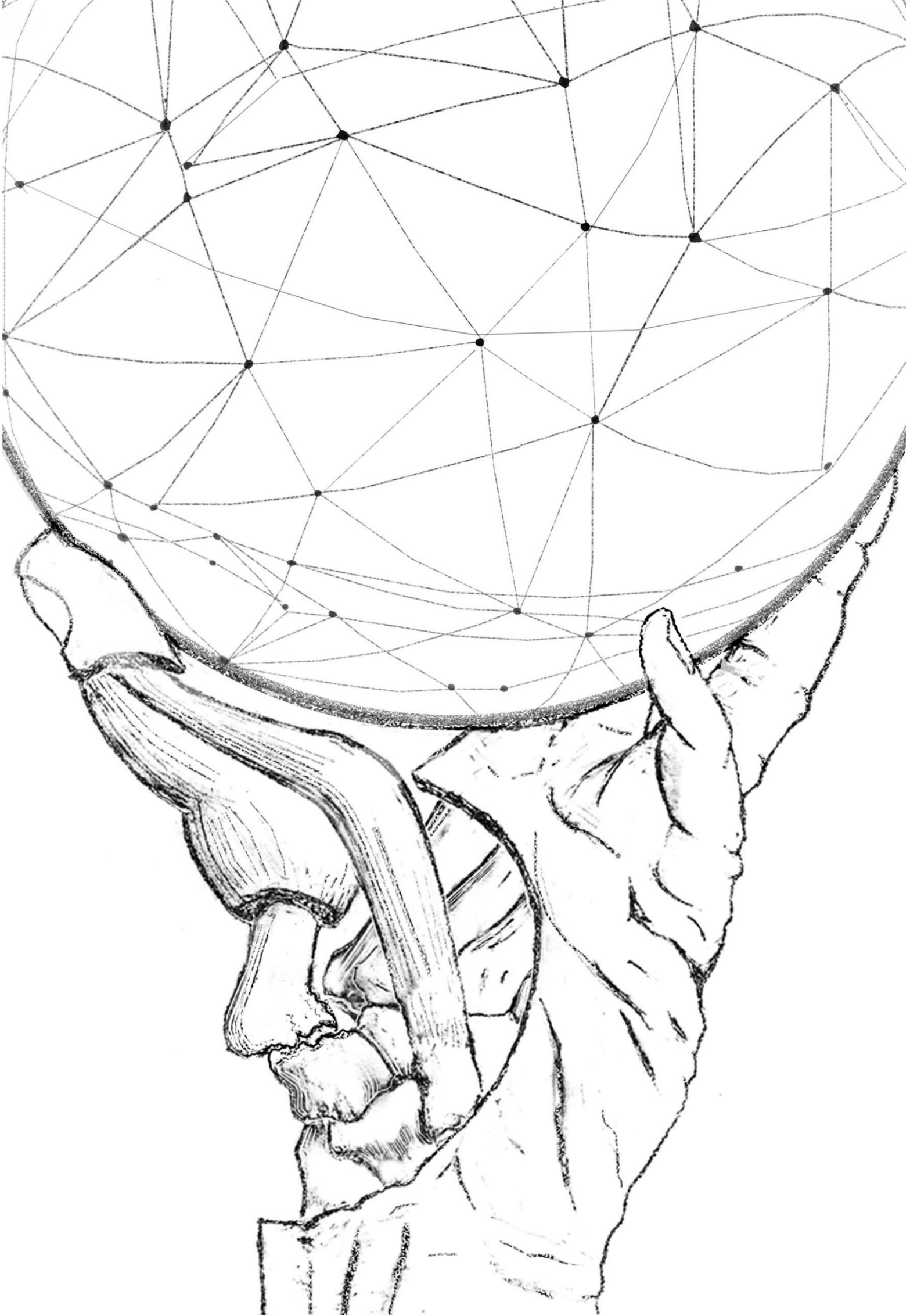
33. Darby C, Hays RD, Kletke P. Development and evaluation of the CAHPS® Hospital Survey. Health Serv. Res. 2005;40:1973–1976.

Appendix

Supplementary Table 1. *Baseline characteristics of not included and included patients*

Variables	Not included patients (n=271)	Included patients (n-233)	*p*-value
Mean age: years (SD)	60 ± 9	59 ± 8	0.11
Sex (% female)	77.9	82.0	0.24
Occupational intensity (%)			0.40
Unemployed/retired	48.4	42.5	
Light	18.3	21.5	
Moderate	21.4	23.6	
Heavy	12.0	12.4	
Surgery on dominant hand (% yes)	48.3	44.8	0.29
MHQ Total	49 ± 14	48 ± 13	0.23
MHQ General hand function	48 ± 17	47 ± 16	0.15
MHQ ADL	52 ± 22	49 ± 21	0.12
MHQ Pain	34 ± 15	33 ± 13	0.81
MHQ Esthetics	76 ± 22	79 ± 21	0.10
MHQ Work	47 ± 25	44 ± 23	0.02
MHQ Satisfaction	29 ± 19	28 ± 17	0.21

Abbreviations: MHQ = Michigan Hand questionnaire, ADL= Activity of daily living



SUMMARY & GENERAL DISCUSSION

10

Thumb carpometacarpal osteoarthritis: Prediction, rehabilitation and contextual effects

This thesis addressed several aspects of thumb carpometacarpal osteoarthritis treatment. The general aims were: To study outcome of exercise therapy and its relationship with surgery; To provide an overview of literature describing different postoperative rehabilitation protocols and to study the effect of different postoperative cast immobilizations after thumb CMC surgery; To study to what extent psychological factors played a role in the experienced pain and disability in patients with thumb CMC osteoarthritis and if patients' experience with healthcare delivery was associated with treatment outcome in patients being surgically treated for their thumb CMC osteoarthritis.

This discussion is structured in three parts: 1. Treatment outcome, prediction and conversion to surgery, 2. Postoperative rehabilitation after CMC arthroplasty, 3. Psychological factors and contextual effects in thumb CMC osteoarthritis. In this chapter, the findings of the three parts mentioned above are discussed. We will end the discussion with our limitations and future perspectives.

General discussion

The general aim in Part 1 was to study outcome after exercise therapy and its relationship with surgery. The primary findings in Part 1 were that superior outcome of exercise therapy and hand orthosis was found in patients with CMC OA compared to hand orthosis alone. When studying the one-year outcome of the patients that received exercise therapy and hand orthosis, we observed that most of this improvement was gained in the first six weeks of treatment, whereafter improvements stabilized until one year. Moreover, we found that satisfaction, pain and function measured at baseline explained a moderate variation of the outcome of these parameters after conservative treatment. Furthermore, after a mean follow-up time of 2.2 years, only a small minority of patients (15%) received additional surgical treatment after receiving exercise therapy and hand orthosis and also that pain and function measured at baseline were significant predictors for converting to surgery. When evaluating the influence of change in outcome during exercise therapy on conversion to surgery, change in self-reported pain during treatment was associated with the probability of conversion to surgery, whereas change in self-reported function had no significant influence on conversion.

Our results support current clinical guidelines stating that treatment for CMC OA should first be non-surgical, because, at a group level, outcome significantly improved up to 1 year after treatment and the majority of patients did not undergo

additional surgical treatment within the first 2 years. Therefore, for all patients with CMC OA, we strongly recommend starting with hand orthosis and exercise therapy, even when experienced pain and disability is high. In addition, we suggest that structured monitoring of self-reported pain during after conservative treatment might help to adjust exercise therapy treatment, providing a more patient-specific treatment.

The general aim in Part 2 was to provide an overview of literature describing different postoperative rehabilitation protocols and to study different postoperative cast immobilizations after thumb CMC surgery. In Part 2, we presented a summary of the present postoperative rehabilitation for different surgical interventions in literature and found that the total immobilization varied substantially, from 2 to 12 weeks. Furthermore, we found that early active recovery (including short immobilization, early initiation of ROM and strength exercises) provides positive outcomes for patients who underwent CMC arthroplasty and is used more often in literature. Additionally, shorter immobilization (3-5 days) provided equal outcomes in terms of pain, function, complications, ROM and strength compared to longer immobilization (10-14 days) after Weilby procedure for thumb CMC osteoarthritis.

Hence, we conclude that shorter immobilization is safe and can be recommended due to its potential benefits by preventing longer patient discomfort and reducing postoperative complications due to longer immobilization.

The general aim in Part 3 was to study to what extent psychological factors play a role in the experienced pain and disability in patients with thumb CMC osteoarthritis and if patients' experience with healthcare delivery was associated with treatment outcome in patients being surgically treated for their thumb CMC osteoarthritis. In Part 3, we found that psychological distress was reported by 7,8% of the patients, and that psychological factors explained 47% of the variance in experienced pain by patients, while patient characteristics and X-ray scores accounted for only 6% of the variation in experienced pain. Our results show that psychological factors are more strongly related to pain levels prior to non-operative treatment in patients with CMC osteoarthritis than patient characteristics and X-ray scores. Furthermore, patients who reported a more positive experience with the delivered healthcare had better self-reported outcomes after surgery in terms of pain and function. Patient experiences with i) general information provided to patients and ii) better postoperative care delivery, were most strongly associated with a positive change in treatment outcomes. In contrast, no association was found between the experience of the delivered care and therapist-reported outcomes of hand strength.

These findings show that in thumb CMC osteoarthritis, the influence of pathology (e.g., radiographic severity) and strength measurements on patient-

experienced pain both before treatment as after treatment is limited. In contrast, these findings show the potential importance of psychological factors and positive experiences with the treatment process for improving treatment outcomes in patients treated for thumb CMC osteoarthritis. Educating surgeons and other healthcare providers about such contextual effects may be a valuable addition to their skillset.

Limitations

The studies in this thesis have limitations that need to be discussed. In Part 1, an important limitation was that exercise therapy was not completely standardized. Therapists adjusted treatment to the specific condition of the patient, severity of the complaints, time schedule, and type of insurance of the patient. At the same time, this limitation was also a strength of the studies, recording how exercise therapy is performed in actual clinical practice, outside of the more controlled and potentially less natural setting of a randomized controlled trial. Furthermore, inherent to the cohort nature of the studies is that a control group was lacking. Therefore, the studies did not provide information on what the relative effectiveness is compared with, for example, no treatment. Furthermore, as with most observational studies, we had to deal with a substantial proportion of missing data. An important reason for missing data was that patients who had residual pain or functional complaints after being treated with exercise therapy and an orthosis received surgical treatment and therefore were "missing" at follow-up. Another possible reason for our missing data is that patients may have gone elsewhere to receive treatment. However, after thoroughly testing if missing data resulted in bias, we concluded that no evident bias occurred. In addition, we used various statistical techniques to account for potential bias.

In Part 2, a weakness of the systematic review was the large number of low-quality studies included. Despite that findings of the individual studies are in line with each other, no conclusions on the effectiveness of postoperative rehabilitation following CMC arthroplasty can be drawn since comparative studies are lacking and large heterogeneity in outcome measures and measurement instruments is present. A limitation of our propensity score matched study comparing two immobilization protocols was that patients were included in two different time periods, resulting in therapists knowing which treatment patients were receiving. However, therapists treating the patients were not aware of the present research question at the time of treatment. Furthermore, we used propensity score matching to correct for potential bias, the only risk being that selection bias still might have occurred if not all relevant covariates were measured at baseline. Another limitation of this study was that we investigated shorter cast immobilization and earlier transition to an orthosis without

wrist immobilization, but only small differences were present in total immobilization period between both groups. For example, we did not study potential differences in outcome following 6 weeks or 10 weeks of total immobilization. Therefore, the effect of different time frames in total immobilization periods remains partially unclear.

In Part 3, a limitation was the quality of the X-rays that we used to score the thumb CMC osteoarthritis. As these X-rays were taken as part of daily clinical practice, we were unable to obtain a Bett's view for all X-rays, making it difficult to score all radiographic osteoarthritis. Another limitation was that the PREM questionnaire had not yet been thoroughly tested and may have omitted other important aspects of treatment context. Additionally, a critical note is that it is impossible to know whether the associations found are causal, i.e. it remains unclear whether patients have a better outcome because of the better experience, or whether they have a better experience because of a better outcome.

Future perspectives

In Part 1, we reported one-year outcome of exercise therapy and conversion to surgery rates after a median follow-up of 2.2 years. The relatively short follow-up made it difficult to draw conclusions regarding the outcome of exercise therapy and the effectiveness of exercise therapy over longer periods in time since thumb CMC osteoarthritis is a degenerative process that develops over multiple years. Future studies could investigate longer-term outcome after exercise therapy and to study how many patients convert to surgery in a later period of their disease. In addition, we found predictors of the variation in treatment outcome in patients treated for their thumb CMC osteoarthritis. With the current predictors, we are not able to accurately predict which patients benefit from exercise therapy and which not. In addition, we are not able to accurately predict which patients will opt for surgery. Future studies could focus on finding other predictors that predict both treatment outcome after exercise therapy as well as conversion to surgery. We will elaborate on this topic in more detail below.

A study of Wilkens et al.[1] showed the variation in treatment choices were influenced by surgeon characteristics and preferences, and ideally, variation should be based on patient's values rather than clinician's values. To do so, decision aids can be used to help patients, as decision aids may reduce decisional conflicts and make patients more comfortable in their decision to choose which treatment to undergo, leading to a more patient-centered care.[2] For example, decision tools can be developed which can predict the percentage of pain reduction or satisfaction after treatment based on certain characteristics/measurements of the patient. Using these tools, surgeons and other care providers are able to better advise and guide patients in their

treatment selection and may sometimes discourage or encourage certain treatments. Future studies may assess if decision aids may lead to better patient selection and treatment outcomes after treatment for thumb CMC osteoarthritis.

In Part 2, we investigated the effect of shorter immobilization, but not of early active and more progressive exercise therapy, including early initiation of ROM and strengthening exercises. Future research should investigate the feasibility and possible beneficial effects of early active exercise therapy in addition to shorter immobilization. Early active exercise therapy may be preferable since less postoperative stiffness and muscle atrophy will occur. Therefore, longer patient discomfort may be prevented and again, patients will recover more quickly while returning earlier to work and daily activities. Additionally, earlier start of rehabilitation may lead to faster recovery of the patient with similar outcomes, which in turn will lead to reduced loss of productivity in working life. One study showed that the average sick leave in patients treated with a CMC arthroplasty was 10 weeks, with average loss of productivity costs of €7500.[3] Earlier initiation of rehabilitation may lead to returning to work and daily activities earlier. Hence further cost-effectiveness studies on this subject are needed to confirm this hypothesis.

Based on the results in Part 1 and Part 3, future studies could focus if psychological factors are associated with treatment outcome. It is becoming clearer that coping mechanisms, catastrophizing, quality of life, emotional, mental health and treatment expectations are associated with outcome. Similar with our findings in chapter 8, a study of Becker et al.[4] found that patients seeking care for CMC OA had more catastrophic thinking and higher rates of depression compared to patients that did not seek treatment for CMC OA. In addition, a study of Lozano-Calderon et al.[5] showed that catastrophic thinking and anxiety was moderately correlated with the Quick DASH in patients with thumb carpometacarpal osteoarthritis. Because of the association between pre-treatment scores and psychological factors, the question arises whether psychological factors will affect treatment outcomes and consequently if an intervention is applied, whether this will change outcome. Future research may investigate 1) the influence of psychological factors on treatment outcome after both non-surgical as surgical treatment, and 2) the potential effect of a psychological intervention on treatment outcomes for patients undergoing treatment for CMC OA. For example, patients could receive additional psychological therapy or other types of psycho-education in addition to their exercise therapy or surgery. We started measuring and screening psychological factors in our routine outcome measurements at Xpert Clinic. Consequently, we hope to gain some new interesting insights

regarding this topic in the near future.

Furthermore, since there is 1) a clear disparity between pathology seen on the X-ray and the perceived pain experienced by patients, and 2) different surgical techniques yielding the same results regarding pain[6], one might wonder if the improvement in pain after surgical treatment is actually caused by changes made in damaged tissue (surgery), or that the change in neuromodulating pain is the reason why patients benefit from surgery. For example, a systematic review performed in 2017 studying sham surgery (faked surgery that skips the steps that was thought to be effective) in orthopedic surgery showed that in knee osteoarthritis, sham surgery was just as effective as arthroscopic debridement or lavage regarding improvement in pain and function up to two years. [7,8] In addition, two articles studying surgery for lateral epicondylitis showed that sham surgery was just as effective in reducing pain as surgical excision of the degenerated tissue.[9,10] The authors of the systematic review state that most patients interpret pain as an indicator of tissue health, and that by using the affected joint, they believe that they will further damage their tissue, resulting in increase of pain. By undergoing surgery, the brain will re-evaluate the pain caused by the affected joint, resulting in a decrease of pain and increase of function. Therefore, it would be very interesting for future studies to compare the effects of surgery with sham surgery in surgical treatment of thumb CMC osteoarthritis.

In our last study (Chapter 9), it was impossible to know whether the associations found are causal, i.e. it remains unclear whether patients have a better outcome because of the better experience, or whether they have a better experience because of a better outcome. Future studies with an appropriate design should further investigate this topic. An RCT for example, where patients are subjected to different experiences may shed some light on the exact association between treatment context and treatment outcome.

As a last suggestion for future research, I would like to see more collaboration between research groups and researchers, both physicians and therapists globally. When attending hand surgery conferences, many studies regarding thumb CMC osteoarthritis were presented with either 1) topics that were already thoroughly researched; 2) studies with low sample sizes and lack of power, making it difficult to obtain significant results and to generalize to a larger population; 3) studies using different sets of outcome measurements making it difficult to compare results of different studies with each other. I therefore would like to plea for more collaboration globally to obtain larger sample sizes and to answer research questions that are not answered yet and that are clinically relevant. An excellent start has been made by the British Association of Plastic, Reconstructive and Aesthetic Surgeons and The British Society for Surgery of the Hand. They set up the reconstructive surgery trials network (RSTN), to support the development of prospective, multicenter clinical research. By

engaging in the network, research groups can join participating in trails and see what is currently being studied. Furthermore, the international consortium for healthcare outcomes (ICHOM) is currently working on a standardized set of outcomes for most common hand conditions. I hope that researchers globally will use this set of outcomes in assessing and evaluating outcome in thumb CMC osteoarthritis.

References

1. Wilkens SC, Menendez ME, Ring D, Chen N. QuickDASH Score Is Associated With Treatment Choice in Patients With Trapeziometacarpal Arthrosis. *Hand*. 2017. doi:10.1177/1558944716677937.

2. Wilkens SC, Ring D, Teunis T, Lee SGP, Chen NC. Decision Aid for Trapeziometacarpal Arthritis: A Randomized Controlled Trial. Journal of Hand Surgery. 2018.

3. Marks M, Vliet Vlieland TPM, Audige L, Herren DB, Nelissen RGHH, van den Hout WB. Healthcare costs and loss of productivity in patients with trapeziometacarpal osteoarthritis. *J Hand Surg (European Vol*. 2015;40(9):927-934. doi:10.1177/1753193414568293.

4. Becker SJE, Makarawung DJS, Spit SA, King JD, Ring D. Disability in patients with trapeziometacarpal joint arthrosis: incidental versus presenting diagnosis. J Hand Surg Am. 2014;39(10):2009-2015.e8. doi:10.1016/j.jhsa.2014.07.009.

5. Lozano-Calderon SA, Souer JS, Jupiter JB, Ring D. Psychological differences between patients that elect operative or nonoperative treatment for trapeziometacarpal joint arthrosis. Hand. 2008. doi:10.1007/s11552-008-9098-y.

6. Vermeulen G, Slijper H, Feitz R, Hovius SER, Moojen T, Selles R. Surgical management of primary thumb carpometacarpal osteoarthritis: a systematic review. The Journal of hand surgery. 2011;36(1):157-169.

7. Louw A, Diener I, Fernández-de-Las-Peñas C, Puentedura EJ. Sham Surgery in Orthopedics: A Systematic Review of the Literature. Pain Med. 2017;

8. Moseley JB. A controlled trial of arthroscopic surgery for osteoarthritis of the knee. New Eng J Med. 2002;347:81–8.

9. Kroslak M. Surgical Treatment of Lateral Epicondylitis: A Prospective, Randomised, Blinded, Placebo Controlled Pilot Study. Syndney: University of New South Wales; 2012.

10. Nirschl RP, Pettrone FA. Tennis elbow. The surgical treatment of lateral epicondylitis. J Bone Joint Surg Am 1979;61:832–9.

Summary

Part 1: Treatment outcome, prediction and conversion to surgery

Guidelines for the treatment of thumb carpometacarpal osteoarthritis advise starting with non-surgical treatment, for example orthotics and exercise programs.[1-3] While these interventions are widely used, evidence that supports these non-surgical treatments is limited.[1,4,5] After exercise therapy and an orthosis, considerable variation has been found in outcome, i.e. some patients report substantial pain relief and functional improvement while others experienced no improvement or even a deterioration.[1] In addition, no predictors are reported for the outcome of conservative treatment; thus, it remains unclear which patients might benefit from conservative treatment and which patients who initially received conservative treatment, eventually are converted to surgical treatment. Moreover, since the decision to undergo elective surgery is based on many factors, including treatment guidelines, scientific evidence, and patient characteristics, it is important to assess the extent to which this decision is based on quantifiable change in pain and function during the exercise therapy. In this thesis, we studied these topics, which we have summarized below.

In **chapter 2**, we compared the effect of a combination therapy consisting of hand exercise therapy and orthotics versus orthotics alone on pain and hand function in patients with CMC OA in an observational cohort. Since comparing groups in observational studies is usually difficult due to differences between groups, we used propensity score matching. Eighty-four patients were matched using this technique. A significant larger decrease in VAS pain at rest and during physical load was found in the exercise + orthotic group compared to the orthotic group at three months. Additionally, larger improvement was found for the MHQ subscales pain, work performance, aesthetics and satisfaction in the exercise + orthotic group.

In **chapter 3**, we studied the one-year outcome of exercise therapy and hand orthosis for thumb CMC OA in daily clinical practice and we investigated when and how many patients need additional surgical treatment. In this multicenter prospective cohort study, 809 patients were included and treated conservatively for primary CMC OA between 2011 and 2014. After a mean follow-up of 2.2 years, 15% of the patients were surgically treated. After exercise therapy, a significant decrease in pain during activities was seen. In addition, function increased significantly after 12 months.

In **chapter 4,** we aimed to identify predictive factors for outcome after splinting and exercise therapy for CMC OA and to identify predictive factors for conversion to

surgical treatment. In this observational prospective multi-center cohort study, 809 patients with CMC OA received splinting and weekly exercise therapy for three months between 2011 and 2014. The multivariable regression model explained 34% of the variance in outcome in pain and 42% of the variance in outcome in function. For the probability of converting to surgery, Cox regression analysis resulted in two significant predictors: function (MHQ) at baseline and pain intensity during the week prior to the baseline measurement.

In **chapter 5**, we investigated how response to conservative treatment, in terms of pain and hand function, influences the hazard that patients convert to surgery. In 809 patients that received three months of exercise therapy and an orthosis, a joint analytical model showed that both MHQ pain level as well as change in MHQ pain score during conservative treatment was significantly associated with conversion to surgery. For example, for each 5 points improvement in MHQ pain at follow-up compared to nu change decreased hazard of converting to surgery with 40%. The model between for functional outcome and conversion to surgery showed only a significant association between MHQ function level but not with change in MHQ score for function and the conversion to surgery.

Part 2: Postoperative rehabilitation after CMC arthroplasty

At present, after CMC arthroplasty, patients are immobilized for an arbitrary number of weeks, without knowing what the optimal time is to start rehabilitation. Theoretically, shorter immobilization may be beneficial by preventing discomfort and may reduce postoperative complications caused by the immobilization. In addition, a shorter immobilization period may allow the patient to start exercise therapy earlier, including earlier initiation of ROM and strengthening exercises. This can possibly lead to returning to daily activities and having a functional hand more quickly. However, data to reach consensus on the content of postoperative rehabilitation is lacking.

In **Chapter 6**, we performed a systematic review off the different components and phases of postoperative rehabilitation protocols for patients who underwent CMC arthroplasty and to quantify how often these are used. We found that the total immobilization varied substantially, from 2 to 12 weeks. Moreover, large variations were observed in postoperative exercises/therapy regimens of the included studies. One comparative study investigated the added value of exercise therapy compared to a home program only in postoperative rehabilitation.[6] No significant differences were found between the groups due to a small sample size, although higher improvements were found for pain intensity, limitations in ADL and grip & pinch six months postoperatively in the group that received exercise therapy.

In **chapter 7**, we compared shorter immobilization (3-5 days plaster cast followed by a thermoplastic thumb spica orthosis immobilization until 4 weeks) versus longer immobilization (10-14 days plaster cast followed by a thermoplastic thumb spica orthosis immobilization until 6 weeks) and matched the participants using propensity score matching. Both the MHQ total as well as the MHQ subscales at three and twelve months did not show any significant differences between both groups as well as complication rates. In addition, outcome in pain during physical load and pain during rest showed no significant differences between both groups at six weeks, three months and twelve months.

Part 3: Psychological factors and contextual effects in thumb CMC osteoarthritis

Since thumb CMC osteoarthritis is highly prevalent with advanced age, and only a small minority of patients seeking care, it is important to gain insight how much of the perceived complaints are caused by objective pathology, and how much by other factors. In addition, in many conditions, influencing the treatment context, e.g. by improving the communication between patient and clinician, can improve patient-reported health status.[7] When these aspects have an effect on treatment outcomes which cannot be attributed to the treatment itself, they are called 'contextual effects'.[8,9]

In **chapter 8**, we studied to what extent psychological factors are related to pain levels prior to non-operative treatment in patients with CMC osteoarthritis. The hierarchical regression model with patient characteristics and X-ray scores only accounted for 6% of the variation in MHQ-pain scores seen in subjects. After adding the psychological factors to our model, 47% of the variance could be explained. Our results show that psychological factors are more strongly related to pain levels prior to treatment in patients with CMC osteoarthritis than patient characteristics and X-ray scores which implies the important role of these factors in the development of symptoms.

In **chapter 9**, we studied which aspects of the experienced healthcare delivery are associated with better treatment outcome after surgery for CMC osteoarthritis in terms of both patient-reported outcomes and therapist-reported outcomes. We found a positive association between patient-reported experience measure (PREM) subscales and patient-reported outcome measures (PROM) subscales, with the 'general information' and "communication" subscales of the PREM having the highest association with the change in PROM subscales. In contrast to the PROMs, no significant association was found between the PREM subscales and change in hand strength. Multiple regression analysis showed that the PREM subscales had the

strongest association with the total score of the MHQ, with 8.4% of the variance explained by the subscales of the PREM.

Conclusion

In conclusion, our results support clinical guidelines stating that treatment for thumb Carpometacarpal osteoarthritis should first be non-surgical, because, at a group level, outcome significantly improved up to 1 year after orthosis and exercise therapy and the majority of patients did not undergo additional surgical treatment. Therefore, for all patients with thumb CMC osteoarthritis, we strongly recommend starting with hand orthosis and exercise therapy, especially when experienced pain and disability is high. In addition, we suggest that structured monitoring of self-reported pain during and after conservative treatment might help to adjust exercise therapy treatment and prevent patients from converting to surgery. Moreover, we conclude that shorter immobilization after CMC arthroplasty is safe, does not lead to more complications or worse outcome. Shorter immobilization can be recommended due to its potential benefits by preventing longer patient discomfort and reducing postoperative complications due to longer immobilization. Furthermore, our findings show that in thumb CMC osteoarthritis psychological factors are more strongly related to pain levels prior to non-operative treatment in patients than patient characteristics and X-ray scores. Lastly, our findings show the potential importance of positive experiences with the treatment process for improving treatment outcomes in patients surgically treated for thumb CMC osteoarthritis. Educating surgeons and other healthcare providers about such contextual effects may be a valuable addition to their skillset.

References

1. Spaans AJ, van Minnen LP, Kon M, Schuurman AH, Schreuders AR, Vermeulen GM. Conservative treatment of thumb base osteoarthritis: a systematic review. 2015(1531-6564 (Electronic)).

2. Handchirurgie NVv. Richtlijn Conservatieve en Chirurgische Behandeling van Primaire Artrose van de Duimbasis. 2014.

3. Bertozzi L, Valdes K, Vanti C, Negrini S, Pillastrini P, Villafane JH. Investigation of the effect of conservative interventions in thumb carpometacarpal osteoarthritis: systematic review and meta-analysis. Disabil Rehabil. 2015;37(22):2025-43.

4. Egan MY, Brousseau L. Splinting for osteoarthritis of the carpometacarpal joint: A review of the evidence. Am J Occup Ther. 2007;61(1):70-78. doi:10.5014/ajot.61.1.70.

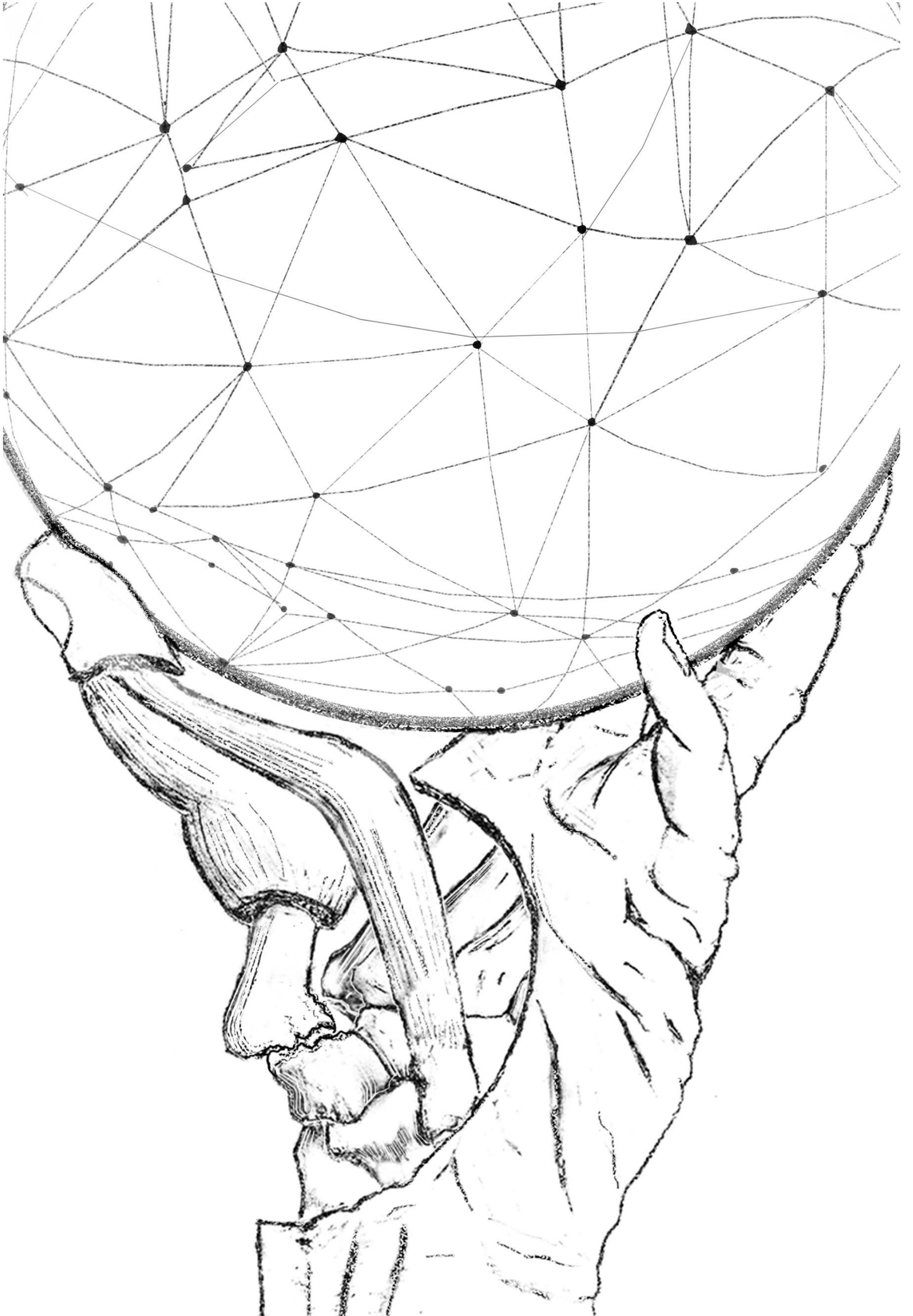
5. Aebischer B, Elsig S, Taeymans J. Effectiveness of physical and occupational therapy on pain, function and quality of life in patients with trapeziometacarpal osteoarthritis - A systematic review and meta-analysis. Hand Ther. 2016;21(1):5-15. doi:10.1177/1758998315614037.

6. Poole JL, Walenta MH, Alonzo V, Coe A, Moneim M. A Pilot Study Comparing of Two Therapy Regimens Following Carpometacarpal Joint Arthroplasty. Physical & Occupational Therapy in Geriatrics. 2011;29(4):327-336.

7. Di Blasi Z, Harkness E, Ernst E, Georgiou A, Kleijnen J. Influence of context effects on health outcomes: a systematic review. Lancet. 2001;357:757–762.

8. Miller FG, Kaptchuk TJ. The power of context: Reconceptualizing the placebo effect. J. R. Soc. Med. 2008;101:222–225.

9. Moerman DE, Jonas WB. Deconstructing the placebo effect and finding the meaning response. Ann. Intern. Med. 2002;136:471–476.



NEDERLANDSE SAMENVATTING

11

Deel 1: Behandeluitkomsten, predictie, conversie naar chirurgie

De behandelrichtlijnen voor de behandeling van duimbasisartrose schrijven voor om te starten met een non-operatieve behandeling, bijvoorbeeld door het aanbrengen van spalken en/of het toepassen van handtherapie.[1-3] Hoewel deze interventies vaak worden ingezet, is het bewijs rondom de effectiviteit van deze non-operatieve behandelingen schaars.[1,4,5] Bovendien variëren de behandeluitkomsten van patiënten die voornoemde behandelingen zijn ondergaan substantiëel van elkaar. Sommige patiënten ervaren grote verbeteringen wat betreft de pijn en functie van het duimbasisgewricht, terwijl andere patiënten geen verbetering ervaren en in sommige gevallen zelfs worden geconfronteerd met een verslechtering.[1] Verder zijn er tot nu toe geen predictoren die deze behandeluitkomsten van de verschillende patiënten kunnen voorspellen. Hierdoor blijft het onduidelijk welke patiënten baat hebben bij non-operatieve behandeling, en welke patiënten uiteindelijk ervoor kiezen om geopereerd te worden. Aangezien de beslissing om geopereerd te worden gebaseerd is op meerdere factoren, inclusief behandelrichtlijnen, wetenschappelijk onderzoek en patiënt karakteristieken, is het belangrijk te onderzoeken in hoeverre deze beslissing gemaakt wordt op basis van kwantitatief verschil in pijn en functie tijdens handtherapie.

In **hoofdstuk 2** werd combinatietherapie bestaande uit spalken + handtherapie vergeleken met spalken alleen op de uitkomsten pijn en handfunctie. In een observationele cohortstudie met in totaal 84 patiënten werden beide groepen met elkaar vergeleken middels een propensiteit gematchte weging. Een significant grotere verbetering in VAS pijn tijdens rust en VAS pijn tijdens belasten werd gezien in de spalk + handtherapie groep versus de groep die alleen gespalkt werd op drie maanden. Ook werd er in de spalk + handtherapie groep ten opzichte van de spalk groep een grotere verbetering gezien in de MHQ subschalen pijn, werk, esthetiek en tevredenheid.

In **hoofdstuk 3** bestudeerden wij de 1-jaars uitkomsten in de dagelijkse klinische praktijk van patiënten die aan hun duimbasisartrose zijn behandeld middels spalken en handtherapie. Daarnaast onderzochten wij hoeveel patiënten converteerden naar chirurgie en hoeveel tijd er in die gevallen verstreek voordat dit gebeurde. In deze multicenter cohortstudie werden 809 patiënten geïncludeerd en non-operatief behandeld aan hun duimbasisartrose. Na handtherapie werd er een significante verbetering gezien in pijn en functie, welke aanhield tot een jaar na start van de non-operatieve behandeling. Na een gemiddelde follow-up duur van 2,2 jaar werd 15% alsnog chirurgisch behandeld.

In **hoofdstuk 4** hebben wij getracht predictieve factoren te vinden die behandeluitkomsten na spalken en handtherapie zouden kunnen voorspellen. Tevens onderzochten wij of er factoren bestaan die behulpzaam zouden kunnen zijn bij het voorspellen van conversie naar chirurgie. In deze observationele studie zijn 809 patiënten geïncludeerd en met spalken en handtherapie behandeld. Multipele regressie analyses verklaarden 34% van de variantie in de uitkomst pijn en 42% van de variantie in functie. Cox regressie analyse liet zien dat de door de patiënt ervaren functie (MHQ) en pijn in de afgelopen week op baseline, significante predictoren waren voor conversie naar chirurgie.In **hoofdstuk 5** onderzochten wij hoe de response op de non-operatieve behandeling betreffende pijn en handfunctie de kans op conversie naar chirurgie beïnvloedt. In deze prospectieve cohortstudie kregen 809 patiënten gedurende drie maanden spalk en handtherapie. Joint modelling werd gebruikt om de analyses uit te voeren en de Hazard Ratio's (HR) te berekenen. Het joint model liet zien dat zowel de ervaren pijn op een bepaald tijdstip als ook het verschil in pijnscore tijdens non-operatieve behandeling de kans op conversie naar chirurgie beïnvloedde. Zo werd voor iedere vijf punten verbetering op follow-up, de kans op conversie naar chirurgie met 40% verkleind (bijvoorbeeld een verbetering van vijf punten in plaats van nul punten over een periode van drie maanden), . Het joint model liet een significante associatie zien tussen functie op een bepaald tijdstip en conversie naar chirurgie, maar geen significante associatie werd gevonden tussen de verandering in functie tijdens non-operatieve behandeling en conversie naar chirurgie.

Deel 2: Postoperatieve revalidatie na CMC arthroplastiek

Sommige studies benadrukken het belang van postoperatieve revalidatie na CMC arthroplastiek om uitkomsten betreffende pijn, ADL en range of motion te verbeteren. Echter, er is nog geen consensus omtrent de inhoud van de postoperatieve revalidatie. Momenteel krijgen patiënten gipsimmobilisatie voor een willekeurig aantal weken, zonder te weten wat de optimale duur is van het verwijderen van het gipsverband en daarmee het starten van de revalidatie. Theoretisch gezien kan een kortere gipsimmobilisatie gunstige gevolgen hebben in het verminderen van discomfort en kan dit er eveneensvoor zorgen dat er minder complicaties optreden die ontstaan door het gipsverband. Daar komt logischerwijs nog bij dat een kortere gipsimmobilisatie de patiënt in staat stelt eerder te starten met het revalideren. Dit kan er mogelijk toe leiden dat patiënten eerder een functionele hand hebben en eerder hun dagelijkse werkzaamheden kunnen hervatten.

In **hoofdstuk 6** is een systematisch overzicht gecreëerd van de verschillende componenten en fases van postoperatieve revalidatie die in de literatuur zijn beschreven bij patiënten die aan hun duimbasisartrose zijn geopereerd. De postoperatieve gipsimmobilisatieduur varieerde substantieel; wisselend van twee tot

twaalf weken. Verder werden er grote variaties gezien in het postoperatieve handtherapiebeleid. Eén vergelijkende studie onderzocht de toegevoegde waarde van handtherapie ten opzichte van thuisinstructies.[6] Geen significante verschillen werden gevonden door de kleine aantallen, hoewel de handtherapie groep meer verbetering liet zien betreft pijn, ADL, grip & knijp kracht.

In **hoofdstuk 7** is onderzocht of een kortere gipsimmobilisatie non-inferieur was aan een langere gipsimmobilisatie. In deze studie vergeleken we middels propensiteit gematchte weging kortere gipsimmobilisatie (3-5 dagen gipsverband gevolgd door een thermoplastische duim spica spalk tot vier weken) met langere gipsimmobilisatie (10-14 dagen gipsverband gevolgd door een thermoplastische duim spica spalk tot zes weken). Tussen 2011 en 2017 ondergingen 648 patiënten een Weilby procedure. Zowel de totale MHQ score alsook de subschalen van de MHQ verschilden op drie en twaalf maanden niet significant tussen beide groepen. Ook de uitkomsten in complicaties, pijn in rust en pijn tijdens belasten lieten geen significante verschillen zien op zes weken, drie maanden en twaalf maanden.

Deel 3: Psychologische factoren en contextuele effecten in duimbasisartrose

Aangezien duimbasisartrose vaak voorkomt op latere leeftijd en slechts een klein deel van de patiënten symptomatische klachten ondervinden, is het belangrijk inzicht te krijgen in de hoeveelheid van de ervaren klachten die zijn ontstaan door objectieve pathologie en hoeveel door andere factoren. Verder wordt er bij veel aandoeningen gezien dat het beïnvloeden van de behandelcontext, bijvoorbeeld door het verbeteren van de communicatie tussen patiënt en arts, positieve effecten heeft op behandeluitkomsten.[7] Als dit effect plaatsvindt zonder daadwerkelijk de inhoud van de behandeling aan te passen, worden deze effecten contextuele effecten genoemd.[8,9]

In **hoofdstuk 8** onderzochten wij in hoeverre psychologische factoren gerelateerd waren aan pijn voorafgaand aan non-operatieve behandeling bij patiënten met duimbasisartrose. Hierbij werden 255 patiënten geïncludeerd. Hiërarchische lineaire regressie modellen werden gebruikt om de analyses uit te voeren. Het hiërarchische regressie model met uitsluitend patiënt karakteristieken en röntgenscores, verklaarden 6% van de variatie in MHQ pijn scores tussen de patiënten. Na het toevoegen van de psychologische factoren aan het model, kon 47% van de variantie in MHQ pijn scores tussen patiënten worden verklaard. Deze resultaten laten zien dat psychologische factoren mogelijk invloed kunnen hebben op het ontwikkelen van symptomen en pijnklachten door duimbasisartrose.

In **hoofdstuk 9** onderzochten wij welke aspecten van de zorgbeleving geassocieerd waren met betere behandeluitkomsten na chirurgie aan duimbasisartrose in zowel patiënt gerapporteerde uitkomsten (PROM) alsook therapeut gerapporteerde uitkomsten (TROM). Data verzameld tussen 2011 en 2017 werd gebruikt om de associatie tussen zorgbeleving, gemeten met een patiënt gerapporteerde ervaring vragenlijst (PREMS), te koppelen aan PROMs en TROMs. Wij vonden een significant positieve associatie tussen de PREM subschalen en PROM subschalen, waarbij de PREM subschaal "algemene informatie" de hoogste associatie heeft met de verandering in PROM subschalen. Geen significante associaties werden gevonden tussen de PREM subschalen en de verandering in TROMs. Multipele regressie analyses lieten zien dat de PREM subschalen het meest geassocieerd waren met de totaal score van de MHQ, waarbij 8,4% van de variantie verklaard werd door de subschalen van de PREM.

Conclusie

Concluderend ondersteunen onze bevindingen de klinische richtlijnen inhoudende dat de behandeling van duimbasisartrose aanvankelijk non-operatief moet zijn. Op groepsniveau verbeterden patiënten significant na handtherapie, waarbij de meerderheid van de patiënten geen aanvullende chirurgie onderging. Om die reden raden wij patiënten met duimbasisartrose sterk aan te starten met spalken en handtherapie, zeker wanneer de ervaren pijn en functionele klachten hoog zijn. Verder suggereren wij dat het baat heeft de ervaren pijn tijdens de conservatieve behandeling te monitoren, omdat dit aanknopingspunten kunnen zijn bij het beoordelen of de handtherapie aanslaat en/of er wellicht andere oefeningen moeten worden voorgeschreven waardoor conversie naar chirurgie kan worden voorkomen. Tevens concluderen wij dat kortere gipsimmobilisatie na CMC arthroplastiek veilig is en niet tot meer complicaties of slechtere uitkomsten leidt. Een kortere gipsimmobilisatie wordt eveneens aanbevolen omdat patiënten zo minder lang een oncomfortabel gipsverband hoeven te dragen en omdat het mogelijk de kans op postoperatieve complicaties kan verminderen welke door het gipsverband kunnen ontstaan. Ook concluderen wij dat psychologische factoren sterk gerelateerd zijn aan pijn die patiënten ervaren nog voordat ze behandeld worden en dat deze associatie sterker is dan pathologie gezien op de röntgen of andere patiëntkenmerken. Tenslotte laten onze resultaten zien dat positieve ervaring met het behandelproces wordt geassocieerd met behandeluitkomsten bij patiënten die chirurgisch zijn behandeld aan hun duimbasisartrose. Ons inziens zouden chirurgen en andere zorgverleners er goed aan doen om in te spelen op deze contextuele effecten.

Bronvermelding

1. Spaans AJ, van Minnen LP, Kon M, Schuurman AH, Schreuders AR, Vermeulen GM. Conservative treatment of thumb base osteoarthritis: a systematic review. 2015(1531-6564 (Electronic)).

2. Handchirurgie NVv. Richtlijn Conservatieve en Chirurgische Behandeling van Primaire Artrose van de Duimbasis. 2014.

3. Bertozzi L, Valdes K, Vanti C, Negrini S, Pillastrini P, Villafane JH. Investigation of the effect of conservative interventions in thumb carpometacarpal osteoarthritis: systematic review and meta-analysis. Disabil Rehabil. 2015;37(22):2025-43.

4. Egan MY, Brousseau L. Splinting for osteoarthritis of the carpometacarpal joint: A review of the evidence. Am J Occup Ther. 2007;61(1):70-78. doi:10.5014/ajot.61.1.70.

5. Aebischer B, Elsig S, Taeymans J. Effectiveness of physical and occupational therapy on pain, function and quality of life in patients with trapeziometacarpal osteoarthritis - A systematic review and meta-analysis. Hand Ther. 2016;21(1):5-15. doi:10.1177/1758998315614037.

6. Poole JL, Walenta MH, Alonzo V, Coe A, Moneim M. A Pilot Study Comparing of Two Therapy Regimens Following Carpometacarpal Joint Arthroplasty. Physical & Occupational Therapy in Geriatrics. 2011;29(4):327-336.

7. Di Blasi Z, Harkness E, Ernst E, Georgiou A, Kleijnen J. Influence of context effects on health outcomes: a systematic review. Lancet. 2001;357:757–762.

8. Miller FG, Kaptchuk TJ. The power of context: Reconceptualizing the placebo effect. J. R. Soc. Med. 2008;101:222–225.

9. Moerman DE, Jonas WB. Deconstructing the placebo effect and finding the meaning response. Ann. Intern. Med. 2002;136:471–476.

PART 4

APPENDICES

List of Publications in this thesis

Exercise therapy in addition to an orthosis reduces pain more than an orthosis alone in patients with thumb base osteoarthritis: a propensity score matching study
Wouters RM, **Tsehaie J**, Slijper HP, Hovius SER, Feitz R, Selles RW.
Arch Phys Med Rehabil. 2018 Dec 11. pii: S0003-9993(18)31516-8. doi: 10.1016/j.apmr.2018.11.010. [Epub ahead of print]

Outcome of a Hand Orthosis and Exercise therapy for Carpometacarpal Osteoarthritis in Daily Practice: A Prospective Cohort Study.
Tsehaie J, Spekreijse KR, Wouters RM, Slijper HP, Feitz R, Hovius SER, Selles RW.
J Hand Surg Am. 2018 Nov;43(11):1000-1009.e1. doi: 10.1016/j.jhsa.2018.04.014.

Predicting outcome after splinting and exercise therapy for carpometacarpal osteoarthritis; a prospective study
Tsehaie J, Spekreijse KR, Wouters RM, Slijper HP, Feitz R, Hovius SER, Selles RW.
Arch Phys Med Rehabil. 2018 Oct 12. pii: S0003-9993(18)31375-3. doi: 10.1016/j.apmr.2018.08.192. [Epub ahead of print]

Response to conservative treatment for thumb carpometacarpal osteoarthritis is associated with conversion to surgery: a prospective cohort study
Tsehaie J, Porsius JT, Rizopoulos D, Slijper HP, Feitz R, Hovius SER, Selles RW, the Hand-Wrist Study Group
Phys Ther. 2019 Jan doi: 10.1093/ptj/pzz009 [Epub ahead of print]

Postoperative Rehabilitation Following Thumb Base Surgery: A Systematic Review of the Literature.
Wouters RM, **Tsehaie J**, Hovius SER, Dilek B, Selles RW.
Arch Phys Med Rehabil. 2018 June doi: 10.1016/j.apmr.2017.09.114.

Short versus prolonged immobilization after surgery for carpometacarpal osteoarthritis: a propensity score matched study
Tsehaie J, Wouters RM, Feitz R, Slijper HP, Hovius SER, Selles RW, the Hand-Wrist Study Group
Arch Phys Med Rehabil. 2019 Apr 23. pii: S0003-9993(19)30259-X. doi: 10.1016/j.apmr.2019.02.016. [Epub ahead of print]

The role of psychological factors and radiographic OA severity in pre-treatment pain of non-surgically treated CMC patients
Hoogendam L, van der Oest MJW, **Tsehaie J**, Wouters RM, Vermeulen GM, Slijper HP, Selles RW, Porsius JT, the Hand Wrist study group
Submitted: Disabil Rehabil. 2019

Positive experiences with treatment is associated with outcome after surgery for Carpometacarpal osteoarthritis
Tsehaie J, van der Oest MJW, Poelstra R, Selles RW, Feitz R, Slijper HP, Hovius SER, Porsius JT
Accepted: J Hand Surg Eur Vol. 2019.

Other Publications

Value of quantitative MRI parameters in predicting and evaluating clinical outcome in conservatively treated patients with chronic midportion Achilles tendinopathy: A prospective study.
Tsehaie J, Poot DHJ, Oei EHG, Verhaar JAN, de Vos RJ.
J Sci Med Sport. 2017 Jul;20(7):633-637. doi: 10.1016/j.jsams.2017.01.234. Epub 2017 Jan 24.

PhD Portfolio

Summary of PhD training and teaching activities

Name PhD candidate: Jonathan Tsehaie

PhD period: 2017-2019

Erasmus MC, Department of Plastic and reconstructive surgery, and hand surgery

Promotor: Prof.em.dr S.E.R. Hovius

Copromotor: Dr. R.W. Selles

1. PhD training

Epidemiology, study design, and statistics courses	***Year***	***Workload***
Biostatistical Methods II: Classical Regression Models (grade: 8.9)	2017	120 hrs
Repeated Measurements (grade: 9.1)	2017	40 hrs
Advanced Analysis of Prognosis Studies (grade: 10.0)	2017	25 hrs
Missing Values in Clinical Research (grade: 8.5)	2017	20 hrs
CPO course	2017	8 hrs

Research integrity courses	***Year***	***Workload***
BROK and Good Clinical Practice	2017	30 hrs
Erasmus Research integrity	2018	8 hrs

Surgical courses	***Year***	***Workload***
Microsurgery Skillslab	2017	250 hrs

Oral, poster presentations	***Year***	***Workload***
Oral - *Predicting outcome after conservative treatment for carpometacarpal osteoarthritis* - Refereeravond plastische chirurgie Erasmus MC	2017	8 hrs
Oral - *Outcome of conservative treatment for carpometacarpal osteoarthritis: A prospective cohort study* - FESSH	2017	20 hrs
Oral - *Predicting outcome after conservative treatment for carpometacarpal osteoarthritis; a prospective study* - FESSH	2017	20 hrs
Oral - *Dynamic prediction modelling to study the association of response to conservative treatment with conversion to surgery for CMC osteoarthritis* – Refereermiddag Revalidatie geneeskunde Erasmus MC	2017	20 hrs

Oral - *Verandering in zelf-gerapporteerde pijn na conservatieve behandeling van CMC artrose is geassocieerd met conversie naar chirurgie* - Dutch Society for Plastic Surgery (NVPC)	2017	20 hrs
Oral - *Association between treatment context and treatment outcome after surgery for carpometacarpal osteoarthritis* – FESSH	2018	20 hrs
Poster - Response to conservative treatment for CMC osteoarthritis is associated with conversion to surgery - FESSH	2018	20 hrs
Oral - *Kortere versus langere immobilisatie duur na chirurgie voor duimbasisartrose: een propensiteit score gematchte studie*– Dutch Society for Plastic Surgery (NVPC)	2018	20 hrs
Oral - *Shorter versus longer immobilization after surgery for thumb carpometacarpal osteoarthritis: a propensity score matched study* – FESSH	2019	20 hrs

Conferences and seminars (attendance)	***Year***	***Workload***
Big hand event: Symposium on 'Truth or Dare'	2017	8 hrs
25th ESSER symposium: Oncoplastic breast surgery	2017	8 hrs
UseR congres: The main meeting of the international R user and developer community.	2017	16 hrs
Scientific meeting Dutch Society for Plastic Surgery (NVPC)	2017	8 hrs
FESSH annual meetings	2017-2019	75 hrs
Scientific meeting Dutch Society for Plastic Surgery (NVPC)	2018	8 hrs
Upperlimb – BHG-NVvH Congress	2019	8 hrs

Lecturing	***Year***	***Workload***
Musculoskeletal elective: common acute and chronic hand Conditions – Erasmus MC	2017	20 hrs
Educational course conservative treatment CMC osteoarthritis – Training day Dutch society of exercise therapy	2017	20 hrs

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Ik wil iedereen bedanken die op enig manier betrokken was in het totstandkoming van dit proefschrift. Dit was allemaal niet mogelijk geweest zonder jullie steun.

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Dank Ralph, voor de mooie tijd op de 15e en daarbuiten! Ik heb erg veel met je gelachen en veel van je geleerd (ik geef toe). Je friendly competition heeft me scherp gehouden. Ik kan me nog erg goed herinneren dat je de eerste keer je Dushi playlist opzette en ik dacht: “Dit gaat een mooie tijd worden”. Het is ongekend hoeveel wijsheden je op zo’n jonge leeftijd hebt weten te vergaren en ik voel me vereerd dat ik hiervan heb mogen profiteren. Ik zal de vrijdagmiddagborrels en stapavonden missen. Waar blijft mijn champagne? Je quotes zijn nu al legendarisch op de 15e: "De wetenschap wacht op niemand". Dat we nog vele uitdagingen aan mogen gaan! Succes in Leeuwarden vriend.

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Curriculum Vitae

Photo made by Nahom Tsehaie

Jonathan Tsehaie was born on March 3th 1993 in Rotterdam, the Netherlands. After graduating from *het Marnix Gymnasium,* he started International Business Administration at the Erasmus University. After completing his first year, he started medical school at the Erasmus University in 2012. During medical school, his interest in plastic and reconstructive surgery was sparked during the minor reconstructive surgery in 2014. His fascination for plastic and reconstructive surgery was further strengthened during his first research project at the Department of Plastic Surgery, Erasmus Medical Center Rotterdam under supervision of K.R. Spekreijse, Dr. R.W. Selles and Prof. dr. S.E.R. Hovius. During 2014-2016, he continued doing research in thumb carpometacarpal osteoarthritis, which was expanded to his master thesis in 2016. After successfully completing his master thesis, he decided to further develop his scientific skills and started a PhD program on thumb carpometacarpal osteoarthritis in 2017. After one year of full-time PhD, he combined the PhD program with his clinical internships of medical school, which he will finish in 2019. After obtaining his medical degree, he aspires a career in Plastic Surgery.

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Propositions pertaining this thesis

Thumb Carpometacarpal osteoarthritis
Prediction, rehabilitation and contextual effects

1. "The higher the pain levels and disability patients experience, the more the patient will benefit from orthosis and exercise therapy for their thumb CMC osteoarthritis." — *This thesis*

2. "In treating thumb CMC osteoarthritis, orthosis and exercise therapy is an effective treatment option, and the majority of patients do not decide to be surgically treated." — *This thesis*

3. "When patients are surgically treated for their thumb CMC osteoarthritis, postoperative immobilization should be three to five days" — *This thesis*

4. "Psychological attributes of the patient are an important source of variation in symptom presentation and should be taken into account in treating thumb CMC osteoarthritis." — *This thesis*

5. "Communication of the doctor and providing sufficient, understandable information to the patient will contribute to better treatment outcome and should be trained more often." — *This thesis*

6. Propensity score matching is an appropriate method for comparing different groups with each other and is an acceptable alternative for an RCT. — Peter C Austin et al., An Introduction to Propensity Score Methods for Reducing the Effects of Confounding in Observational Studies, *Multivariate Behav Res*. 2011 May; 46(3): 399–424.

7. Het huidige zorgstelsel van marktwerking heeft er in Nederland voor gezorgd dat zorgverzekeraars teveel macht hebben gekregen, waardoor de kwaliteit van zorg achteruit gaat en de financiële kosten stijgen — Gerard Bosman, Niet de zorg, maar het zorgstelsel is duur, *BNN Vara*

8. "It's more important to know what sort of person has the disease than to know what sort of disease the person has." — Hippocrates

9. In our increasingly complex world, global collaboration between research groups and researchers is necessary to continue expanding our knowledge regarding disease and illness — Ghazwan Butrous, International cooperation to promote advances in medicine, *Ann Thorac Med.* 2008 Jul-Sep; 3(3): 79–81.

10. Social media use among adolescents leads to negative effects in the developing brain and should therefore be limited — Eveline A. Crone et al., Media use and brain development during adolescence, *Nature Communications.* 2018, Article number: 588

11. "The pump is one of the better highs in life. You don't need to shoot up for it, you don't need to snort it. All you've got to do is sweat for it." – Greg Plitt