Thumb Base Osteoarthritis: Prevalence, Occupational Risk, and Surgical Outcomes

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Thumb Base Osteoarthritis

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Jennifer Moriatis Wolf

DOCTORAL DISSERTATION

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Abstract

Osteoarthritis of the carpometacarpal joint at the base of the thumb (CMC1 OA) is common and causes difficulty in grasp, grip, and fine manipulation of the hand. Surgery is recommended after failure of non-operative treatment, and evidence from short and medium-term follow-up studies shows successful relief of pain and return of function. Previous investigations of epidemiology and risk factors were drawn from small case series or radiographic reviews; similarly, surgical outcomes studies have been limited by lack of robust follow-up.

The objectives of this thesis were to: 1) evaluate the clinically important prevalence of CMC1 OA by age and sex using physician-assigned diagnoses; 2) study the impact of occupational load on the occurrence of CMC1 OA; and 3) evaluate surgical outcomes including register-based sick leave length as well as long-term follow-up in a tightly captured population.

Epidemiologic analysis using the Skåne Healthcare Register showed a sex difference in prevalence of CMC1 OA with 2.2% of women compared to 0.6% of men assigned this diagnosis over a 15-year period, with peak prevalence in women at age 70-74 years. Occupational load analysis showed that jobs with the heaviest manual work stress conferred the greatest risk of a diagnosis of CMC1 OA, with a monotonic relationship between work load and thumb base OA in men. Lengthy sick leave periods were noted after both soft tissue and prosthetic implant arthroplasty, but prosthetic implant surgery patients returned to work a mean of 30 days earlier than those treated with soft tissue reconstruction. Finally, in a single-site cohort with 17 years mean follow-up of 96 of 100 (96%) patients after abductor pollicis longus (APL) tendon suspension interposition arthroplasty, we noted good to excellent patient-rated pain and functional outcomes as well as grip and pinch comparable to the non-operated side.

These findings confirm long-held beliefs that there is greater female prevalence of CMC1 OA and that heavy labor is associated with increased risk of CMC1 OA. Surgical treatment can relieve pain and improve function, with prosthetic implant arthroplasty associated with earlier return to work.

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‘Energy and persistence conquer all things’
-- Benjamin Franklin

‘The longest journey of any person is the journey inward’
-- Dag Hammarskjöld

Dedicated to my family – Douglas, Ben, and David,
whose support has enabled this accomplishment.

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Abstract

Osteoarthritis of the carpometacarpal joint at the base of the thumb (CMC1 OA) is common and causes difficulty in grasp, grip, and fine manipulation of the hand. Surgery is recommended after failure of non-operative treatment, and evidence from short and medium-term follow-up studies shows successful relief of pain and return of function. Previous investigations of epidemiology and risk factors were drawn from small case series or radiographic reviews; similarly, surgical outcomes studies have been limited by lack of robust follow-up.

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These findings confirm long-held beliefs that there is greater female prevalence of CMC1 OA and that heavy labor is associated with increased risk of CMC1 OA. Surgical treatment can relieve pain and improve function, with prosthetic implant arthroplasty associated with earlier return to work.

List of Papers

This dissertation is based on the following papers, referred to in the text by their Roman numerals. The original articles have been reprinted with the permission of the publishers.

Paper I **Moriatis Wolf J**, Turkiewicz A, Atroshi I, Englund M. Prevalence of doctor-diagnosed thumb carpometacarpal joint osteoarthritis: an analysis of Swedish health care. *Arthritis Care Res* 2014; 66(6): 961-965.

Paper II **Wolf JM,** Turkiewicz A, Atroshi I, Englund M. Occupational load as a risk factor for clinically relevant base of thumb osteoarthritis. *Occup Environ Med* 2020; 77(3): 168-171.

Paper III **Wolf JM,** Atroshi I, Zhou C, Karlsson J, Englund M. Sick leave after surgery for thumb carpometacarpal osteoarthritis: a population-based study. *J Hand Surg Am* 2018; 43(5): 439-447.

Paper IV **Wolf JM,** Turkiewicz A, Englund M, Karlsson J, Arner M, Atroshi I. Trapeziectomy and tendon suspension-interposition arthroplasty: Patient-reported and radiographic outcomes in 125 hands at 13 to 21 years follow-up. Manuscript submitted for publication.

Abbreviations

APL	Abductor pollicis longus
AUSCAN	Australian Canadian Osteoarthritis Hand Index
CMC	Carpometacarpal
CMC1	Thumb carpometacarpal
DASH	Disabilities of the Arm, Shoulder and Hand
QuickDASH	Quick-Disabilities of the Arm, Shoulder and Hand
FCR	flexor carpi radialis
IC	Intercarpal
ICD-10	International Classification of Diseases, update 10
IP	Interphalangeal
LRTI	Ligament reconstruction and tendon interposition
MCP	Metacarpophalangeal
OA	Osteoarthritis
PRWHE	Patient-Rated Wrist and Hand Evaluation
RC	Radiocarpal
SHR	Skåne Healthcare Register
SSIA	Swedish Social Insurance Agency
STT	Scaphotrapeziotrapezoid
ST	Scaphotrapezoid
VAS	Visual Analog Scale

Introduction

The thumb provides approximately 50% of the function of the hand, and is thought to be the most important digit for use of the hand.[1] Thus, injury or disease impacting this joint are of concern. Osteoarthritis (OA) of the thumb base, or thumb carpometacarpal joint (CMC1) is common and has been observed more frequently in postmenopausal women.[2] The typical complaints on presentation are pain, weakness, and decreased function in grasp and manipulation.[3]

Pathophysiology

The CMC1 joint is made up of the first metacarpal and the trapezium, which articulate at a unique joint composed of two interlocking saddles.[4] The first metacarpal base has a radius of curvature that is 34% greater than that of the trapezial articulating surface,[5] allowing for the multiple motions of the thumb, including flexion, extension, abduction, adduction, and opposition.[6] The bony anatomy of this complex joint allows the degree of motion which allows both fine manipulation and manual grasp.

The stability of the CMC1 joint is based on the ligaments which provide constraint to motion and support during use. Bettinger et al described 16 ligaments in their study of the functional anatomy of the joint, and noted two key ligaments: the dorsoradial and the deep anterior oblique ligaments.[7] Historical evidence focused on the anterior oblique or 'beak ligament' as the most important stabilizer of the CMC1 joint,[8-10] but recent studies have supported the primacy of the dorsoradial ligament (DRL).[11,12] Anatomic studies have shown the dorsoradial ligament to be thick and stout, with a tripartite origin, conferring biomechanical advantage to prevent dorsal translation of the first metacarpal.[13]

It is theorized that OA of the CMC1 joint occurs secondary to abnormal loading of the joint during functional use, due to insufficiency or laxity of the supporting ligaments.[14] This theory is supported by evidence of uneven contact loading in biomechanical analyses of arthritic joint[15] as well as evidence of increased CMC1 OA in hyperlax individuals.[16] The CMC1 joint has been shown to bear the highest load among the joints of the thumb, with biomechanical studies demonstrating that simple pinch placed loads of 12 kg across the CMC1 joint, compared to 3 and 5.4 kg at the interphalangeal and metacarpophalangeal joints, respectively. Strong grasp causes loads approximately 10 times higher in magnitude, up to 120 kg across the CMC1 joint.[17] (Figure 1)

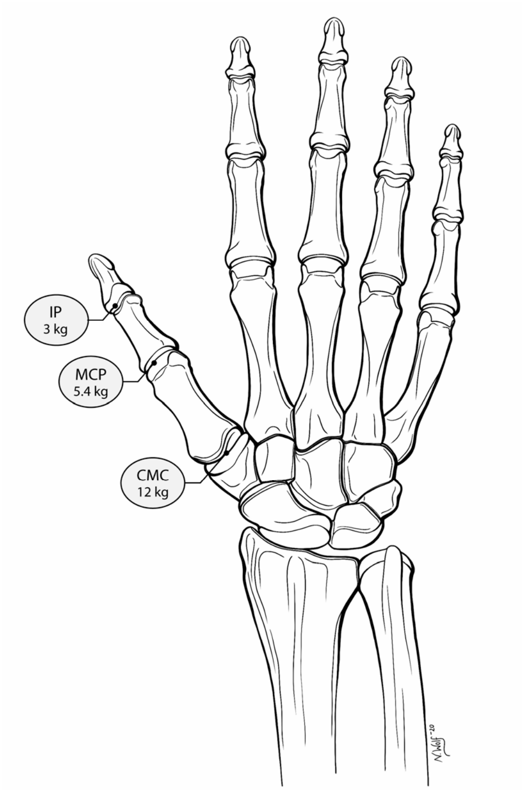

Figure 1. Biomechanical modeling has shown differences in load borne by the interphalangeal (IP), metacarpophalangeal (MCP), and carpometacarpal (CMC) joints of the thumb. (Figure created from data presented by Cooney and Chao, *J Bone Joint Surg Am,* 1977.) Used with permission.

Diagnosis – Physical Examination

Patients with CMC1 OA often present with prominence of the base of the first metacarpal, termed the 'shoulder sign', due to the adducted position of the metacarpal that develops as OA worsens.[18] As the metacarpal adducts, the patient is forced to hyperextend the metacarpophalangeal (MCP) joint to get the thumb out of the palm, called a Z-deformity.[2]

With CMC1 OA, palpation of the CMC1 joint is painful, as is the 'grind test' where axial load and shift of the metacarpal on the trapezium results in crepitance.[19] Other tests include the extension test, where the metacarpal is passively extended out of the palm, and the adduction test, where the metacarpal is firmly pushed into the palm. These maneuvers are positive in patients with CMC1 OA, and have been shown to have 94% sensitivity and 91% specificity compared to the CMC grind test.[20]

Diagnosis – Imaging

Plain radiographs are standard in the evaluation of CMC1 OA and include posterior-anterior, oblique, and lateral views of the hand. Radiographs can show joint space narrowing, spurs, loose bodies, and the position of the metacarpal in relation to the trapezium. Special views are used to focus on the CMC1 joint. These include the Robert view, which is an anterior-posterior view of the CMC1 joint and shows all four trapezial articulations.[21] The Bett view is a true lateral of the CMC1 joint and shows the scaphotrapeziotrapezoid joint as well as the CMC1 joint.[4] Finally, the CMC stress view evaluates the degree of dynamic laxity of the CMC1 joint as the patient has to actively press the MCP and interphalangeal (IP) joints together to place stress on the ligaments stabilizing the CMC1 joint.[22] The amount of subluxation seen is divided by the width of the metacarpal base to produce the subluxation ratio (Figure 2).

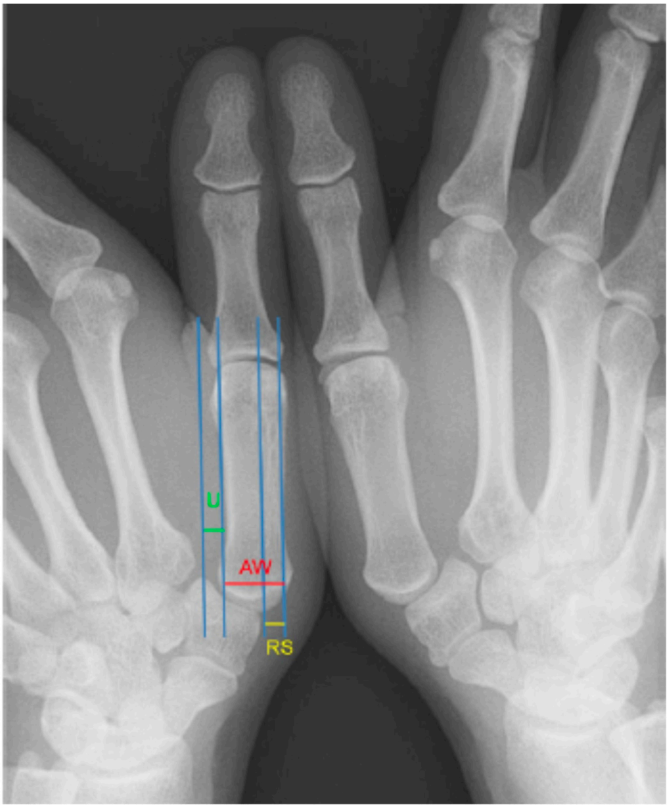

Figure 2. The trapeziometacarpal stress ratio, defined as the ratio of radial subluxation (RS) divided by the articular width of the first metacarpal base (AW). From Oren et al, *J Hand Surg Am,* 2009. Reproduced with permission.

The role of advanced imaging in CMC1 OA is limited. While MRI evaluation has been described for evaluation of ligament integrity[23] and early bony changes,[24] the utility of MRI in clinical decision-making is not yet known.

The radiographic severity of CMC1 OA is most commonly graded using the Eaton and Littler classification as described in 1973 (Table 1).[25] This classification scheme, which focuses on joint subluxation as well as the size of the loose bodies or bone fragments about the joint, was later modified to include scaphotrapezial (ST) joint involvement.[26]

Table 1. Eaton-Littler Radiographic Classification for CMC1 OA

Stage	Description
I	Normal or slightly widened joint space (capsular distension due to synovitis); normal articular contours, and less than one-third joint subluxation on any radiographic view
II	At least one-third joint subluxation; small bone fragments < 2mm in diameter
III	Greater than one-third joint subluxation; bone fragments >2mm in diameter with slight joint space narrowing
IV	Advanced degenerative changes with cystic and sclerotic subchondral bone changes; trapezial osteophyte formation and involvement of the STT joint

Adapted from Eaton RG, Litter JW, *J Bone Joint Surg Am,* 1973. Used with permission.

An alternative classification used by many authors is the Kellgren-Lawrence grading scheme, described in 1957 and applicable to all joints. The authors graded OA severity based on osteophyte formation on the joint margins, periarticular ossicles, joint space narrowing, subchondral sclerosis, and pseudocysts (Figure 3).[27]

Figure 3. Kellgren and Lawrence classification and delineation of osteoarthritis of the CMC1 joint. *Ann Rheum Dis,* 1957. Reproduced with permission.

While the Eaton-Littler classification is the most commonly used scheme,[28] studies of interobserver agreement have shown only moderate agreement on radiological classification among hand surgeons and radiologists.[29,30] Several recent cohort studies and randomized trials have preferentially used the Kellgren-Lawrence classification in grading CMC1 OA.[31,32] The major difference between the two classifications is the Eaton score's emphasis on the degree of radial subluxation, the significance of which has been debated. A recent study of 100 subjects showed that lower radial subluxation ratios were associated with higher Kellgren-Lawrence grades, but showed no correlation with Eaton-Littler scores.[33] The authors theorized that joint stabilization by osteophyte formation and capsular stiffening decreased radial subluxation.

Epidemiology

Overall hand OA and specific CMC1 OA is common.[3] Several epidemiological studies have shown that the hand is the second most common site affected by OA after the knee joint, with estimated rates of hand OA at 100 per 100,000 person-years, compared to 240 per 100,000 person-years for the knee.[34]

Many epidemiology studies are based on radiographic evidence of OA, as defined by Kellgren and Lawrence in their original article grading the severity of OA.[27] Armstrong et al evaluated the prevalence of CMC1 OA in 143 post-menopausal women, and reported radiographic findings of OA in 25%, with 8% demonstrating both CMC1 and scaphotrapeziotrapezoid (STT) OA.[3] Of these groups, one quarter of the women with isolated CMC1 OA were symptomatic. Sodha et al evaluated the radiographs of 615 patients who presented with distal radius fractures for the presence and severity of CMC1 OA, and noted a sex difference in prevalence of OA. When stratified by severity of CMC1 OA and age>80 years, the prevalence was 66% in women compared to 23% in men.[35] A Finnish register study similarly showed a radiographic difference in prevalence of CMC1 OA in men and women, in a sample of 3595 radiographs. The authors noted that women showed a 15% radiographic prevalence of CMC1 OA compared to men at 7%, with additional findings that BMI was directly correlated to CMC1 OA in both sexes.[36]

It is well-known that radiographic signs of OA do not always translate to symptomatic OA, as shown by studies in the hip[37] and CMC1 joints.[38] The symptomatic prevalence of CMC1 OA in the Framingham Study was evaluated in 1,041 subjects between ages 71-100 years.[39] Women demonstrated a prevalence of 26.2% CMC1 OA, as measured by interviewer questionnaire and confirmed by radiographs, compared to men at 13.4%. Bijsterbosch et al evaluated a group of 308 patients with hand OA and stratified them into groups of isolated CMC1 OA, isolated interphalangeal (IP) joint OA, and combined symptoms.[40] Using a standardized upper extremity functional score (the AUSCAN), the authors noted that symptomatic CMC1 OA patients had the highest (worst) scores for function compared to patients with IP joint OA, emphasizing the impact of symptomatic

OA being greater in the CMC1 joint. The majority of studies in the epidemiology of CMC1 OA have relied on either radiographs or census interviews for data.

Risk Factors for Development of CMC1 OA

Factors proposed to predispose to the development of CMC1 OA include age, genetics/family history, obesity and occupation. In a study of 59 patients noted to have incidental CMC1 OA on radiographs, older age was the only factor associated with more advanced radiographic CMC1 changes, after evaluation for body mass index, tobacco use, depression scale, and grip/pinch strength.[41] Other studies have confirmed increased age as a risk factor for a diagnosis of hand OA.[3,36,42]

In evaluating genetic risk, a study in Iceland evaluated patients seeking medical services for hand OA compared to non-symptomatic controls, and evaluated kinship coefficient (a measure of the probability of a genetic relationship between two individuals) and relative risk of hand OA diagnosis in family members. In a large cohort of 2,919 subjects with hand OA compared to controls, the kinship coefficient was significantly greater in the OA population for both the IP and CMC1 joints, and the relative risk of hand OA in sisters of female subjects was 2.0.[43] A twin study in the UK also demonstrated an increase in risk of hand OA diagnoses, including CMC1 OA.[44] These studies provide evidence of a familial risk for CMC1 OA.

Obesity has been described as a risk factor for OA of multiple joints including the hand.[45] In a large Finnish population study which included screening interviews and radiographs, increased body mass index was shown to be directly proportional to the prevalence of CMC1 OA in both men and women.[36]

Finally, in considering occupation as a potential risk factor, increased risk of joint degeneration and OA due to impact of repetitive and heavier loading have been relatively consistently reported for the hip and knee,[46,47] but the same evidence has not been shown for CMC1 OA. A few small studies have shown elevated odds ratios of hand OA in those engaged in work requiring dexterity or repetitive work, or with vibrational tools.[48]

Conservative Treatment of CMC1 OA

There are multiple non-operative treatments described to treat individuals with symptomatic CMC1 OA. Conservative management is generally recommended as initial treatment, as many patients' pain and dysfunction are resolved by these modalities.

Medications

While studies specific to the use of medications for the CMC1 joint are minimal, there is some evidence for short-term positive effects on pain with the use of oral and topical nonsteroidal anti-inflammatory drugs (NSAIDs).[49] Comparative studies in patients with DIP joint OA have shown significant positive effects of NSAID topical gels or creams when compared to oral ibuprofen or acetaminophen.[50]

Splinting

The use of orthoses to both stabilize and rest the CMC1 joint is well-established, and has been shown to decrease symptom severity and improve function.[51] There are multiple types of splints used, which can be divided by length – short or long opponens, which indicate either hand- or forearm-based splinting; and by material, generally thermoplastic or neoprene. A study comparing short vs. long opponens splints in 26 hands showed similar improvement in CMC1 radiographic subluxation and pain in the short term; patients preferred the shorter splint.[52] A recent randomized comparison of thermoplastic vs. neoprene splints in 62 patients showed no differences in Disabilities of the Arm, Shoulder, and Hand (DASH) scores, pain, grip or pinch; however, patients rated the neoprene splint as more comfortable.[53] The results of a systematic review of 12 studies on splinting for CMC1 OA showed no significant effect on pain or function in the short term, but moderate to large effects on pain and small to moderate impact on function in medium term follow-up, noting that evidence was of lower quality.[54]

Splinting in combination with other modalities has also been shown to be effective. Day et al performed a prospective study of splinting in combination with a single corticosteroid injection into the CMC1 joint in 30 patients, noting relief of pain and improved DASH scores in those with milder Eaton stages of CMC1 OA, and minimal relief in those with more advanced OA.[55]

Injections

Corticosteroid is the most commonly studied standard injection for CMC1 OA. Glucocorticoids were isolated from the adrenal gland at the Mayo Clinic in 1929.[56] As has been shown in other joints such as the knee and shoulder,[57,58] intraarticular injection of steroid can decrease pain and improve function of the arthritic CMC1 joint, at least in the short term.[59] A systematic review of the use of steroid injections at the CMC1 joint showed positive benefits of pain relief for 1-3 months after injection.[60] A randomized trial comparing steroid injection to placebo in 40 patients with moderate to severe CMC1 OA showed no differences in joint tenderness, pain, or patient global assessment at 4, 12, or 24 weeks after injection.[61]

Hyaluronic acid injections are synthetic derivatives of hyaluronan, a component of joint synovial fluid,[62] and have been used to treat knee OA. Their use has been described at the CMC1 joint, with findings of pain relief and improvement of function sustained longer in comparison to steroid.[63] A randomized placebo-controlled trial comparing hyaluronate to corticosteroid and placebo in 60 patients showed early pain relief with steroid and placebo, and more sustained pain relief with hyaluronate.[62] There were no significant differences in DASH scores, range of motion, or overall pain scores among the groups at any time point up to 6 months post injection.

While other injection materials have been described, the literature on these is minimal. A randomized trial of platelet-rich plasma compared to steroid injection in 33 patients with Eaton grades I-III CMC1 OA showed significantly better pain scores, QuickDASH, and satisfaction at 1 year.[64] A new innovation is the injection of autologous fat into the CMC1 joint.[65] A prospective comparative study of fat injection vs steroid in 24 subjects showed sustained pain relief in the autologous fat group at 3 months compared to the steroid group.[66]

Therapy

Therapeutic exercise for CMC1 OA can be beneficial to increase strength and joint mobility. Specific modalities such as first dorsal interosseous muscle activation, thought to ‘reduce’ the subluxated CMC1 joint and thus pain and dysfunction, have been described.[67] Wouters et al performed a prospective cohort study with propensity score matching to compare therapeutic exercise and orthotics to orthotics alone in 84 patients, and noted a larger decrease in pain visual analog scale (VAS) at rest and with loading in the exercise/orthotics group compared to the orthotic only group.[68]

Surgical Options and Outcomes

There are multiple surgical options for CMC1 OA, and these can be stratified practically by early-stage and late-stage of OA.

Surgery in Early-Stage CMC1 OA

In the patient who presents with pain at the CMC1 joint but no or minimal signs of OA on radiographs, and has failed conservative management, options for treatment include ligament stabilization as described by Eaton and Littler; dorsoradial capsular imbrication; CMC1 joint arthroscopy and synovectomy; or metacarpal extension osteotomy.

Ligament stabilization of the CMC1 joint was described for the hypermobile patient, and involves restoring the stability of the CMC1 joint by transfer of one-half the flexor carpi radialis (FCR) tendon through a transverse drill hole in the base of the first metacarpal, thus restoring dorsal and volar stability.[25] A retrospective study of 35 patients treated with this procedure and followed up at an average of 5.2 years showed 67% excellent and 30% good results, with nearly all reporting complete pain relief.[69]

The concept of reinforcing or imbricating the dorsoradial ligament in a lax CMC1 joint makes sense as this is now considered the key ligament for stability. Rayan and Do described the technique and case series in 5 patients, noting good relief of pain and improved function.[70] Other small series have noted similar good outcomes.[71]

CMC1 joint arthroscopy was originally described by Menon, who performed synovectomy and interposition with autogenous tendon, allograft, or synthetic material in 33 patients.[72] Yao and others have described both interposition and hemitrapeziectomy as arthroscopic techniques,[73] with a recent study suggesting that arthroscopic resection arthroplasty alone is just as efficacious in relieving pain and improving function when compared to arthroscopic resection and interposition.[74]

Finally, metacarpal extension osteotomy was described as a way to redistribute the forces through the CMC1 joint by shifting the load area to relieve pain.[75] A retrospective study of 12 patients with a mean followup of 2.1 years treated with osteotomy reported increased grip and pinch, with high satisfaction.[76]

Surgery in Late-Stage CMC1 OA

When conservative treatment of CMC1 OA fails, the classically described surgical treatment is removal of the trapezium[77] with additional procedures to further stabilize the first metacarpal base such as tendon suspension;[78-80] or implant arthroplasty to replace the joint using silicone or metal materials.[81-84]

Simple removal of the trapezium was first described in a case report in 1947 as a way to treat CMC1 OA.[77] Davis et al demonstrated in a randomized prospective study that the 1-year outcomes of simple trapeziectomy were comparable to those after tendon interposition or ligament reconstruction in 76 women with CMC1 OA.[85] Long-term follow-up has confirmed these results.[86,87]

While the need to suspend the first metacarpal or reconstruct the ligaments has been debated, there are multiple techniques described to perform this. Burton and Pellegrini described the well-known ligament reconstruction and tendon interposition (LRTI), in which half the FCR tendon was harvested and placed through a drill hole in the first metacarpal base to both reconstruct the ligaments and act as a spacer within the trapezial gap.[78]

The use of the abductor pollicis longus (APL) tendon has been described as an alternative option for suspension of the first metacarpal, with the advantages of surgery through a single incision.[88] Other techniques include the Weilby suspensionplasty, whereby the FCR tendon is harvested and looped in a figure-of-eight fashion around the APL to provide a sling.[89] Other ways to suspend the first metacarpal include suture suspension[90] and the use of commercial suture-button modalities.[91] While there are several reports of short term results after FCR and APL suspension,[92,93] there is a paucity of studies focused on long-term outcomes after trapeziectomy and suspensionplasty.[94,95]

Alternatives to trapeziectomy and suspensionplasty include arthrodesis or implant arthroplasty. Arthrodesis has traditionally been limited to younger laborers,[96] but some authors have expanded their indications to patients of middle age and reported function and pain relief similar to LRTI in comparative series.[97] A randomized trial comparing trapeziectomy/LRTI to arthrodesis in 43 women was terminated due to a high rate of complications in the arthrodesis group, specifically hardware issues and non-union, although outcomes measured by DASH and Patient-Rated Wrist and Hand Evaluation (PRWHE) scores were similar.[98]

Implant arthroplasty for the CMC1 joint was originally described by Swanson, who proposed and created a silicone rubber implant with intramedullary fixation into the base of the first metacarpal after trapezial removal.[99] Long-term outcomes of silicone arthroplasty have shown mixed results, with concerns for silicone synovitis and failure[100] but other reports showing low revision rates and high patient satisfaction.[81] Alternative implant materials include metal/plastic[101] and pyrocarbon,[102] with medium-term outcomes showing mixed results.[103] While high patient satisfaction and good pain relief are reported, more comprehensive studies including register data have shown survivorship between 70-90% at 5-10 years with complications including implant dislocation, fracture, and need for revision.[104-106]

With multiple surgical techniques described for CMC1 OA, the literature includes many series and cohort studies showing successful relief of pain and good function in the short term.[107,108] Comparative studies have shown that soft-tissue arthroplasty is overall successful, with simple trapeziectomy showing the lowest rate of complications.[109] Implant arthroplasty has higher failure and revision rates when compared to soft tissue surgery.[110,111]

Sick Leave after CMC1 Surgery

There are very limited data specifically addressing sick leave after CMC1 surgery. A number of single-center studies have noted return to work as a factor reported in the outcomes of surgery. A study of trapeziectomy and LRTI reported that 25 of 28 (89%) patients were able to return to their previous occupation, but did not stratify patients by occupation or time to return to work.[112] A prospective study of 20 patients with a mean age of 55 years (range, 43-65 years) treated with arthroscopic partial trapeziectomy reported return to work for 7/16 (44%) employed patients at 3 months. By 6 months, 14/16 (88%) had returned to their occupation.[113] Another study compared 34 trapeziectomies combined with tendon interposition to 35 trapeziectomy-suspensionplasty cases, and noted nearly equivalent strength and satisfaction, but poor endurance at work in both groups. Although there was no specific work-level data, the authors stated that it took 2 years for patients to return to normal activity post-surgery.[114]

Studies of post-surgery sick leave in the Swedish population have shown variable time out of work based on the type of surgery performed. A study of carpal tunnel syndrome showed median duration of sick leave after surgery was 35 days in women and 41 days in men.[115] In evaluation of knee and hip replacement surgery, more analogous to CMC1 surgery, Stigmar et al showed a median sick leave length of 117 days in women and 96 days in men following surgery.[116]

Revision after CMC1 Surgery

The need for revision after CMC1 surgery is low, based on the evidence. A single-center retrospective analysis of 654 procedures at the Mayo clinic showed that 15 patients with 17 arthroplasties (2.6%) required revision.[117] These were all soft-tissue arthroplasties, and revision surgery included neurolysis, soft-tissue interposition, or ligament reconstruction, with good results reported in 13/17 and failures of revision in 4, associated with nerve injury. Megerle et al reported on 12 patients undergoing secondary surgery, with an overall revision rate of 2.9% at a single center, with the most common reasons for revision being residual osteophytes at the base of the first metacarpal, superficial radial neuroma or injury, and scaphotrapezoid OA.[118]

A retrospective database review at two institutions noted 32 patients undergoing revision CMC1 surgery at a mean age of 58 years, with median time to revision of 34 months (range, 6-133 months).[119] All patients had pain and radiographic metacarpal subsidence, with 11/32 with ST joint OA. This group was treated with distraction pinning, combined with multiple soft tissue procedures.

Aims

I. To evaluate the clinically important prevalence of CMC1 OA by age and sex using physician-assigned diagnoses

II. To examine the impact of varying load by occupation on the odds of a diagnosis of CMC1 OA in the working population, and to analyze differences in risk of CMC1 OA by sex

III. To evaluate sick leave after surgery for CMC1 OA, with specific comparison of soft tissue versus implant arthroplasty surgery in a large population of working age

IV. To assess long-term outcomes after APL tendon suspension-interposition arthroplasty surgery with physical examination, patient reported outcomes, and radiographs

Subjects and Methods

Region Skåne

This research study is based on data derived from the population of the Skåne region in Sweden, in the southernmost portion of the country (Figure 4).

Figure 4. Map showing location of Skåne (highlighted) in southern Sweden.

This geographic region encompasses 33 municipalities and has a total population of 1.32 million residents (2016 data, Statistics Sweden), making up 13% of the Swedish population overall. The population density is high, at 121 persons per square kilometer, compared to the average population density in Sweden at 25 persons/km^2.[120]

Register Data and Research

Because of the location of Lund University in Skåne as well as government support of register and epidemiological studies, there is a multitude of epidemiological cohorts existing in Skåne. Some examples include the Malmö Offspring Study, formed in 2013 with the goal to map family patterns of cardiovascular disease and diabetes,[121] and the Malmö Diet and Cancer Study (MKC) with original enrollment of 17,000 women and 11,000 men, focused on the link between diet and cancer.[122]

Three of the studies presented in this thesis involve the use of data derived from several registers, some internal to Skåne and some at the national level. In evaluation of epidemiology, occupational risk, and sick leave, we accessed data from the Skåne Healthcare Register (SHR). The SHR is an administrative healthcare repository, with information from medical records and administrative data collected from healthcare accessed in Region Skåne from 1998-present.[123] It includes individual-level data in both primary and specialty care, on an in-patient and outpatient level, and captures each contact with healthcare. The SHR also captures the diagnostic codes as assigned by physicians using International Classification of Diseases-10 (ICD-10). Studies of coding accuracy in the SHR have shown high validity in assigned diagnoses.[123]

For information on occupation and sick leave, we accessed the Swedish Social Insurance Agency register.[124] This database contains annual data collected since 1990 on all individuals aged 16 years or older, including individual-level information on registered occupation, places of employment, disability and other compensation, highest level of education, and residence. Because data are identified by personal identification number, this information can be crosslinked with SHR data for correlation with health records.

The Skåne population register and Swedish cause of death register were utilized to confirm individuals who had moved out of the region or had died.[125] The population register contains linked data by identification number, with information on residency, family, marriage status, and civil registration. The electronic version of the death register has been in existence since 1952, with multiple data points including ICD-10 codes.

Ethical Approval

Papers I, II, and III all used data derived from register information. The use of the SHR data was approved by the regional ethics board as an opt-out study, in that data is included automatically unless a resident of Skåne contacts a study's principal investigator to restrict access to their health data. All data is retrieved using the encrypted personal identification number that is unique to every individual Swedish citizen, with no access to identifying characteristics such as name or address. Use of linked data from the SSIA database was approved by ethical screening with confirmation that data was anonymised.

The protocol for the study in Paper IV was approved by the Regional Ethical Review Board (# 2018-485) and each patient included gave written informed consent for participation.

Definition of Doctor-Diagnosed CMC1 OA (Paper I)

Previous prevalence studies defined CMC1 OA based on radiographic criteria,[35,42,126] or self-defined diagnosis, i.e. an affirmative answer to a study interviewer who asks "do you have arthritis in your hand?"[127,128] Other studies have performed detailed interviews by trained nurses, with followup radiographs.[36] We believe a physician-assigned diagnosis is the most stringent method of diagnosis of CMC1 OA, in that the physician is evaluating a patient who specifically sought care for this issue and can use comprehensive criteria, to include history, physical examination, and imaging, to make this diagnosis.[129,130]

The SHR data includes diagnostic codes derived from the ICD-10. The ICD-10 codes were introduced in 1992 by the World Health Organization as an update to the previous revision, and included many more codes for specificity of location and disease, including joint-specific codes.[131] These codes are input by physicians for each clinical encounter. We queried the SHR for physician-diagnosed CMC1 OA using the ICD-10 code specific to CMC1 OA, which is M18 (including subsets M18.0, M18.1, M18.2, M18.3, M18.4, M18.5 and M18.9, some of which characterize post-traumatic or secondary OA at this joint).

In this study, we included all residents of Skåne from age 20 years, who had an M18 code assigned from 1998-2012. We excluded those who had died or moved outside the region using linkage with the population register. One code per patient was counted; because approximately 30% of all outpatient care in Skåne is provided by private practice, with diagnostic codes not routinely included in the register, we reduced the population denominator by 20% to account for this loss of codes. We chose to reduce the denominator by less than 30% because register data has shown that approximately one-third of patients who are managed in private health care for a specific condition also are seen at some point in the course of their condition by a provider in the public system, where the coding is captured.[132]

Stratification of Occupational Load (Paper II)

In order to evaluate for a relationship between occupational load and a diagnosis of CMC1 OA, it was necessary to categorize the amount of load stress by occupation. The Swedish Occupational Register contains information on the occupation of all persons aged 16 years or older, reported yearly by employers. The register classifies individuals into categories using the Swedish Standard Classification of Occupations (SSYK) from 2012, which is based on the International Standard Classification of Occupations-08 (published in 2008). This classification is an international standard adopted by the International Labour Office with support from the United Nations.[133] The ISCO (and thus the SSYK) divide occupations into 10 major groups. (Table 2)

Table 2. Categories from the International Standard Classification of Occupations

ISCO Major Group Number	ISCO Definition
1	Managers
2	Professionals
3	Technicians and Associate Professionals
4	Clerical Support Workers
5	Services and Sales Workers
6	Skilled Agricultural, Forestry, and Fishery Workers
7	Craft and Related Trades Workers
8	Plant and Machine Operators and Assemblers
9	Elementary Occupations
0	Armed Forces Occupations

Each of the major groups has a number of subset types into which the ISCO-08 and SSYK place individuals. In order to define occupational load, we stratified occupations by load into light, light-moderate, moderate and heavy occupational load based on a previous occupational study.[134] We also separately defined a subset of occupations requiring repetitive hand use, which included restaurant staff, nurses, dental hygienists, and computer workers. These occupations drew from every occupational level except heavy or manual labor.

Using this classification scheme, we identified all individuals between 30-65 years of age who received at least two diagnoses of CMC1 OA between 1998-2013. We then created a control cohort by matching up to 4 individuals by birth year, sex, postcode and level of education. To estimate the relationship between load and occupation, we linked the case and control cohorts to occupation using the occupational register. We defined exposure by assigning each person in both groups to the profession in which they were registered in 2013.

Measurement of Sick Leave Time (Paper III)

In order to measure sick leave taken in relation to a surgical procedure for CMC1 OA, we cross-referenced data from the SHR with individual level data from the Swedish Social Insurance Agency. In Sweden, the first 14 days of leave for illness are paid by the employer, and thus this payment cannot be differentiated from salary pay. Those persons with disability pension documented in the 365-day period before the identified surgery date occurred were excluded.

We identified two surgical cohorts of individuals undergoing surgery for CMC1 OA by querying the SHR for the following:

1. Code of M18 to indicate CMC1 OA
2. Procedure code of NGD12 (soft tissue CMC-I arthroplasty) or NDB (prosthetic implant arthroplasty)
3. Age between 40-59 years
4. Resident of Region Skåne a full year prior to date of surgical procedure code

Using the SHR, two surgical cohorts were analyzed: 421 people who were treated with soft tissue arthroplasty and 220 people who underwent prosthetic implant arthroplasty during the 8 year period from 2004-2012. Reference cohorts totalled 1,677 persons for the soft tissue arthroplasty group and 874 persons for the prosthetic implant group.

We then excluded 95 and 567 persons in the soft tissue group and reference group respectively due to sick leave in the year before the surgical date. Similarly, 51 and 300 persons were excluded in the prosthetic implant cohort for the same reasons.

We also created a comparison control group by matching 4 individuals to each case individual by birth year and sex, each of whom had consulted for any medical care noted within the SHR. These control subjects were excluded if they had disability pension in the year before the index date of surgery of their case matched subject.

Long Term Followup of a Surgical Cohort (Paper IV)

From the orthopedic surgery register for Skåne, we identified all adults who had been treated with surgery at one orthopedic department (Hässleholm and Kristianstad Hospitals) for the diagnosis code for CMC1 OA (ICD-10 code M18.0 or M18.1) over the time period 1998-2005. We then limited the cohort to patients who were treated with surgical trapeziectomy and APL suspension-interposition arthroplasty. Each patient was then contacted by a research nurse and asked to attend the hospital for clinical and radiographic evaluation.

We evaluated each patient for range of motion of the thumb CMC, MCP, and IP joints, as well as wrist flexion, extension, radial deviation and ulnar deviation. We also measured grip strength and key pinch strength. Each patient had radiographs of both hands, with three standard views obtained.

Each patient completed the following standardized outcomes questionnaires: QuickDASH,[135] a thumb-specific 2-item pain scale to rate the severity of pain in the thumb and related activity limitations,[136] VAS to measure pain,[137] and were asked to rate their satisfaction with the results of surgery (satisfied, somewhat satisfied or dissatisfied).

Data from the National Quality Registry for Hand Surgery (HAKIR)

Because preoperative patient-reported outcome measures were not available, we obtained data from two referent cohorts from the Swedish national quality registry for hand surgery (HAKIR).[138] Specialized hand surgery departments in Sweden register all surgeries in HAKIR by ICD-10 codes and Scandinavian surgical codes. Patient-reported outcome is collected preoperatively and 1 year postoperatively, including the QuickDASH and three questions about pain: pain on load, pain on motion without load, and pain at rest, scored on a scale with 10-point increments 0 to 100 (lower is better).[139,140]

In the present study we used preoperative registry data (pain and QuickDASH) for all patients, within the same age span as the study cohort, who between April 2011 and January 2020 were treated for CMC1 OA with trapeziectomy and any type of tendon suspension-interposition arthroplasty (because the indication for surgery is usually similar irrespective of the type of tendon used). We also obtained 1-year postoperative registry data for patients treated specifically with trapeziectomy and APL suspension-interposition arthroplasty.

Epidemiological Methods

Prevalence

We calculated the overall prevalence for the diagnosis of CMC1 OA from 1998-2012, then stratified by gender and age. We also evaluated the incidence within the year 2012, as an incidence proportion using the known Skåne population for that year, and compared this to the prevalence over time. We also performed a sensitivity analysis to confirm robustness of the data. This was done to examine variables with expected impact on the analysis - in this case, life expectancy and the chance in that time period that someone would be diagnosed with this disease. The analysis was performed by multiplying the 2012 incidence with the mean disease duration. This was defined as equal to the remaining number of years of life expectancy at age 65, derived from Statistics Sweden.

Conditional Logistic Regression Analysis

In evaluation of occupational exposure, we analysed for a relationship between load and CMC1 OA diagnosis using conditional logistic regression. We used a conditional model because of the matched population, with 4 controls matched by sex, birth year, postcode and education level. Using this analysis, we derived odds ratios for associations between the selected group and a CMC1 OA diagnosis.

Negative Binomial Regression

Negative binomial regression is used to compare counts (or the number of times an event occurs). We used this technique to compare sick leave between surgical cohorts, after calculating the mean number of sick leave days for each month for 12 months before and 24 months after surgery. The differences in sick leave days were expressed using incidence rate ratios, with 95% confidence intervals.

This model was chosen because days of sick leave are count variables with variance of the means that exceed the mean. Negative binomial regression is typically used for over-dispersed count data such as this.

Linear Mixed Effects Regression Model

To evaluate the association between trapezial space on radiographs and pinch strength at the thumb, we used a linear mixed effects regression, with the exposure being the trapezial space and the outcome as pinch strength. The model was adjusted for confounders including pain, age, sex, and grade of OA.

Results

Prevalence of CMC1 Osteoarthritis (Paper I)

Using the population of region Skåne in 2012, reduced by 20%, we defined the population denominator as 780,204 persons. We identified the total number of residents given a CMC1 OA diagnosis as 11,111. The overall prevalence for the diagnosis was 1.42% (95% CI, 1.40 to 1.45). Stratified by gender, the prevalence of CMC1 OA was 2.2% in women vs. 0.6% in men. The highest prevalence in women was at age 65-70 years (5.1%) and in men at 75-80 years and greater than 80 years, both 1.9%. (Figure 5)

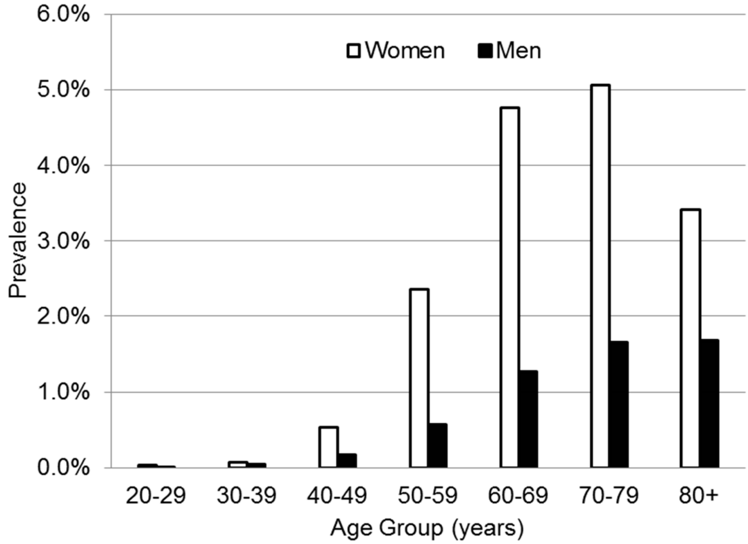

Figure 5. Prevalence of CMC1 OA by age and sex.

The incidence in the year 2012 was 228 per 100,000 in women and 71 per 100,000 in men. The sensitivity analysis showed that an expected point prevalence would be 4.8% in women and 1.3% in men, which are similar to the actual results for the prevalence in that age group.

Positive Relationship between Occupational Load and CMC1 OA (Paper II)

Using the SHR, we identified 3,813 people with a diagnosis of CMC1 OA in region Skåne in 2013. We then excluded those serving in the military (32 persons), 41 persons with missing data, and those not assigned to any occupation in 2013. The overall study sample included 3,462 CMC1 OA patients and 13,211 controls.

The CMC1 population had a mean age of 63 years, consisting of 2770 women and 692 men (Table 3).

Table 3. Occupational Exposure for Men and Women CMC1 OA Cases and Controls

	n (%)		**Age (years), mean (SD)**	
Level of work demand	CMC1 OA cases	Controls	CMC1 OA cases	Controls
Men, all categories	662	2532	63 (7)	63 (7)
Light	194 (29)	997 (39)	64 (7)	63 (7)
Light-moderate	71 (11)	302 (12)	62 (9)	63 (8)
Moderate	79 (12)	268 (11)	63 (8)	63 (8)
Heavy	318 (48)	965 (38)	62 (8)	63 (8)
Women, all categories	2838	10,679	63 (7)	63 (7)
Light	1209 (43)	5311 (50)	64 (7)	64 (7)
Light-moderate	1106 (39)	3499 (32)	63 (7)	63 (7)
Moderate	363 (13)	1308 (12)	63 (8)	63 (8)
Heavy	160 (6)	561 (5)	62 (8)	63 (8)

We found that the heavy occupational load group had a significantly higher odds of having a CMC1 OA diagnosis overall, with a dose-response effect in men. The overall estimated ORs for CMC1 OA were 1.46 (95% CI, 1.33 to 1.60) for light-moderate manual work, 1.34 (95% CI, 1.18 to 1.53) for moderate manual work, and 1.58 (95% CI, 1.38 to 1.82) for heavy manual work as compared with the light work category as the referent. When stratified by sex, the analysis showed a dose-response pattern in men, with heavier occupational demand associated with higher OR for doctor-diagnosed CMC1 OA (Table 4). We did not find a similar association for women, although all three occupational categories were associated with higher odds of CMC1 OA compared to the referent light work population.

Table 4. Occupational Level and Odds Ratio (OR) for CMC1 OA Diagnosis

	All		Men		Women	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Light	referent	referent	referent	referent	referent	referent
Light-moderate	1.46	1.33 to 1.60	1.31	0.96 to 1.79	1.46	1.32 to 1.61
Moderate	1.34	1.18 to 1.53	1.76	1.29 to 2.40	1.27	1.10 to 1.46
Heavy	1.58	1.38 to 1.82	2.00	1.59 to 2.51	1.31	1.07 to 1.59

We performed a second analysis to compare occupations defined as repetitive to both light and heavy loads and noted that repetitive occupations had a higher risk of CMC1 diagnosis (overall 1.31, 95% CI 1.18 to 1.46) than the light referent group, but still less than the heavy group (1.75, 95% CI 1.48 to 2.06), and that women in repetitive occupations had risks of CMC1 diagnosis comparable to those in heavy occupations (Table 5).

Table 5. Repetitive Occupations and Odds Ratio (OR) for CMC1 OA Diagnosis

	All		Men		Women	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Light (n=4752)	referent	referent	referent	referent	referent	referent
Repetitive (n=2393)	1.31	1.18 to 1.46	1.47	1.08 to 2.01	1.27	1.14 to 1.43
Heavy (n=1861)	1.75	1.48 to 2.06	2.30	1.76 to 3.02	1.41	1.12 to 1.77

Sick Leave is Shorter after Prosthetic Implant Arthroplasty Surgery Compared to Soft Tissue Arthroplasty Surgery (Paper III)

After exclusions, we compared 169 individuals who underwent prosthetic arthroplasty to 326 who were treated with soft tissue surgery. Table 6 shows the remaining surgical and control subjects available for analysis:

Table 6. Surgical and Control Cohorts by Sex and Age

	Surgical Cohort, n **Reference Cohort, n**	**Women, n (%)**	**Men, n (%)**	**Mean Age, y (SD)**
Soft tissue arthroplasty	326 1,1110	286 (88) 970 (87)	40 (12) 140 (13)	54 (4) 54 (4)
Implant arthroplasty	169 574	138 (82) 466 (81)	31 (18) 108 (19)	55 (4) 54 (4)

In the soft tissue arthroplasty group, 261 of 326 (80%) had documented sick leave after surgery. The duration in women was a mean of 202 days (median, 124 days). In men, the mean sick leave was 170 days (median, 138 days) (Table 7). We then excluded the data of those individuals who had sick leave for any reason 8 to 30 days prior to surgery – using this factor as a proxy for a 'healthier' group without other illnesses or reasons to be out of work. This group was composed of 152 women and 23 men. In this group, the mean and median duration of sick leave in women were 137 and 100 days after soft tissue arthroplasty, respectively; men were out of work a mean of 125 days and a median of 90 days post surgery.

Table 7. Sick Leave by Procedure Type

Procedure	Number of Subjects	Number with Sick Leave Days (n)	Mean (SD) Days of Sick Leave	Median Days of Sick Leave	10th percentile (days)	90th percentile (days)
Soft Tissue Arthroplasty						
All Surgical Patients	326	261				
Women	286	228	202 (192)	124	55	539
Men	40	33	170 (144)	138	77	371
Subgroup with No Sick Leave before Surgery*	240	175				
Women	210	152	137 (127)	100	50	226
Men	30	23	125 (93)	90	53	192
Implant Arthroplasty						
All Surgical Patients	169	146				
Women	138	121	177 (190)	95	56	445
Men	31	25	188 (236)	71	29	720
Subgroup with No Sick Leave before Surgery*	117	94				
Women	93	76	109 (117)	79	43	148
Men	24	18	94 (127)	62	29	153

*Patients with no registered sick leave 8-30 days before the surgery date.

In the implant arthroplasty group, 146 of 169 (86%) had documented sick leave time after surgery. In the overall group, the mean duration of sick leave was 177 days for women (median, 95 days) and 188 days for men (median, 71 days). We performed a similar exclusion as was done in the arthroplasty group to examine a more healthy cohort with no sick leave in the month prior to surgery. This group, composed of 94/169 patients (55%), was made up of 76 women and 18 men. Women had a mean of 109 days sick leave (median, 79 days) and men had 94 days of sick leave (median, 62 days).

Overall, sick leave was lower in all categories when comparing the prosthetic to the soft tissue arthroplasty groups, although the differences were not significant (IRR 0.91, 95% CI 0.77 to 1.08). When comparing the groups with no sick leave 8-30 days prior to surgery, the differences between surgical types were significant with prosthetic implant patients having a shorter time out of work (IRR 0.79, 95% CI 0.66 to 0.94).

Comparing sex and age, we noted no differences. Women had IRR of 1.07 compared to men with regard to sick leave (95% CI 0.85 to 1.35). Age also did not affect sick leave length (IRR 0.99, 95% CI 0.97 to 1.01).

Trapeziectomy and APL Suspension-Interposition Arthroplasty Surgery is Durable and Effective in Long-Term Followup (Paper IV)

The original cohort of 100 patients (125 hands) was composed of 92 women and 8 men with a mean (SD) age of 59 (6) years at the time of surgery. Surgical side was nearly evenly divided between right and left; 99 patients were right hand dominant. Mean followup time was 17 (range, 13-21) years. (Table 8)

Table 8. Patient Characteristics

	All	Women	Men
No. of Patients (Hands)	100 (125)	92 (117)	8 (8)
Side (n)			
Right	62	59	3
Left	63	58	5
Age at surgery, median (range) y*	58 (42-72)	58 (42-72)	57 (42-71)
Age at follow-up, median (range) y*	74 (61-90)	74 (61-90)	74 (62-86)
Follow-up length, mean (range) y*	17 (13-21)	17 (13-21)	17 (13-20)

*Data for the 96 patients (119 hands) who participated in follow-up.

Of the group of 100 patients (125 hands) that underwent trapeziectomy and APL suspension-interposition arthroplasty, 80 subjects (101 hands) were available for follow-up examination in 2018. A total of 71 women and 7 men with a mean age (SD) of 74 (6) years were examined by one of two hand therapists.

For the operated study hands of all respondents to the thumb pain scale (n=119), the mean thumb pain score was 19 (SD 26, median 0), with a score of 0 (no pain and related activity limitations) recorded in 71 (60%) of the study hands and score below 30 in 17 (14%) of the hands. In patients with unilateral surgery the mean and median thumb pain scores were lower in the study hands than in the contralateral hands (Table 9). For the operated study hands of all respondents to the full questionnaire (n=108) the hand pain VAS score was 20 (SD 25, median 20) and QuickDASH score 25 (SD 22, median 21). In patients with unilateral surgery the mean and median hand pain VAS and QuickDASH scores did not differ between the study and contralateral hands, with mean QuickDASH of 27 in the operated and 28 in the contralateral hand.

Table 9. Patient-Reported Outcomes Measures

Scale	Unilateral Surgery n=64*				Bilateral Surgery n=22†			
	Operated		Contralateral		Right		Left	
	mean (SD)	median (quartiles)	mean (SD)	median (quartiles)	mean (SD)	median (quartiles)	mean (SD)	median (quartiles)
Thumb Pain scale‡	20 (28)	0 (0, 48)	29 (31)	16 (0, 59)	16 (24)	0 (0, 28)	16 (25)	0 (0, 49)
Hand Pain VAS	24 (26)	20 (1, 36)	29 (27)	21 (5, 50)	30 (28)	30 (2, 50)	16 (19)	7 (1, 31)
QuickDASH	27 (21)	25 (8, 40)	28 (22)	24 (8, 39)	25 (25)	18 (6, 48)	21 (20)	15 (5, 42)

Score range: 0 (best) to 100 (worst)
*16 patients had undergone contralateral APL arthroplasty (6 before and 10 after the study period) and 2 patients had undergone contralateral CMC1 fusion before the study period; 5 patients with only questionnaire response (2 had undergone contralateral CMC1 fusion during the study period before the surgery on the study hand).
†1 patient with only questionnaire response.
‡Completed (through telephone interview) by additional 9 patients with unilateral surgery (2 had contralateral CMC I fusion prior to the tendon arthroplasty) and 1 patient with bilateral surgery.

The pain and QuickDASH scores were generally similar to the 1-year postoperative scores in the hand surgery registry cohort (Table 10). The difference between the mean preoperative and postoperative QuickDASH scores is greater by a large margin than the minimal clinically important difference (MCID)[141] of 6.8 for the QuickDASH.

Table 10. Referent Cohorts from the Swedish Quality Registry for Hand Surgery (HAKIR) and the Study Cohort

	HAKIR Register Referent Cohorts				Study Cohort	
	Preoperative*		1y Postoperative		13-21y Postoperative	
	Women n=656	Men n=146	Women n=44	Men n=15	Women n=101	Men n=7
Age at surgery (y)	59 (7)	62 (5)	59 (8)	65 (7)	58 (6)	62 (8)
Side, n (%)						
Right	323 (49)	59 (40)	25 (67)	6	49 (49)	3
Left	333 (51)	87 (60)	19 (43)	9	52 (51)	4
Pain at rest	52 (25)	45 (26)	14 (23)	3 (5)		
Pain on motion without load	60 (21)	51 (23)	19 (23)	6 (13)		
Pain on load	77 (16)	73 (19)	31 (29)	14 (20)	19 (26)‡	17 (29)‡
QuickDASH	57 (16)	48 (16)	29 (24)	12 (12)	26 (22)	17 (15)

Values are mean (SD). Score range 0 (best) to 100 (worst).
*Patients who had underwent trapeziectomy and any type of tendon interposition arthroplasty, including APL in 92 women and 26 men.
†Patients who underwent trapeziectomy and APL suspension interposition arthroplasty.
‡Thumb-specific 2-item pain scale score range from 0 (best) to 100 (worst)

Patients stated that they were very satisfied with the outcome in 87 hands (86%) whereas in 14% they stated being either rather satisfied (13 hands) or dissatisfied (1 hand).

Additionally, range of motion measurements of the thumb and wrist were similar to the contralateral hand. (Table 11)

Table 11. Physical Examination Measures

	Unilateral Surgery n=59*		Bilateral Surgery n=21	
	Operated	Contralateral	Right	Left
Strength (kg) (SD)				
Grip	17.1 (7.0)	17.2 (7.4)	16.3 (7.4)	15.7 (6.8)
Tip Pinch	4.3 (1.4)	4.8 (1.6)	4.5 (1.5)	4.2 (1.6)
Range of Motion (°) (SD)				
Thumb				
IP extension†	10 (11)	11 (16)	11 (9)	10 (14)
IP flexion	64 (12)	62 (12)	61 (15)	61 (11)
MCP extension†	15 (15)	11 (18)	13 (10)	16 (14)
MCP flexion	41 (13)	41 (14)	39 (15)	40 (10)
Palmar abduction	39 (10)	40 (10)	36 (8)	37 (9)
Radial abduction	42 (7)	42 (7)	45 (7)	44 (7)
Opposition (mm)‡	7 (0, 11)	8 (0, 13)	6 (0, 10)	6 (0, 11)
Wrist (°) (SD)				
Flexion	60 (14)	57 (14)	65 (14)	63 (12)
Extension	60 (13)	56 (11)	62 (13)	63 (12)
Radial deviation	23 (13)	20 (7)	20 (7)	20 (5)
Ulnar deviation	39 (10)	40 (10)	39 (9)	42 (9)

Values are mean (SD) unless otherwise specified.
*16 patients had undergone contralateral APL arthroplasty (6 before and 10 after the study period) and 2 patients had undergone contralateral CMC1 fusion before the study period.
†Values represent hyperextension; MCP fusion in 2 operated and 2 contralateral hands in the unilateral group and in 3 hands (2 right and 1 left) in the bilateral group, and MCP extension deficit (>10º) was present in 1 operated hand and 2 contralateral hands in the unilateral group.
‡Values are median (quartiles) distance to base of small finger.
IP - interphalangeal; MCP - metacarpophalangeal

Radiographic evaluation

The mean unloaded trapezial space was 4.6 mm (SD 2.3, median 4.4, range 0.6-12.7 mm). The median Kellgren-Lawrence OA grade was 2 for the ST joint, with OA grade of 2 to 4 seen in 72 (72%) of joints. Among the 39 unilaterally operated patients with unoperated contralateral CMC1 joint, ST OA grade 2 to 4 was observed in 26 (67%) of the operated hands and 34 (87%) of the contralateral hands (Table 12).

Table 12. Radiographic Scaphotrapezoid Joint Osteoarthritis (ST OA)

OA grade*	All operated hands n=101†	Operated hands with unoperated contralateral CMC1 joint (n=39)	
	Operated	Operated	Contralateral
0	10 (10)	4 (10)	4 (10)
1	18 (18)	9 (23)	1 (3)
2	30 (30)	12 (31)	13 (33)
3	30 (30)	8 (21)	11 (28)
4	12 (12)	6 (15)	10 (26)

Values are n (%)
*Kellgren-Lawrence grading, range 0 (no OA) to 4 (most severe OA).
†1 hand had been revised with fusion of the scaphotrapezoid joint before follow-up.

The estimated association between trapezial space and pinch strength (in kg per 1-mm increase in trapezial space) was 0.05 (95% CI -0.07 to 0.16) when adjusted for age, sex and side and 0.07 (95% CI -0.04 to 0.18) when additionally adjusted for pain and STT OA grade. The model adjusting for time since surgery gave similar results (0.05, 95% CI -0.07 to 0.17).

Discussion

Epidemiology of CMC1 OA

The majority of studies on the epidemiology of CMC1 OA are based on radiographic reviews or questionnaire/census studies.[36,127,142,143] A recent report from the Framingham Osteoarthritis Study used evaluations of radiographs in combination with interviews where subjects self-reported pain, aching, or stiffness in joints of the hand.[142] Reporting perceived pain, with or without correlative radiographs, is not equivalent to a physician diagnosis of OA. We identified subjects who were assigned a diagnosis specific to CMC1 OA by a physician; 63% of subjects were assigned a diagnosis by a specialist in orthopedics or hand surgery. Thus, the epidemiological estimates presented in this study are based on more stringent criteria, rather than on X-rays only or patient perception of OA.

Our findings confirm the previously noted sex differences in the prevalence of CMC1 OA, with women receiving a diagnosis nearly 4 times more than men. This difference has been previously reported in both radiologic[35] and interview[127] studies. In a study of men and women with early CMC1 OA as well as asymptomatic controls, investigators noted increased joint space narrowing in women with early OA as well as older asymptomatic women, a pattern not seen in men.[38]

Evaluation by age showed a peak prevalence in women between 70-74 years, with the peak in men a decade older at 80-84 years, when evaluating the entire population over time. These findings mirror other epidemiological studies, showing highest incidence over 75 years.[36,144] We evaluated prevalence in 5 year increments up to 80 years, with resulting high specificity in peaks of presentation.

We evaluated an incidence proportion for CMC1 OA for the year 2012, noting that the peak rate of first time CMC1 OA diagnosis in women was a decade earlier at 60-69 years, with men also showing the highest consultation rate a decade earlier at 70-79 years. These findings suggest that this site of hand OA is a primary complaint and reason for seeking care at these ages. A recent study of conservative management of CMC1 OA showed similar baseline age of 60 years in a group of 391 patients treated with orthosis and therapy.[145] The drop in diagnoses in the oldest population groups may indicate that medical care is more focused on cardiac or other common health issues at advanced ages.

Our study was limited primarily by database limitations; specifically, the SHR does not include radiographic data, precluding any correlation of OA diagnosis with X-rays.

Additionally, the side of OA or length of symptoms is not available for analysis but would be very useful in forming a more comprehensive picture of this disease's prevalence.

Occupation and Risk of CMC1 OA

The link between occupational load and the development of CMC1 OA has been explored primarily in small case series. Fontana et al evaluated a group of women treated with surgery for CMC1 OA, with age-matched control group without history of CMC1 OA.[48] The authors then performed a detailed qualitative interview to evaluate occupational factors, and noted that the primary risk factors for CMC1 OA were occupations presumed 'at risk' for CMC1 OA (secretaries, dressmakers, tailors, domestic helpers and cleaners); repetitive thumb use, and jobs perceived by the subjects as not having enough rest breaks in the day. A recent meta-analysis of 19 studies focused on finger and wrist OA showed an association between pinch grip work and CMC1 OA.[146]

We performed a comprehensive analysis of occupation, with stratification of load stress, and showed a dose-response linear relationship between increased occupational load and odds ratio of diagnosis of CMC1 OA in men. In women, the highest odds ratio of CMC1 OA was related to the light-moderate group. Overall, the highest risk of CMC1 OA was in the heavy occupational group, confirming findings in the biomechanical literature which have shown that mechanical loading is associated with development and progression of OA.[147]

The findings of similar risks of CMC1 OA between repetitive and heavy occupation in women within the subset of persons performing fine manipulation or repetitive hand grasp or grip are consistent with previous studies in CMC1 OA.[48] This suggests a role for repetitive use as an additional mechanism for the development of CMC1 OA, especially in women. Recent findings of weaker key pinch strength in subjects with early CMC1 OA suggest that early awareness of occupational risk could be useful for employers and workers.[148]

This study was limited by SHR study limitations as detailed under paper I; in addition, other risk factors for CMC1 OA including family history, trauma, and obesity were not available in the register and thus not controlled for in the study. Additionally, the categorization of occupational groups was based on previous definitions[134] but is still subject to misclassification.

Comparing Sick Leave Length and Surgery Type in CMC1 OA

There are multiple surgical options for CMC1 OA, including trapeziectomy, suspension tendon arthroplasty, arthrodesis and implant arthroplasty.[86,105,149,150] While soft tissue or tendon arthroplasty is the most commonly performed surgery,[86] prosthetic implant arthroplasty is still an accepted surgical option in Scandinavia and elsewhere.[81,105,106,140] However, the issue of the cost of the implant has not been studied in depth but must be considered.[151] The cost of an implant made of surgical-grade silicone or machined metal or plastic is charged in addition to surgical and hospital costs. A recent systematic review of implant arthroplasty for the CMC1 joint reported variable outcomes and failure rates among several prostheses, noting the extra cost of the implant itself.[151]

When comparing sick leave length between patients treated with implant and soft tissue arthroplasty in the Skåne population, our study demonstrated that implant arthroplasty was associated with shorter sick leave than soft tissue arthroplasty, by a mean of 30 days, especially in patients without other comorbidities. These findings are similar to those in a prospective study of CMC1 implant surgery compared to tendon interposition.[152] The authors compared 84 patients with an Ivory prosthesis with significantly better outcomes measures and faster return to work, at 4.7 months, to a group of 62 patients treated with LRTI who returned at a mean of 8.9 months.

It has been postulated that implant arthroplasty allows faster return of function and more rapid ability to resume activities and occupation because of the immediate stability afforded by placement of an implant, as opposed to the need to wait for healing of soft tissues to stabilize the joint.[153] A series of 100 patients treated with Elektra prostheses demonstrated outcomes with return to function at 7 weeks post surgery (occupational return was not specified), and mean grip of 28 (range, 15-50 kg) at 5 months post surgery.[154]

In our study, men and women had comparable lengths of sick leave for both surgical procedures. Additionally, age did not impact sick leave length, similar to Katz's findings about time off after carpal tunnel release.[155] The length of sick leave overall was substantial, and must be considered within the context of a health system with support for time away from work.[156] A comparison of sick leave policies across the 22 countries ranked at the top of the United Nations Human Development Index indicated that countries with substantial support for time out of work for illness, surgery, or family illness include Sweden, Denmark, and the United Kingdom.[157] In contrast, the United States, Canada, and Japan have no national policies to support workers recovering from flu illness and limited medical leave policies overall.

Our study was limited by database information limitations from the SHR register, which prevents knowledge of the exact prosthetic implant used in surgery or the surgical soft tissue technique, as these could influence results. In addition, there are limitations in the Social Insurance register, which does not specifically identify the cause of sick leave.

While it is likely safe to assume that sick leave in close proximity to a surgical procedure is due to that procedure, we cannot confirm this definitively.

Long-Term Outcomes of Trapeziectomy and APL Suspension-Interposition Arthroplasty

Our cohort study of a tightly captured surgical cohort presents the longest followup available for soft tissue arthroplasty at mean of 17 years. Trapeziectomy and ligament reconstruction using tendon is the most commonly performed surgery for CMC1 OA,[158,159] but long term followup is lacking. Avisar et al presented a series of 13 patients (15 thumbs) with a mean of 15 years of followup, noting minimal pain and grip/pinch comparable to the unoperated side.[94] Another study compared trapeziectomy to ligament reconstruction and arthrodesis, with longest followup at 13 years, and noted similar outcomes with regard to pain, function, and satisfaction.[160]

The strengths of this study include in-person followup on 81% of the original cohort, with comprehensive examination, outcomes measures, and radiographs. This stringent followup allows an in depth evaluation of the results of APL suspensionplasty surgery with honest assessment over time. The results suggest that for most patients this procedure yields durable results with overall good long-term pain relief and function as evaluated with the thumb-specific pain scale and QuickDASH.

Comparison with a cohort from the Swedish national quality registry for hand surgery (HAKIR) showed that the long-term follow-up QuickDASH scores in the study cohort (mean 26 in women and 17 in men) did not differ substantially from the 1-year postoperative scores in the HAKIR cohort (mean 29 in women and 12 in men).

The results of the present study show some residual pain and activity limitations. Patients with CMC1 OA may have OA in other hand joints, which may cause some of the residual symptoms. This may explain the somewhat higher scores in the hand pain VAS than the thumb pain scale. Other comorbidities in this mainly elderly cohort may also contribute to higher QuickDASH scores.

The limitations of this study include a single-center cohort, lack of preoperative measures of pain and function, and loss of a small percentage to followup. We attempted to address the lack of preoperative data with comparison to a contemporary cohort from the Swedish national quality registry.

In summary, the findings of these research studies and the literature on this topic underline the significance of the CMC1 joint in daily function and the effect of CMC1 OA on patients. While radiographic CMC1 OA does not always translate to symptomatic OA,[42,161] those patients presenting for care do so because of impacted ability to perform both fine tasks and more manual functions.[162,163] This type of hand

OA can affect occupation, particularly with activities that require repetitive loading of the thumb or hand.[164]

In treating CMC1 OA, there is moderate evidence in support of splinting, corticosteroid injections, and therapy to reduce pain.[59,165,166] When these modalities no longer help the patient, there are a multitude of surgical options as described in the introduction. While none have been shown to be superior, systematic reviews have shown simple trapeziectomy to have the lowest rate of complications.[159,167,168]

In evaluation of outcomes after surgery, most studies present good to excellent results.[86,169,170] The need for revision has been reported at 3-5%, secondary to retained osteophytes, nerve injury, painful subsidence, or persistent unexplained pain.[111,117] Salem and Davis noted degenerative changes at the joints adjacent to the trapezium at a mean of 6 years after surgery, to a greater degree in the simple trapeziectomy patients than the LRTI patients, but these radiographic changes did not impact functional outcomes, with no differences between groups.[95]

Conclusions

This thesis has focused on several aspects of CMC1 OA: prevalence, occupation, and surgical outcomes. What have we learned from this research?

- In individuals presenting for care of and diagnosed with CMC1 OA in Skåne, there is strong female predominance in a group made up primarily of those aged 60 years and older. These findings represent clinically relevant evidence of the epidemiology of CMC1 OA, as they are drawn from a geographically contained population's health care record, and indicate that the elderly population is impacted by this disease disproportionately.
- Our findings suggest a link between occupational load and subsequent risk of CMC1 OA in a large population. In Skåne, we noted a monotonic relationship between increasing load at work and CMC1 OA diagnosis in men, and the highest odds of CMC1 OA diagnosis overall in the heaviest work group.
- In a subgroup of working persons, those characterized as performing repetitive occupations also showed increased odds of CMC1 OA compared to the referent population. These findings may be used to counsel employers and patients about future risks depending on the job type.
- In evaluation of comparative data on sick leave after either soft tissue CMC1 surgery or implant arthroplasty, we noted that implant arthroplasty was associated with earlier return to work, by approximately 30 days. These differences were significant in patients presumed to have minimal comorbid disease, while those with other reasons for sick leave did not demonstrate a large difference in time out of work after implant or soft tissue CMC1 surgery. The results of this study would be most useful to surgeons in discussing these surgical options with patients.
- In a rigorous analysis of long-term outcomes after trapeziectomy and APL suspension-interposition surgery in a group of 100 patients, 17-year follow-up in 96% showed physical function comparable to the unoperated side and patient-rated outcomes demonstrating good pain relief and subjectively improved function. The findings of this study confirm the durable results of this surgery for CMC1 OA and can be used to counsel patients about expected results.

Future Perspectives

While many of the aspects of CMC1 OA have been well-studied, there remain several unanswered questions. The lack of direct association between radiographic changes and symptomatic CMC1 joint symptoms is not well-explained. One possible explanation is the genetic basis of this disease, which has been explored in a few studies. In Iceland, a large genetic database study of individuals with severe CMC1 OA and finger joint OA demonstrated associated risk alleles for a gene, ALDH1A2, which encodes aldehyde dehydrogenase.[171] This gene is highly expressed in cartilage. Other studies showed an association of polymorphism in the MATN3 gene with CMC1 OA.[172] This gene encodes matrilin-3, a protein component of the extracellular matrix of joints.

Another important topic to address in future studies would be the need for secondary surgery after soft tissue arthroplasty, as this is the most commonly performed procedure for CMC1 OA and the only studies performed on this topic are single-center retrospective reports. Finally, prevention and/or protection for early stage CMC1 OA are critical gaps in knowledge; we as surgeons and scientists know how to treat the disease once established, but do not have effective tools to prevent it or slow its course.

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