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ORIGINAL RESEARCH

Beneficial Effects of Nonsurgical Treatment for Symptomatic Thumb Carpometacarpal Instability in Clinical Practice: A Cohort Study

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Abstract

Objective: To describe outcomes of nonsurgical treatment for symptomatic thumb carpometacarpal joint (CMC-1) instability. Secondary, to evaluate the conversion rate to surgical treatment.

Design: Prospective cohort study.

Setting: A total of 20 outpatient clinics for hand surgery and hand therapy in the Netherlands.

Participants: A consecutive sample of patients with symptomatic CMC-1 instability (N=431).

Intervention: Nonsurgical treatment including exercise therapy and an orthosis.

Main Outcome Measures: Pain (visual analog scale [VAS], 0-100) and hand function (Michigan Hand Outcomes Questionnaire [MHQ], 0-100) at baseline, 6 weeks, and 3 months. Conversion to surgery was recorded for all patients with a median follow-up of 2.8 years (range, 0.8-6.7y).

Results: VAS scores for pain during the last week, at rest, and during physical load improved with a mean difference at 3 months of 17 (97.5% CI, 9-25), 13 (97.5% CI, 9-18), and 19 (97.5% CI, 12-27), respectively ($P<.001$). No difference was present at 3 months for MHQ total score, but the subscales activities of daily living, work, pain, and satisfaction improved by 7 (97.5% CI, 1-14), 10 (97.5% CI, 4-16), 5 (97.5% CI, 2-9), and 12 (97.5% CI, 2-22) points, respectively ($P<.001$-$.007$). After median follow-up of 2.8 years, only 59 participants (14%) were surgically treated. Both in the subgroups that did and did not convert to surgery, VAS pain scores decreased at 3 months compared with baseline ($P<.001$-$.010$), whereas MHQ total score did not improve in both subgroups. However, VAS and MHQ scores remained worse for patients who eventually converted to surgery ($P<.001$).

Conclusions: In this large sample of patients with symptomatic CMC-1 instability, nonsurgical treatment demonstrated clinically relevant improvements in pain and aspects of hand function. Furthermore, after 2.8 years, only 14% of all patients were surgically treated, indicating that nonsurgical treatment is a successful treatment of choice.

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Symptomatic thumb carpometacarpal joint (CMC-1) instability can arise from multiple causes, such as generalized hypermobility, congenital disorders, or trauma and may cause pain and limitations in activities of daily living (ADL).[1-4] Furthermore, it has been suggested in literature that CMC-1 instability may predispose CMC-1 to osteoarthritis (OA) later in life.[5-10]

Whereas multiple studies have investigated nonsurgical treatment for CMC-1 OA.[11-15] to our knowledge, there are no studies describing outcome of nonsurgical treatment for symptomatic CMC-1 instability. Similar to patients with CMC-1 OA, orthotics and exercise programs may provide a long-term solution by improving lifestyle, joint mechanics, and function, but evidence for their effectiveness in symptomatic CMC-1 instability is lacking.[11-15]

Exercise therapy for CMC-1 instability intends to improve active stability and positioning of the CMC-1 into a more stable position of extension/abduction because the CMC-1 is less stable

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during flexion/adduction.[6,8-10,16-18] Additionally, exercise therapy aims to maintain the first web space and improve thumb pinch strength.[3,6,12,17,18] Furthermore, (temporary use of) orthotics often complement exercise therapy to reduce subluxation and inflammation.[6,12] Theoretically, improving joint mechanics in patients with CMC-1 instability might be very beneficial because CMC-1 instability may precede CMC-1 OA later in life.[5-10]

In cases of symptomatic CMC-1 instability where insufficient improvement occurs following nonsurgical treatment, surgical stabilization of the CMC-1 joint can be considered.[2,19,20] However, the outcome of these procedures are not very predictable, and it has been reported that results of these surgical procedures are unsatisfactory in 12%-55%.[2,19] In addition, surgical treatment comes with long recovery, prolonged patient discomfort and limitations, and high costs.[21-23] Hence, because nonsurgical treatment potentially has many advantages compared with surgical treatment and because no studies are available on this topic, more research on nonsurgical treatment for CMC-1 instability is needed. Therefore, the aim of this study is to describe the outcomes of nonsurgical treatment, exercise therapy, and an orthosis for symptomatic CMC-1 instability. Secondary, the objective was to evaluate the conversion rate to surgical treatment.

Methods

Study design

This is a prospective cohort study using a consecutive, population-based sample reported following the Strengthening the Reporting of Observational Studies in Epidemiology statement.[24]

Setting

Data were collected at Xpert Clinic and Handtherapie Nederland, comprising 20 outpatient clinics for hand surgery and therapy in the Netherlands, and took place between January 2012 and September 2018 after approval by the local Medical Research Ethical Committee. Data collection was part of routine outcome measurement using GemsTracker[a] electronic data capture tools. GemsTracker (GEneric Medical Survey Tracker) is a secure web-based application for distribution of questionnaires and forms during clinical research and quality registrations; details have been published earlier.[11,15,25]

Participants

All patients were initially diagnosed as having CMC-1 instability by one of the certified hand surgeons by physical examination. Radiographic evaluation of the CMC-1 joint was not systematically performed, but radiographs were obtained if CMC-1 OA was suspected. Subsequently, patients were referred for hand therapy. Follow-up with the hand surgeon took place after 3 months to decide if additional treatment was needed. For this study, we excluded patients who (1) were diagnosed as having CMC-1 OA (including radiographic confirmation), (2) had comorbidity interfering with treatment and/or outcome (ie, de Quervain's tenosynovitis), (3) had a patient history includes surgery interfering with treatment and/or outcome, or (4) received a steroid injection <6 weeks ago in hand or wrist.

List of abbreviations:

ADL	**activities of daily living**
CMC-1	**thumb carpometacarpal joint**
MHQ	**Michigan Hand Outcomes Questionnaire**
OA	**osteoarthritis**
VAS	**visual analog scale**

Treatment

The treatment in this study was not completely standardized as in randomized controlled trials because data collection was part of usual care. However, treatment by the hand therapists was carried out using a strict guideline,[26] which prescribes the use of both exercises and orthotics when needed. The exercises and orthotics were not applied in every patient because the treatment was tailored to the patient's needs and based on a shared decision-making process (eg, influenced by patient preferences, therapy costs, and traveling distance).

If an orthosis was provided, this included a static orthosis to reduce synovitis and instability.[12,27] The orthosis was custom made and thermoplastic; it immobilized the CMC-1 in extension/abduction and the first metacarpophalangeal joint in slight flexion. The exercise program included hand therapy sessions and exercises performed by the patient at home. These exercises aimed to improve the active stability of the thumb during pinch in extension/abduction because flexion/adduction causes instability and eventually degeneration.[3,6,8-10,18] In the first 6 weeks, the exercises aimed to improve coordination of the intrinsic thenar muscles (except the adductor pollicis), extensor pollicis brevis, and the first dorsal interosseous.[3,6,11,18] Because of the observational design of this study, no strict prescriptions regarding orthotic use were provided, but in general, if an orthosis was applied, participants were instructed to use it during heavy and provocative activities. Guided by the hand therapist, orthosis use was reduced in the subsequent 6 weeks. Furthermore, strengthening exercises for the thenar muscles (except adductor pollicis) were initiated in this phase in addition to the coordination exercises.[3,6,11,18]

Variables, data sources/measurement

Primary and secondary outcomes

Primary outcomes in this study were pain and hand function at 3 months. Mean pain in the last week, pain at rest, and pain during physical load were measured at baseline, 6 weeks, and 3 months using a visual analog scale (VAS; range, 0-100; higher scores indicate more pain). The VAS is a widely used, reliable, and valid tool for measuring pain intensity and has a minimal clinically important difference of 11 points.[28] Hand function at baseline and 3 months was evaluated using the Michigan Hand Outcomes Questionnaire (MHQ).[29] We used the MHQ total score as primary outcome while its 6 subscales were secondary outcomes (range, 0-100; higher scores indicate better performance except for the subscale pain).[29] The MHQ is a widely used tool for measuring hand function and has a high internal consistency, high internal validity, and acceptable reliability.[29] The MHQ has a minimal clinically important difference of 8-13 points (3-23 for the subscales).[30,31] Additional measurements included patient satisfaction at 6 weeks, 3 months, and 12 months, assessed using a self-designed questionnaire on the perceived treatment effect and the patients' willingness to undergo the treatment again. Conversion to surgery within a median follow-up of 2.8 years (range, 0.8-6.7y) was derived from patient charts and additional questionnaires distributed 1 year after start of nonsurgical treatment. If

a patient converted to surgery, we measured the time in months between the start of the nonsurgical treatment and the decision to proceed to surgical treatment.

Additional variables that were routinely collected in our database at baseline included age, sex, type of work, symptom duration, treatment side, and dominance (table 1).

Study size

Power analysis for a repeated measures design with 2 primary outcomes using a conventional medium effect size of 0.15 (defined by Cohen[32]), $\alpha = 0.025$, and a power of 0.80 showed that a total sample of 87 participants was needed, which was well below the sample of 435 participants that we were able to include.

Statistical methods

At baseline, 62%-72% of the primary outcomes were available. If there were missing data, we checked whether it could be retrieved from patient charts. Missing value analysis for outcomes at 3 months demonstrated a nonsignificant Little's test ($P = .771$), which suggested that missing values were missing completely at random.[33-35] To further evaluate missing data at 3 months, significance testing on demographic characteristics and baseline primary outcomes was performed to compare participants with the presence of a primary outcome at 3 months with participants without the presence of a primary outcome at 3 months. No significant differences between participants with and without the presence of a primary outcome at 3 months were found (supplemental table S1, available online only at http://www.archives-pmr.org/). Because the data were missing completely at random and no differences between participants with and without the presence of a primary outcome at 3 months were present, we used multiple imputation to obtain missing data for continuous variables with <75% missing.[33,36,37]

Treatment outcomes were analyzed using univariate linear mixed model analyses, using the outcome of interest as a dependent variable and time point as a fixed factor. Assumptions were checked using residual plots and normal probability plots. The threshold for significance is lowered to .025 from a conventional .05 to correct for multiple testing.

In addition to the overall treatment effect in the entire sample, we performed subgroup analysis for the patients who eventually converted to surgery, again using linear mixed model analyses.

Table 1 Demographic characteristics

Variable	Demographic Characteristics (N = 431)
Age, mean ± SD (y)	38.2±13
Female sex (%)	80
Symptom duration, mean ± SD (mo)	16.4±24.9
Treatment Side (%)	
- Left	40
- Right	60
Dominance (%)	
- Left	6
- Right	91
- Both	3
Type of work (%)	
- Unemployed	18
- Light physical labor	32
- Moderate physical labor	36
- Heavy physical labor	14
Second opinion (%)	9

Results

Pain, hand function, and satisfaction with treatment result

A total of 462 participants were screened for eligibility, and 431 participants were included after applying the eligibility criteria. From the excluded participants, 26 participants received an injection, 1 had comorbidity (de Quervain's tenosynovitis), and 4 had recurrent CMC-1 instability following previous surgery (fig 1). VAS scores for pain during the last week, pain at rest, and pain during physical load improved with mean differences at 3 months of 17 (97.5% CI, 9-25), 13 (97.5% CI, 9-18), and 19 (97.5% CI, 12-27) points, respectively ($P < .001$) (fig 2). Figure 3 demonstrates the distribution of VAS pain during physical load at baseline and 3 months, indicating large variability in pain levels both prior to and after treatment. However, fig 4 shows the course of VAS pain during physical load over time for 4 quartiles of baseline pain levels, indicating that higher baseline pain during physical load not necessarily leads to more pain at follow-up.

For the MHQ total score, no significant difference was present at 3 months, but the MHQ subscales ADL, work performance, pain, and satisfaction with hand function improved compared with baseline ($P < .001$-$.007$) (table 2). No significant changes were found in the MHQ subscales overall hand function and aesthetics. At 3 months, 83% of the participants would consider to undergo the nonsurgical treatment again under similar circumstances (table 2).

Conversion to surgery

Figure 5 shows the survival curve for conversion to surgery, indicating that after a median follow-up of 2.8 years, 59 participants (14%) converted to surgical treatment. For the participants who converted to surgical treatment, median time to make the decision to convert to surgery was 3.4 months (range, 1-37mo) after the start of the nonsurgical treatment. Figures 6A-B demonstrate the difference between patients who eventually did or did not convert to surgery regarding the development of VAS pain during physical load and MHQ total score, respectively. When analyzing the course of VAS pain during physical load separately for participants who did and did not convert to surgical treatment eventually, both subgroups demonstrated decreased pain levels at 3 months compared with baseline ($P < .001$-$.010$). For MHQ total score, no significant improvement was achieved in both subgroups ($P = .046$-$.152$). However, patients who converted to surgery overall reported worse VAS and MHQ total scores than patients who did not convert to surgery (see fig 6A-B) ($P < .001$). Furthermore, there was an interaction between subgroup and change in VAS or MHQ score over time, indicating that patients who converted to surgery demonstrated less improvement in VAS and more improvement in MHQ score over time than patients who did not convert to surgery ($P < .001$).

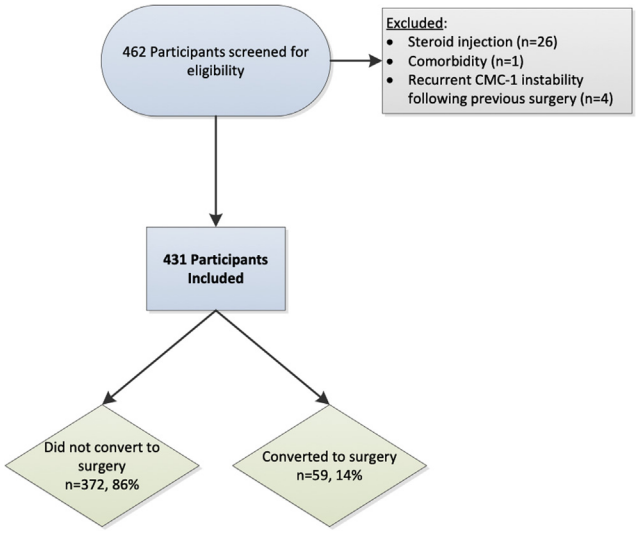

Fig 1 Flowchart of the study.

Discussion

We found a clinically relevant decrease in pain for patients treated nonsurgically for symptomatic CMC-1 instability. Furthermore, only 14% of the patients were surgically treated after a median follow-up of 2.8 years. In addition, improvements were found in secondary outcomes for ADL, work performance, and satisfaction with hand function. Additionally, our subgroup analysis indicated that for patients who eventually converted to surgery, there still was a clinically relevant decrease in pain scores despite the decision to proceed to surgical treatment. However, both pain and hand function scores remained worse over time in the subgroup that converted to surgery compared with those who did not convert to surgery.

To our knowledge, this is the first study reporting outcomes for nonsurgical treatment for symptomatic CMC-1 instability; hence, we cannot compare our results with previous studies. Because our study indicates clinically relevant improvement in patient-reported outcome measures and surgical treatment may lead to unsatisfactory results,[2,19] it is highly recommended that nonsurgical treatment for symptomatic CMC-1 instability is considered as a primary treatment of choice in patients with CMC-1 instability. This is especially the case because nonsurgical treatment for CMC-1 instability is aiming to improve lifestyle, joint mechanics, and function and might therefore prevent or at least delay the development of CMC-1 OA in later life because CMC-OA might be a result of CMC-1 instability.[5-10] However, because we did not evaluate the disease course over a longer period of time in this study, future studies should investigate if nonsurgical treatment for CMC-1 instability has a preventive effect in CMC-1 OA development.

When analyzing the subgroup of patients with CMC-1 instability who eventually converted to surgery, we found a clinically relevant decrease in pain scores at 3 months compared with baseline scores. This decrease in pain levels over time is in contrast to findings by Tsehaie et al,[15] who found that in patients with CMC-1 OA who eventually converted to surgery, pain levels did not change over time. In

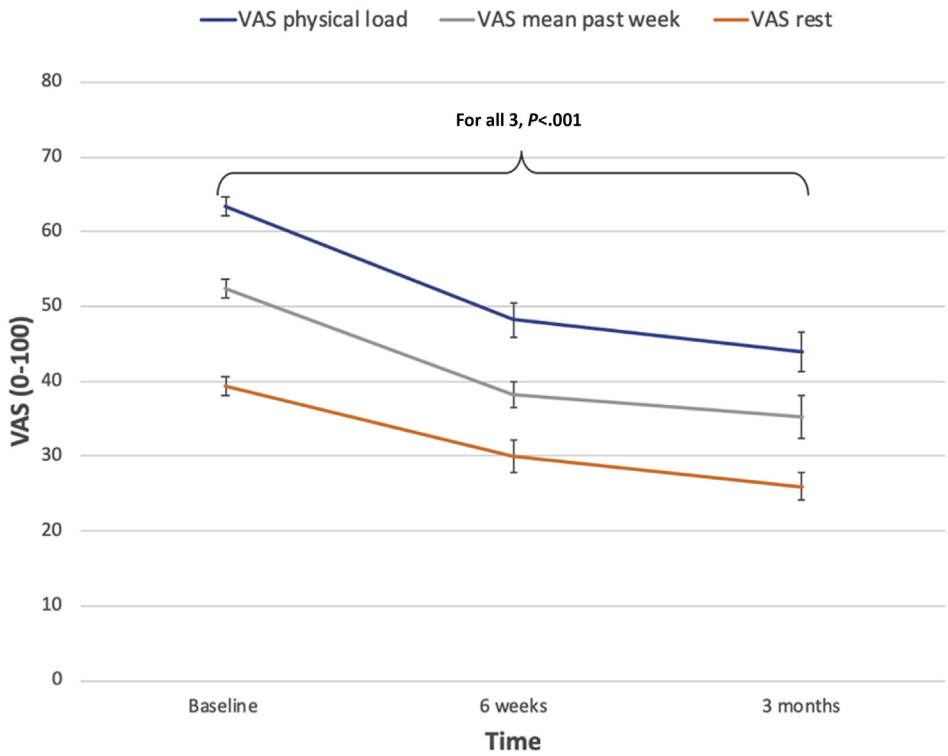

Fig 2 VAS (range, 0-100; higher scores represent more pain) scores for pain physical load, mean pain last week, and pain at rest at baseline, 6 weeks, and 3 months. Linear mixed model analysis demonstrated that pain during physical load, mean pain last week, and pain at rest decreased at 3 months compared with baseline ($P<.001$). Group means and standard errors are plotted.

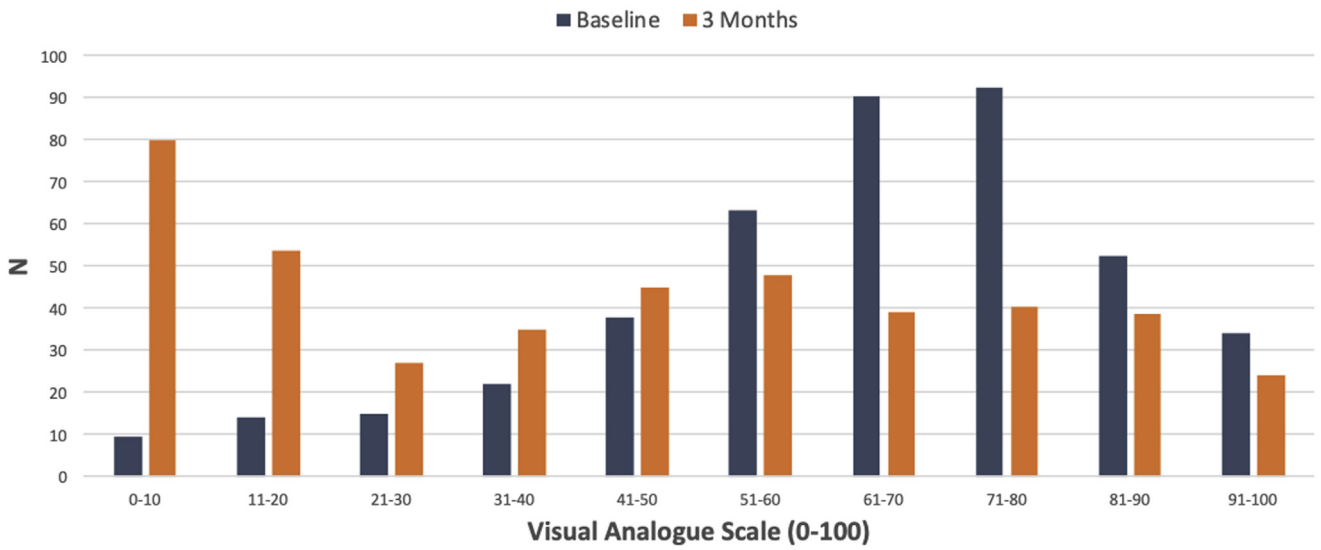

Fig 3 Overall distribution of the entire sample for VAS during physical load (range, 0-100; higher scores represent more pain) at baseline and 3 months after nonsurgical treatment, displaying the number of patients per 10-point intervals in VAS score.

another study, Tshaie et al[38] found that the decision to undergo surgical treatment strongly depends on a change in pain levels during nonsurgical treatment. Our findings suggests that in patients with CMC-1 instability this is not the case, and the decision to undergo surgery might depend on higher residual pain levels and not on change in pain score over time. This is supported by our finding that while pain levels decreased in the subgroup that converted to surgery, pain levels and hand function scores remained worse than those of the subgroup of patients who did not convert to surgery. However, future studies using prediction models in patients with CMC-1 instability are needed to validate this hypothesis.

Another remarkable finding is that, in general in our sample, we found a relatively large variability in outcomes. For example, we found that while 83% of the patients would undergo the same treatment again, 17% would not. Further, we found large variation in pain levels both prior to treatment and 3 months after treatment. However, whereas some studies report that higher baseline pain predicts higher residual pain in patients with CMC-1 OA,[11,14] our study also indicates that this pattern might be otherwise in patients with CMC-1 instability. These findings indicate that while the majority of patients respond well to this nonsurgical treatment, some patients do not. Hence, future studies need to investigate factors that contribute to this variability in outcome.

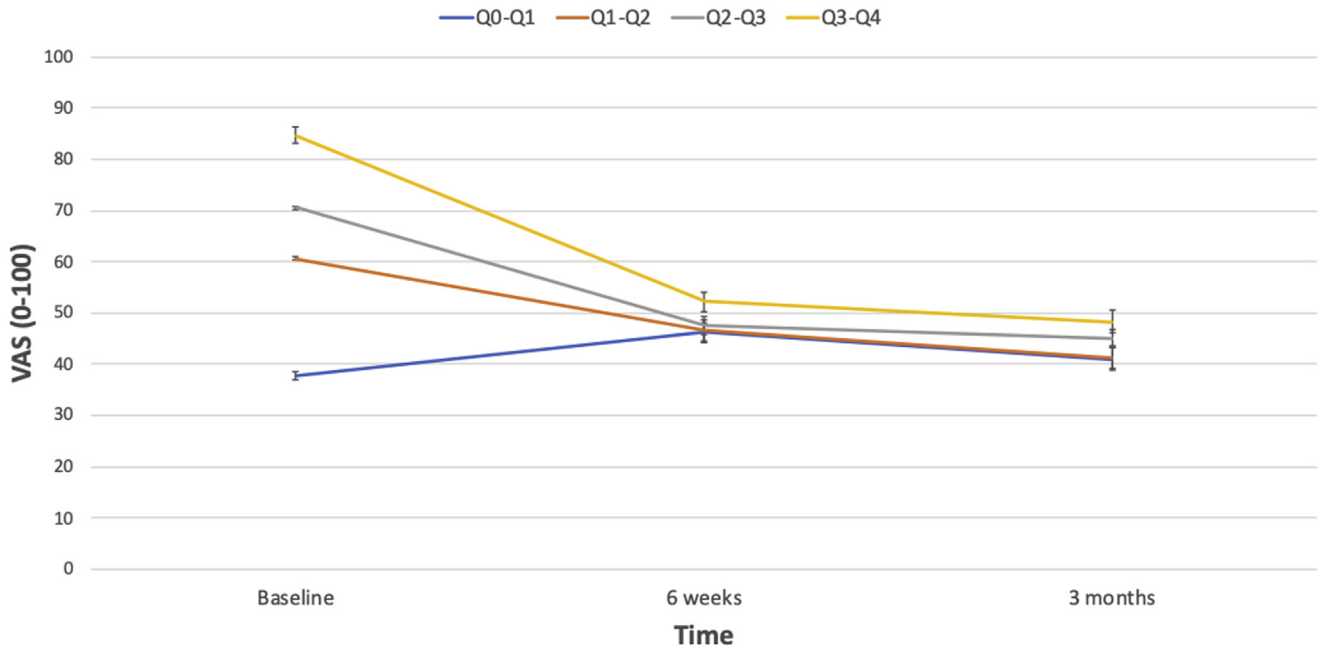

Fig 4 Course over time for VAS (range, 0-100; higher scores represent more pain), categorized by quartiles for baseline pain during physical load, indicating that patients with higher baseline pain demonstrate the largest improvement and patients with lower baseline pain demonstrate little improvement. Subgroup means and standard errors are plotted.

Table 2 Outcomes for MHQ (score range 0-100, higher scores indicate better performance except for the pain subscale) at baseline and 3 months and patient satisfaction at 3 months following nonsurgical treatment

Variable	Baseline	3 mo	Mean Difference Baseline−3 mo (97.5% CI)	*P* Value
Total MHQ, mean ± SD	60.7 ± 14.1	64.8 ± 18.9	4.2 (−2 to 11)	.036
MHQ subscales, mean ± SD:				
- Overall hand function	57.6 ± 17.7	60.2 ± 25.6	2.6 (−2 to 8)	.154
- ADL	62.3 ± 23	69.7 ± 26.7	7.4 (1-14)	<.001*
- Work performance	53.3 ± 26	63.1 ± 23.8	9.8 (4-16)	<.001*
- Pain (higher scores indicate more pain)	36.9 ± 24.2	31.6 ± 14.5	5.2 (2-9)	.007*
- Aesthetics	81.9 ± 19.2	72 ± 28.9	9.9 (−5 to 25)	.096
- Satisfaction with hand function	43.3 ± 20.5	55.7 ± 34.3	12.4 (2-22)	<.001*
Satisfaction with treatment result (%)				
- Excellent		10		
- Good		38		
- Fair		23		
- Moderate		21		
- Poor		8		
Participants who would undergo treatment again (%)		83		

NOTE. Significance testing for mean differences in MHQ at 3 months was performed using linear mixed model analysis.
* $P<.025$.

Study limitations

A strength of this study is that this is, to our knowledge, the first study reporting outcomes of nonsurgical treatment for CMC-1 instability. Furthermore, we were able to evaluate a large group of 431 using standardized patient-reported outcome measures. However, there are also a number of limitations. First, a limitation of this study is its observational character. Despite standardization

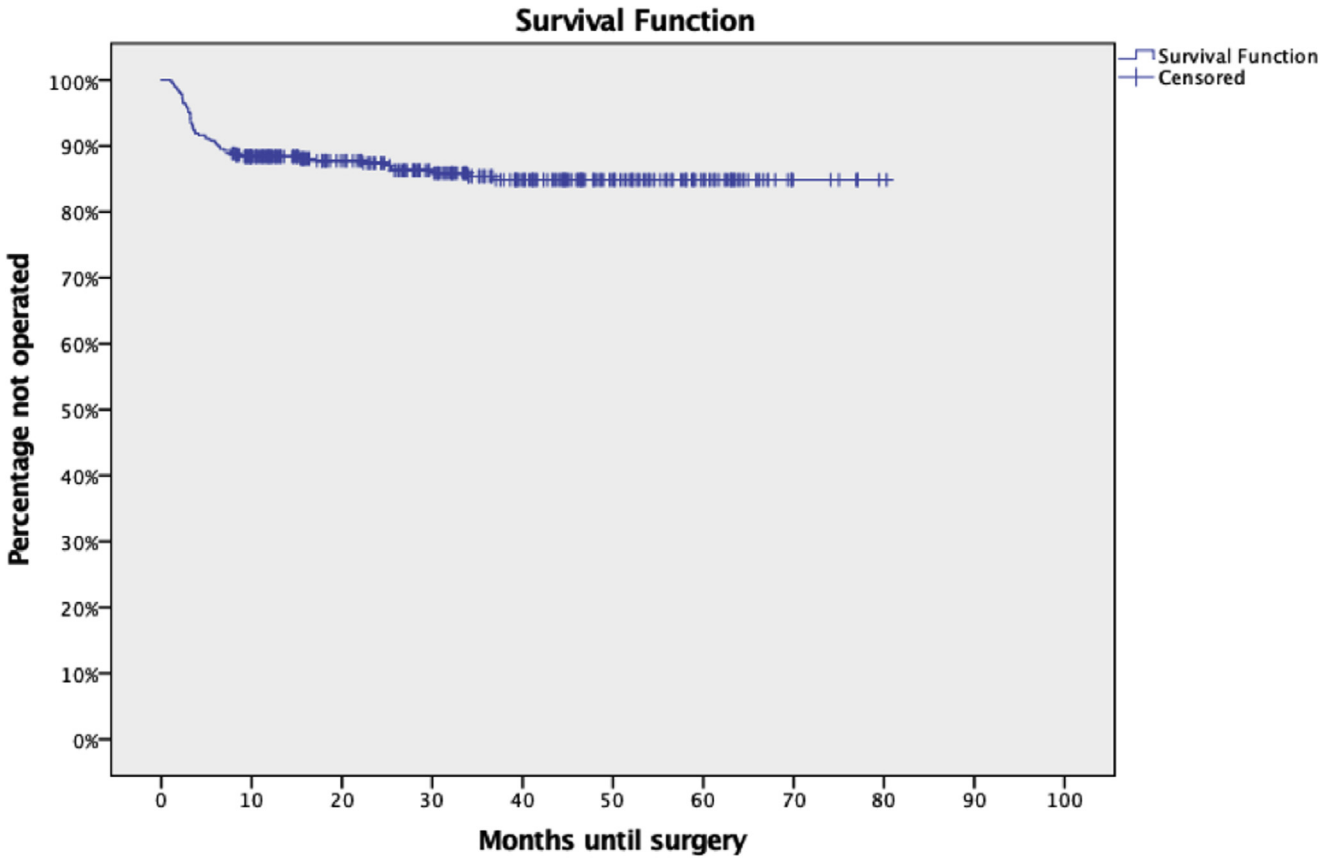

Fig 5 Survival curve displaying the number of patients who converted to surgery over time. The y-axis represents the percentage of patients not converting to surgery, and the x-axis represents the time in months after start of treatment. After a median time of 3.4 months after the start of the nonsurgical treatment (range of conversion, 1-37mo), 14% decided to convert to surgery.

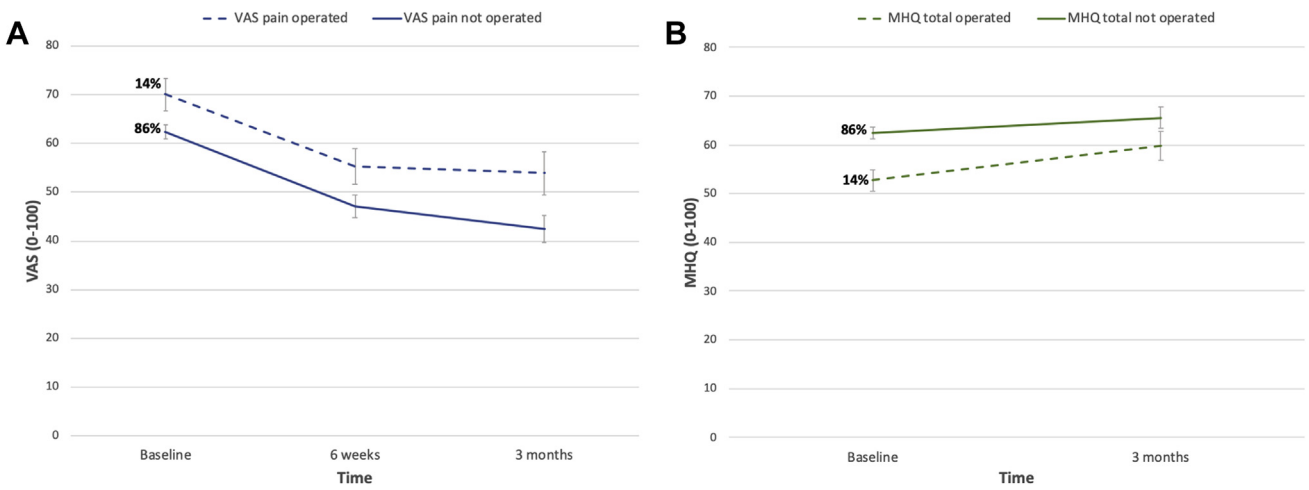

Fig 6 VAS (range, 0-100; higher scores represent more pain **[A]**) score for pain during physical load and MHQ (range, 0-100; higher scores represent better function **[B]**) separately for participants who converted to surgery (n = 59, 14%) and participants who did not convert to surgery (n = 372, 86%). Linear mixed model analysis demonstrated that pain during physical load decreased in both participants who did ($P = .010$) or did not convert to surgery at 3 months compared with baseline ($P < .001$). For MHQ total score, no significant improvement was achieved in both subgroups ($P = .046$-$.152$). However, both pain and hand function levels were worse for patients who eventually converted to surgery ($P < .001$). Moreover, there was an interaction between subgroup and change in pain or hand function scores over time ($P < .001$). VAS scores during rest and VAS last week demonstrated the same pattern as VAS during physical load. Group means and standard errors are plotted.

of treatment using strict protocols and standardized procedures for data collection, inherent to observational studies, the actual provided treatment might have deviated from the treatment protocols. For example, the exercises and orthotics might not have been applied in every patient. However, in contrast to a randomized controlled trial setting, an advantage of our observational study design is that the results are highly representative for actual daily practice.

An additional limitation of this study is that the present study does not allow evaluation of separate treatment effects of exercise therapy or the use of orthoses in CMC-1 instability. While the exercise therapy aims to improve joint mechanics, active stability, and strength, and the orthosis aims to reduce subluxation and inflammation, it is unknown if combining this treatment with orthoses is useful. Hence, future studies should investigate the long-term outcomes for these different nonsurgical treatments for CMC-1 instability separately in a more standardized setting.

Another limitation of this study is the amount of missing data and the need for multiple imputation. However, our nonresponder analyses and the nonsignificant Little's test give us confidence that our outcomes represent the target population.

Furthermore, a limitation of this study is that the percentage of conversion to surgery that we report might be an underestimation because, despite our efforts to follow our patients over time, a patient might have been surgically treated elsewhere. Hence, this percentage of patients converting to surgery following nonsurgical treatment for CMC-1 instability needs validation in future prospective research.

Conclusions

In conclusion, patients treated nonsurgically for symptomatic CMC-1 instability showed a clinically relevant decrease in pain and improvement in secondary outcomes such as ADL, work performance, and satisfaction with hand function. Furthermore, only 59 of all 431 patients (14%) converted to surgery after a median follow-up of 2.8 years, indicating this nonsurgical treatment is a successful treatment of choice, although we found large variation in pain levels. Future studies should investigate predictive factors that contribute to this variability in outcome following nonsurgical treatment for CMC-1 instability.

Supplier

a. GEneric Medical Survey Tracker version 1.8.2; Erasmus MC and Equipe Zorgbedrijven.

Keywords

Carpometacarpal joints; Ehlers-Danlos Syndrome; Exercise therapy; Joint instability; Orthotic devices; Physical therapy modalities; Rehabilitation; Thumb

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References

1. Lane LB, Henley DH. Ligament reconstruction of the painful, unstable, nonarthritic thumb carpometacarpal joint. J Hand Surg Am 2001; 26:686-91.
2. Spekreijse KR, Vermeulen GM, Moojen TM, et al. Surgical stabilization for symptomatic carpometacarpal hypermobility; a randomized comparison of a dorsal and a volar technique and a cohort of the volar technique. Eur J Plast Surg 2016;39:345-52.
3. Poole JU, Pellegrini VD Jr. Arthritis of the thumb basal joint complex. J Hand Ther 2000;13:91-107.
4. Chenoweth BA, O'Mahony GD, Fitzgerald C, Stoner JA, O'Donoghue DL, Rayan GM. Efficacy of dorsoradial capsulodesis for trapeziometacarpal joint instability: a cadaver study. J Hand Surg Am 2017;42:e25-31.
5. Hunter DJ, Zhang Y, Sokolove J, Niu J, Aliabadi P, Felson DT. Trapeziometacarpal subluxation predisposes to incident trapeziometacarpal osteoarthritis (OA): the Framingham Study. Osteoarthritis Cartilage 2005;13:953-7.
6. Neumann DA, Bielefeld T. The carpometacarpal joint of the thumb: stability, deformity, and therapeutic intervention. J Orthop Sports Phys Ther 2003;33:386-99.
7. Eaton RG, Glickel SZ, Littler JW. Tendon interposition arthroplasty for degenerative arthritis of the trapeziometacarpal joint of the thumb. J Hand Surg Am 1985;10:645-54.
8. Edmunds JO. Current concepts of the anatomy of the thumb trapeziometacarpal joint. J Hand Surg Am 2011;36:170-82.
9. Hagert E, Lee J, Ladd AL. Innervation patterns of thumb trapeziometacarpal joint ligaments. J Hand Surg Am 2012;37:706-14.
10. Ladd AL, Lee J, Hagert E. Macroscopic and microscopic analysis of the thumb carpometacarpal ligaments: a cadaveric study of ligament anatomy and histology. J Bone Joint Surg Am 2012;94:1468-77.
11. Wouters RM, Tsehaie J, Slijper HP, Hovius SER, Feitz R, Selles RW. 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. Arch Phys Med Rehabil 2019;100:1050-60.
12. 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;63:834-48.
13. 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;37:2025-43.
14. Tsehaie J, Spekreijse KR, Wouters RM, et al. Predicting outcome after hand orthosis and hand therapy for thumb carpometacarpal osteoarthritis: a prospective study. Arch Phys Med Rehabil 2019;100:844-50.
15. Tsehaie J, Spekreijse KR, Wouters RM, 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;43:1000-9.
16. 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;51:245-9.
17. 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;26:44-52.
18. Valdes K, Von Der Heyde R. An exercise program for carpometacarpal osteoarthritis based on biomechanical principles. J Hand Ther 2012; 25:251-62.
19. Schoenaers M, Degreef I, De Smet L. Eaton and Littler ligament reconstruction for the painful first carpometacarpal joint : patient satisfaction. Acta Orthop Belg 2017;83:30-4.
20. Lane LB, Eaton RG. Ligament reconstruction for the painful "pre-arthritic" thumb carpometacarpal joint. Clin Orthop Relat Res 1987: 52-7.
21. 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 2018;99:1177-212.
22. 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;36:157-69.
23. NVPC, NVvH. Dutch Plastic (NVPC) and Hand (NVvH) Surgery Societies: guideline for conservative and surgical treatment for primary osteoarthritis of the thumb base joint (Richtlijn Conservatieve en Chirurgische Behandeling van Primaire Artrose van de Duimbasis); 2014.
24. 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;370:1453-7.
25. 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;138:837-46.
26. Handtherapie Nederland. Guideline thumb training program (richtlijn duimprogramma). Handtherapie Nederland; 2018.
27. Valdes KMT. A systematic review of conservative interventions for osteoarthritis of the hand. J Hand Ther 2010;23:334-50.
28. Hawker GA, Mian S, Kendzerska T, French M. 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):240-52.
29. 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):189-99.
30. 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;133:616-25.
31. Shauver MJ, Chung KC. The minimal clinically important difference of the Michigan hand outcomes questionnaire. J Hand Surg Am 2009; 34:509-14.
32. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Mahwah, NJ: Lawrence Erlbaum Asscociates; 1988.
33. 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;21:139-48.
34. Little RJ. A test of missing completely at random for multivariate data with missing values. J Am Stat Assoc 1988;83:1198-202.
35. 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;367:1355-60.
36. Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. Biometrics 1986;42:121-30.
37. Preisser JS, Lohman KK, Rathouz PJ. Performance of weighted estimating equations for longitudinal binary data with drop-outs missing at random. Stat Med 2002;21:3035-54.
38. Tsehaie J, Porsius JT, Rizopoulos D, Slijper HP, Feitz R, Hovius SER. Response to conservative treatment for thumb carpometacarpal osteoarthritis is associated with conversion to surgery: a prospective cohort study. Phys Ther 2019;99:570-6.