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Original Research

Radiographic Progression of Thumb CMC Osteoarthritis: A Systematic Review

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Purpose: Thumb carpometacarpal (CMC) osteoarthritis (OA) is a prevalent disease that causes pain and disability. Determining the progression of CMC OA is problematic given the lack of consensus for classifications and scoring systems. We performed a systematic review to (1) determine which imaging modalities or scoring systems are used to evaluate CMC OA progression, and (2) describe the progression of CMC OA through available metrics.

Methods: This review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. An English language literature search was performed in July 2019 and included studies evaluating CMC OA progression with an imaging modality or radiographic scoring system, with a minimum 1-year follow-up. Studies were analyzed with respect to their methodology, scoring systems, and relevant findings.

Results: The initial search yielded 4,097 articles, 10 of which met inclusion criteria. Study size varied from 32 to 289 subjects; many subjects were included in multiple cohorts. Eight studies used radiography whereas 2 used scintigraphy. Estimates of progression varied from 20% to 70% (with large variation in follow-up time); the magnitude of progression varied from 3% to 48% (joint space narrowing) and from 0.6 to 1 points (Kellgren–Lawrence scale). The percentage of subjects who progressed and the progression degree varied widely and depended on follow-up length and the scoring system used.

Conclusions: A paucity of literature exists to measure CMC OA progression; there is a lack of uniformly accepted imaging modality, scoring system, or follow-up interval. This absence provides the opportunity to determine consensus techniques and metrics to assess the natural history of thumb CMC OA.

Type of study/level of evidence: Diagnostic III.

Given the importance of the thumb to overall hand function, carpometacarpal (CMC) osteoarthritis (OA) is a debilitating, disabling disease.[1,2] Carpometacarpal OA is common; its prevalence is reported to be 7% in men and 15% in women[3] and its etiology is multifactorial; risk factors include age, sex, genetics, and trauma.[4–9] The diagnosis of thumb CMC OA begins with a thorough history and physical examination. Imaging is frequently used to confirm the diagnosis. Plain film radiographs, including anteroposterior, lateral, Roberts view, and stress views have proved useful in examining the CMC joint and provide more information with regard to disease severity.[10–13] Scintigraphy (triphasic bone scanning), computed tomography, magnetic resonance imaging, and ultrasound can also be used to help image thumb CMC OA, although these are often reserved for research settings.[14–18]

Radiographic and clinical criteria have been established to characterize the degree and progression of OA. These criteria vary based on the definition of OA, follow-up length, and scoring system used; furthermore, clinical symptoms do not correlate well with imaging.[19,20] The Eaton–Littler classification,[12] adapted from the Kellgren–Lawrence (KL) classification,[21] is the categorization system most commonly used. Despite modification to the

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Eaton–Glickel classification scheme,[13] reports demonstrate low interobserver and intra-observer reliability and poor correlation to clinical findings.[22]

Other systems to characterize OA of the hand and fingers include the Osteoarthritis Research Society International (OARSI) atlas,[23,24] Verbruggen–Vers score,[25] and other clinical criteria developed by Kallman et al.[26] Visser et al[27] conducted a review to assess the use of radiography to study hand OA. They concluded that there were no major differences among scoring systems with regard to metric properties, and noted a variation of joints and metric properties evaluated. Bijsterbosch and colleagues,[28,29] in studying sensitivity to change of OA progression, noted that at 2- and 6-year follow-up, KL, OARSI, and the Verbruggen–Vers system were comparably reliable and similar. Many scoring systems assess only the distal interphalangeal (DIP) and proximal interphalangeal (PIP) joints. Although debate continues, some evidence suggests that thumb CMC OA may result from a pathophysiologic process different from that of OA of other hand joints.[30,31] We chose to evaluate the CMC joint distinct from the PIP and DIP joints because of its greater incidence of OA and its inherent complexity.[32]

Although CMC OA typically progresses slowly, some evidence suggests that progression rates vary among patients.[32] Characterizing OA progression may provide improved stratification of disease and potential metrics for predicting progression. This enhanced characterization would promote improved treatment analysis and improved prognostic information for patients and providers. Given the lack of consensus regarding a single methodology, this work systematically reviewed studies investigating thumb CMC OA progression to (1) determine which imaging modalities or scoring systems are used to evaluate CMC OA progression, and (2) characterize the progression of CMC OA through available metrics. We hypothesized that variation would exist in imaging modalities and scoring systems used to evaluate CMC OA progression.

Materials and Methods

We conducted a systematic review according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[33] Search strings (Appendix) were developed with the help of a medical librarian (C.S.). We reviewed all peer-reviewed studies published and available on-line before July 2019. This review included PubMed, SCOPUS, and Cochrane medical literature databases.

All English language studies that enrolled patients with clinical or radiographic evidence of thumb CMC OA and baseline and follow-up imaging assessments were recorded. Exclusion criteria were follow-up of less than 1 year, case reports, cross-sectional studies, and letters to the editor. We believed these studies would not allow for sufficient evaluation of progression on enough subjects to draw meaningful conclusions. Subjects with rheumatoid arthritis, psoriatic arthritis, or other autoimmune arthropathies were also excluded because the pathophysiology and rates of progression may differ from those with thumb CMC osteoarthritis. Using full-text review, we also excluded studies that did not report specifically on the CMC joint individually. References from included studies were cross-referenced and evaluated for inclusion.

We conducted a thorough analysis on each of the included studies after a full text review. The study design, number of subjects, follow-up duration, joints evaluated, and radiographic scoring systems were recorded. A systematic, qualitative review (eg, an in-depth read) of relevant results from each study regarding the CMC joint was performed, noting any studies that used similar cohorts, which may have introduced bias, as well as specific characteristics of each study (eg, study type, number of patients, follow-up duration). Primary summary measures included conclusions regarding the percentage of subjects who progressed, as well as the degree of progression as measured by a particular scoring system. Two junior authors (L.M.S. and T.J.M.) conducted article screening, data extraction, and analysis. Discrepancies were reviewed by the senior author (A.L.). Data were stored using Covidence software (Melbourne, Victoria, Australia).

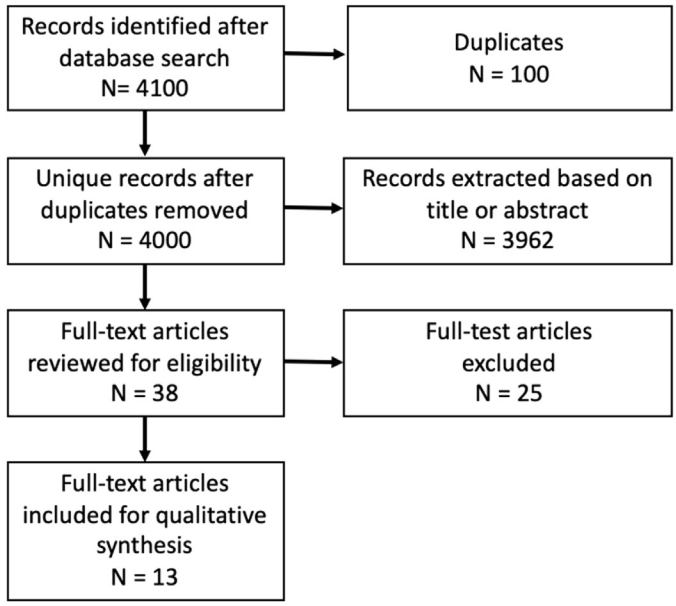

Figure 1. Flowchart of studies identified, excluded, and included.

To assess the presence of publication bias, a funnel plot was created to report the percentage of patients who demonstrated trapeziometacarpal osteoarthritis progression per year of follow-up. The average of all reviewed studies was set as the benchmark. Control limits were calculated by double (95%) and triple (99%) the standard error (SE) (number of observations per benchmark).

Results

Figure 1 details the algorithm and article selection used. We excluded 25 articles based on full text review, primarily because of a lack of data specific to the thumb CMC joint. Thirteen articles were included for final review.

Table 1 details characteristics extrapolated from the included studies. No studies evaluated progression of OA in the CMC joint exclusively; all studies included some combination of the metacarpophalangeal, PIP, DIP, or wrist joints in addition to the thumb CMC joint. Seven of the radiographic studies used the KL scale; no studies used the Eaton, modified Eaton, or other CMC-specific systems.

Table 2 details pertinent study findings. Eleven studies indicated progression. All studies with greater than 5-year follow-up indicated evidence of progression. Of the studies indicating progression radiographically, the percentage of progression varied from 20% to 70%, with magnitude of progression varying from 3% to 48%, largely dependent on follow-up length.

The funnel plot in Figure 2 depicts almost all reviewed studies within 3 SDs of the SE. The reported effects were not larger in the high–sample size studies. There did not appear to be a publication bias.

Harris et al[32] observed that the CMC joint of patients with a baseline KL grade of 0, 1, 2, and 3 deteriorated at least one grade by 83%, 45%, 47%, and 89%, respectively. They noted that the baseline

Table 1
Extrapolated Details from Included Studies

First Author	Year	Study Type and Source Population	N	Follow-Up Duration	Other Joints Studied
Radiographic studies					
Altman	1987	Cohort study with mixed severity of hand OA	48 (24 pairs)	Minimum 1 mo, maximum 8 y	MCP, PIP, DIP
Bjisterbosch	2011a	Cohort study (Genetics Arthrosis and Progression Study), sibling pairs	90	Minimum 2 y, maximum 6 y	MCP, PIP, DIP
Bjisterbosch	2011b	Cohort study (Genetics Arthrosis and Progression Study), sibling pairs	289	6 y	MCP, PIP, DIP Hip, knee, spine
Bjisterbosch	2014	Cohort study (Genetics Arthrosis and Progression Study), sibling pairs	263	Mean 6.1 y	Scaphotrapezium-trapezoid, MCP, PIP, DIP
Botha-Scheepers	2009	Cohort study (Genetics Arthrosis and Progression Study), sibling pairs	172	2 y	DIP, PIP
Harris	1994	Retrospective cohort study, secondary care (rheumatology clinic)	59 (paired radiographs)	10 y	PIP, DIP, knee
Haugen	2011	General population, symptomatic hand OA (Framingham OA Study)	464	9 y	Wrist, MCP, PIP, DIP
Kallman	1990	Cohort study, men (Baltimore Longitudinal Study of Aging)	177	20 y	Scaphotrapezoid, PIP, DIP
Buckland-Wright	1991	Prospective cohort study, secondary care (rheumatology clinic)	32	18 mo	MCP, PIP, DIP
Cvijetić	2004	Cohort study (random patient selection from 2 Croatian rural populations)	286	10 y	PIP, DIP
Paradowski	2010	Prospective cohort study, patients undergoing meniscectomies	118	Mean 9.6 y	PIP, DIP
Nuclear medicine studies					
Macfarlane	1993	Prospective cohort study, secondary care (rheumatology clinic)	32	1 y	MCP, PIP, DIP
McCarthy	1994	Prospective, cohort of knee OA patients	67	5 y	Wrist, MCP, PIP, DIP

MCP, metacarpophalangeal.

Table 2
Pertinent Study Findings

Author, Year	N	Primary Findings: CMC Progression	Other Findings
Altman, 1987	48 (24 pairs)	Overall: 17% had isolated progression of the CMC joint arthritis in paired radiographs (range, 1 mo to 8 y)	Osteophytes were more predictive of progression than erosions, which were more predictive than JSN at DIP, PIP, and CMC joints
Bijsterbosch, 2011a	90	Overall, at 6 y, mean progression scored by 3 readers was 58.67%	Of 3 radiographic scoring methods, the KL scale detected a slightly higher proportion of progression
Bijsterbosch, 2011b	289	Appendix 2: Subjects progressed a mean of 0.1–0.4 KL grade (range, 0–8) after 2 y, 0.7–1.2 grades after 6 y. Subjects progressed a mean of 0.1–0.5 OARSI grade (range, 0–20) after 2 y, 0.9–2.0 grade after 6 y	Patients were recruited based on OA at other sites. The KL grading demonstrated more progression and took less time than OARSI across multiple joints
Bjisterbosch, 2014	263	A total of 22.1% of patients demonstrated radiographic progression of OA at the thumb CMC joint at a mean of 6.1 y; 16.5% and 10.5% of patients demonstrated progression of osteophytes and JSN, respectively	The thumb CMC joint demonstrated the greatest radiographic progression of joints evaluated
Botha-Scheepers, 2009	172	Overall, 8 of 172 patients progressed at CMC joint via JSN and osteophytes after 2 y	Subjects recruited based on hand OA at any site (DIP, PIP, and MCP OA) were more likely to progress than those with CMC OA
Buckland-Wright, 1991	32	Overall, no significant increase occurred in the number of osteophytes at the CMC joint at the end of the study period ($P < .05$)	Baseline osteophyte size was noted to be greater on the trapezium of the nondominant hand
Cvijetić, 2004	286	Overall, significant progression of OA was noted after 10 y: 24.4% of males with CMC OA at baseline, compared with 54.6% at 10-year follow-up; and 19.3% of females with CMC OA at baseline, compared with 48.7% at 10-year follow-up ($P < 0.0001$)	DIP OA was more prevalent than CMC and PIP OA and disease at this joint progressed more rapidly than at other joints
Harris, 1994	59	Overall, there was 47% progress > 1 KL scale over 10 y, 38% with new osteophytes, and 48% with JSN; baseline KL 0 with 83% progression, KL 1 with 45%, KL 2 with 47%, and KL 3 with 89%	Interobserver reliability (kappa) was 0.5–0.7. Similar progression was observed among DIP, PIP, and CMC
Haugen, 2011	464	Overall, 64.8% of men progressed > 1 KL scale over 9 y and 70.7% of women did so	There was a cumulative incidence of radiographic CMC OA in baseline KL 0 cohort: 17.4% of men and 21.2% of women at 9 y
Kallman, 1990	177	Overall, time for >50% of cohort to progress >1 KL grade >9 y for subjects aged >60 y, >12 y for 40–60 y, and >16 y for <40 y	JSN was predictive of the development of definitive small osteophytes in all joints studied (PIP, DIP, CMC, and scaphotrapezoid)
Macfarlane, 1993	32	There was no significant difference in number, score, or distribution pattern of positive joints via bone scan after 1 y ($P < .0005$)	Isotope bone scans also did not detect progression at the PIP, DIP, or metacarpophalangeal joints at 1 y
McCarthy, 1994	67	Overall, 27 of 64 patients progressed at thumb CMC joint via bone scan at 5 y	A total of 32% of patients had abnormal bone scans at the thumb CMC joint at baseline
Paradowski, 2010	118	A total of 13% of subjects had an increase in JSN at the thumb CMC joint and 16% had osteophytic progression at a mean of 9.6 y	Progression of JSN and osteophytic changes were greatest in DIP joints

KL grade was not related to progression, and they found no relationship between DIP and PIP progression and CMC progression.

Haugen et al[34] estimated progression of thumb base OA via one KL grade to be 64.8% and 70.7% for males and females, respectively. Osteoarthritis progression of the thumb base was the highest of all joints studied. Although no breakdown by specific joint was provided, they noted that of patients without symptomatic hand OA, a greater percentage of those with erosive OA (KL equal to or greater

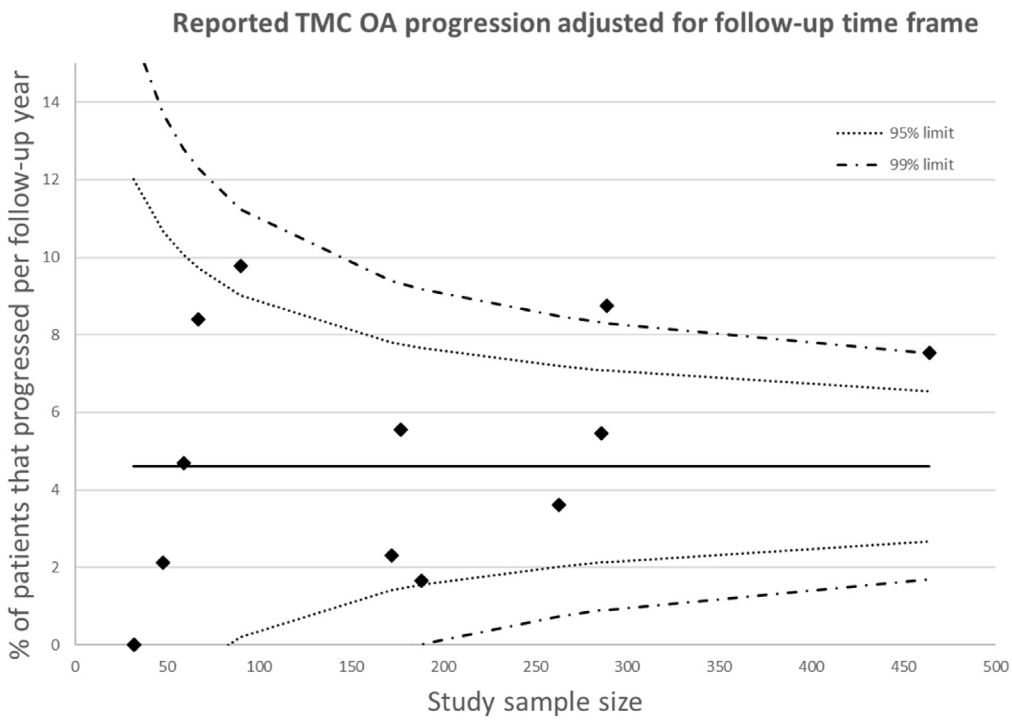

Figure 2. Funnel plot of reported patient percentage demonstrating trapeziometacarpal (TMC) OA progression per year of follow-up. The target (solid black line) is the average of all reviewed studies. Control limits were calculated by double (95% [dotted lines]) and triple (99% [dashed and dotted lines]) the SE (number of observations per target).

than 2 with central erosion) were more likely to develop symptoms, compared with those without erosive OA (54.2% compared with 28.3%).

In 2011, Bijsterbosch et al[29] noted greater progression at the DIP and PIP joints compared with the CMC joint. In that study, a high number of nodes and osteophytes (at baseline) were related to radiographic progression; however, the researchers did not note how this relationship held true for each joint. In a 2014 study of the same population, Bjisterbosch et al[35] noted greatest progression at the first CMC joint (compared with other joints evaluated).

Cvijetić et al[36] evaluated the prevalence of radiographic OA (using the KL criteria) over 10 years in a rural Croatian population. At baseline, they noted a 24.4% and 19.3% prevalence of CMC OA in males and females, respectively, and at 10 years' follow-up, they noted a 54.6% and 48.7% prevalence of OA in males and females, respectively. This change was statistically significant for each sex ($P < .0001$).

Botha-Scheepers et al[37] noted that joint space narrowing (JSN) progression was moderately correlated with osteophyte progression in the DIP and PIP joints; however, this was not the case for the CMC joint. Kallman et al[38] observed that JSN predicted the development of KL grade 2 OA (relative risk = 1.94) and that KL grade 1 predicted the development of JSN (relative risk = 2.06); however, that study appeared to have included only the most severely affected DIP and PIP joints in the longitudinal analysis.

Paradowski et al[35] evaluated subjects undergoing meniscectomies and found that 13% of subjects had an increase in JSN at the CMC joint and 16% had osteophytic progression at a mean of 9.6 years. The authors noted that progression of OA (as defined by JSN and osteophytes) was worst at the DIP joints.

Altman and colleagues[39] noted that narrowing and erosion of the first left CMC joint were 2 of 3 features most correctly identifying the time sequence of OA progression (when identifying the most important variable in identifying disease progression).

With the hypothesis that scintigraphy may demonstrate change earlier than that seen on conventional imaging methods or that it may reflect a physiologic process as opposed to an anatomy change, authors have studied scintigraphy as a marker for progression. Macfarlane and colleagues[40] found no statistically significant change in tracer uptake in the CMC joint with 1-year follow-up. With 5-year follow-up, McCarthy and colleagues[41] found that a statistically significantly ($P < .0001$) higher number of baseline scintographically positive patients progressed compared with those who were negative. McCarthy and colleagues also concluded that scintigraphy was a better predictor of progression at the thumb base than for other hand joints.

Discussion

This review represents an evaluation of the literature regarding the progression of thumb CMC OA by assessing relevant imaging modalities, scoring systems, and noteworthy findings. We observed that a wide variety of scoring methods were used, and studies varied widely in their methodology and length of follow-up. Given the lack of established criteria on these key parameters, we found substantial variation in the degree of progression of OA measured at the thumb CMC joint. Many of these longitudinal studies reflect epidemiology and rheumatology perspectives related to OA rather than one focused on the hand and from the perspective of hand surgery. Accordingly, no studies analyzed the progression of thumb CMC OA using the Eaton stage, a common scoring system used to diagnose OA of this joint in the hand surgery literature. Consequently, we advocate the need for longitudinal studies comparing various methods of measuring progression of CMC OA in large cohorts with multiple end points to establish a classification system that has satisfactory sensitivity, specificity, and interrater and intrarater reliability.

Most studies evaluated plain film radiographs to quantify the extent of OA, the most common imaging modality used to assess OA

throughout the musculoskeletal system. Using multiple different scoring systems for plain radiographs, however, does not enable comparison between studies or corroboration among different cohorts. Validated scoring systems included the KL, Verbruggen–Vers, and OARSI scores. Furthermore, Buckland-Wright and colleagues[42] also used their own tool to evaluate the progression of osteophytes at the CMC joint. Notably, however, there is a lack of studies analyzing the progression of thumb CMC OA employing the Eaton stage, especially because of its frequency of use in a clinical setting.

The wide variety of scoring systems and length of follow-up resulted in rates of progression that ranged from 20% to 70%, which is unsurprising given the lack of a standardized end point for follow-up (range, 1–20 years' follow-up). These authors recommend additional research with a standardized length to validate the use of these scoring systems in different populations. Furthermore, although the modified Eaton stage demonstrates only moderate intra-observer and interobserver reliability, these authors recommend further studies that assess progression that also employ common clinical benchmarks.

The evidence is mixed for using scintigraphic studies to evaluate for the progression of OA. Although this may be an enhanced technique with which to study OA progression, it is expensive and time-consuming, and poses a greater health risk than other imaging modalities because it requires contrast and high radiation exposure.

Whether the thumb CMC was specifically addressed varied in the reviewed studies. Studies were included as long as they reported on the CMC joint, but several studies were excluded because they did not discretely analyze this joint. The association between thumb CMC OA and arthritis at the DIP and PIP joints is not well understood, especially in populations without underlying autoimmune or rheumatologic conditions, or heterogeneous populations. Further investigation will better determine the relationship between these patterns of arthritis. Furthermore, the relationship of scoring systems that aggregate measurements of OA at different joints as a representative characterization of progression at the CMC joint remains unclear. Given the unique biomechanics of the thumb CMC joint, it is reasonable to postulate that patterns of progression may vary at the base of the thumb compared with the DIP, PIP, and metacarpophalangeal joints.

The results of this study should be viewed in light of the limitations. Although we strictly adhered to a protocol for systematic reviews and facilitated a broad search abstraction and careful analysis, it is possible that we missed some studies. An ad hoc analysis of several excluded studies and a review of the references of included studies were conducted to prevent missing articles. Heterogeneity is a known aspect of systematic reviews, but the ability to compare studies with various study designs, scoring systems, and lengths of follow-up limits the ability to draw conclusions. Only 3 studies had 10 or more years of follow-up data and only one study had more than 300 participants. As mentioned, the follow-up modalities and scoring systems varied among studies. More uniform reporting of outcomes and follow-up data in larger cohorts of patients is recommended.

This review demonstrates the variety of scoring methods used and the variance in study methodology and follow-up length for the evaluation of CMC OA progression. Owing to this variation, insufficient information exists to date to recommend a particular scoring method or length of follow-up. We assert that longitudinal studies comparing various methods of measuring progression in large cohorts will be necessary to understand the progression of thumb CMC OA better. Ideally, these studies will have multiple end points to assess progression and will analyze the CMC joint specifically, because of its unique biomechanics and functional importance.

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