Osteoarthritis and Cartilage 27 (2019) 468–475

Osteoarthritis and Cartilage

Assessment of osteoarthritic features in the thumb base with the newly developed OMERACT magnetic resonance imaging scoring system is a valid addition to standard radiography

S. van Beest † *, F.P.B. Kroon †, H.M. Kroon ‡, W. Damman †, R. Liu †, J.L. Bloem ‡, M. Reijnierse ‡, M. Kloppenburg † §

† Department of Rheumatology, Leiden University Medical Center (LUMC), Leiden, the Netherlands
‡ Department of Radiology, Leiden University Medical Center (LUMC), Leiden, the Netherlands
§ Department of Clinical Epidemiology, Leiden University Medical Center (LUMC), Leiden, the Netherlands

ARTICLE INFO

Article history:
Received 1 March 2018
Accepted 19 November 2018

Keywords:
Hand osteoarthritis
Thumb base
Magnetic resonance imaging
Radiography
OMERACT
Validity

SUMMARY

Objective: To investigate the construct validity of the new thumb base OA magnetic resonance imaging (MRI) scoring system (TOMS) by comparing TOMS scores with radiographic scores in patients with primary hand OA.

Design: In 200 patients (83.5% women, mean (SD) age 61.0 (8.4) years), postero-anterior radiographs and MR scans (1.5 T) of the right first carpometacarpal (CMC-1) and scaphotrapeziotrapezoid (STT) joints, were scored using the OARSI atlas and TOMS, respectively. The distributions of the TOMS scores (specified in results section) were stratified for the OARSI scores of corresponding radiographic features and investigated using boxplots and non-parametric tests. Furthermore, Spearman's rank or Phi correlation coefficients (ρ/φ) were calculated.

Results: For all features, especially for erosions and osteophytes, the prevalence found with MRI was higher than with radiography. TOMS osteophyte and cartilage loss scores differed statistically significant between corresponding OARSI scores in CMC-1 (0 vs 1; 1 vs 2). TOMS scores were positively correlated with radiographic scores in CMC-1 for osteophytes (coefficient [95% confidence interval], $\rho = 0.75$ [0.69; 0.81]), cartilage loss/joint space narrowing ($\rho = 0.70$ [0.62; 0.76]), subchondral bone defects (SBDs)/erosion-cyst ($\rho = 0.41$ [0.29; 0.52]), bone marrow lesions (BMLs)/subchondral sclerosis ($\rho = 0.65$ [0.56; 0.73]) and subluxation ($\varphi = 0.65$ [0.57; 0.73]); and in STT for osteophytes ($\rho = 0.30$ [0.17; 0.42]) and cartilage loss/joint space narrowing ($\rho = 0.53$ [0.42; 0.62]).

Conclusions: In patients with hand OA, TOMS scores positively correlated with radiographic scores, indicating good construct validity. However, the prevalence of features on MR images was higher compared to radiographs, suggesting that TOMS might be more sensitive than radiography. The clinical meaning of these extra MR detected cases is currently still unknown.

Introduction

Osteoarthritis (OA) in the hands frequently affects the thumb base, including the first carpometacarpal (CMC-1) and scaphotrapeziotrapezoid (STT) joints, and interphalangeal (IP) joints[1]. Although OA in the thumb base and IP joints often co-exist in patients, underlying pathophysiological mechanisms[2–4] and clinical burden[5] are considered to be different; also treatment options vary[6,7]. Still much is unknown about the pathophysiology and disease course of the different subsets. In order to improve research and performance of clinical trials in hand OA sensitive outcome measures are needed for each of these subsets[8].

In research, magnetic resonance imaging (MRI) has proven to be a valuable and sensitive method to assess structural damage and inflammation in IP OA using the Hand OA MRI scoring system (HOAMRIS)[9,10]. However, no MRI scoring system assessing the

* Address correspondence and reprint requests to: S. van Beest. Department of Rheumatology, Leiden University Medical Center, C1-R, PO Box 9600, 2300 RC Leiden, the Netherlands. Tel.: 31-71-5261280; fax: 31-71-5266752.
E-mail addresses: s.van_beest@lumc.nl (S. van Beest), f.p.b.kroon@lumc.nl (F.P.B. Kroon), h.m.j.a.kroon@lumc.nl (H.M. Kroon), w.damman@lumc.nl (W. Damman), r.liu@lumc.nl (R. Liu), j.l.bloem@lumc.nl (J.L. Bloem), m.reijnierse@lumc.nl (M. Reijnierse), g.kloppenburg@lumc.nl (M. Kloppenburg).

https://doi.org/10.1016/j.joca.2018.11.007
1063-4584/

thumb base joints existed until recently the Outcome Measures in Rheumatology (OMERACT) MRI Working Group developed the thumb base OA MRI scoring system (TOMS)[11].

HOAMRIS and TOMS are complementary scoring systems, both assessing similar features for different hand OA subsets, which offers the opportunity for a complete MRI assessment of all commonly affected joints in hand OA. The OMERACT group already established that TOMS has good feasibility and cross-sectional reliability[11], but before it can be recommended as core research instrument also its validity should be investigated. Therefore our aim was to investigate the construct validity of TOMS by comparing TOMS scores with radiographic scores.

Patients and methods

Study design

We used cross-sectional data of Hand OSTeoArthritis in Secondary care (HOSTAS), an ongoing observational cohort of consecutive patients from our outpatient clinic who were included after being diagnosed by their treating rheumatologist with primary hand OA[12]. In the present study, we selected patients who had both postero-anterior (PA) radiographs and MR scans of the right thumb base (included between November 2012 and October 2015).

Exclusion criteria were: routine MR contraindications, any other pathological condition explaining the hand symptoms, secondary OA, and prior surgery of the right thumb base joints. Written informed consent was obtained from all participants. The study was approved by the Leiden University Medical Center (LUMC) medical ethics committee.

Demographics and clinical assessment

Demographics and clinical characteristics were collected by standardized questionnaires. Self-reported hand pain was assessed by visual analogue scale (VAS, range 0–100 mm). Trained research nurses examined thumb bases for tenderness upon palpation (0–3), and soft and bony swelling (absent/present), and we determined whether patients met the American College of Rheumatology (ACR) classification criteria for clinical hand OA[13]. Since the CMC-1 and STT joint lie in close proximity to each other, the thumb base was evaluated as a whole during physical examination.

Radiograph acquisition and scoring

Digital right hand radiographs were obtained in PA view, using a tube voltage of 45 kV, 250 mA and 5 mAs with 20 ms exposure time and a film focus distance of 1.20 m (type of film cassette Canon Detector CXDI, 100 micron pixel spacing, grayscale resolution 12-bit).

Radiographs of right hand thumb base joints were scored following the OARSI atlas[14]: osteophytes and joint space narrowing (JSN) in CMC-1 (0–3) and STT (absent/present), and subluxation, erosion, subchondral sclerosis and subchondral cyst only in CMC-1 (absent/present). Readers HMK (>25 years of experience as musculoskeletal radiologist) and SvB (PhD candidate, well-trained in reading hand radiographs) scored in consensus, while blinded for demographic, clinical and MRI data. Intraobserver reliability (based on 20 patients) was good: prevalence-adjusted bias-adjusted kappa (PABAK)[15] values were 0.80–1.00 for the different dichotomous features and intraclass correlation coefficients (ICCs; mixed model, exact agreement, single measure) for osteophytes and JSN scores in CMC-1 were 0.94 and 0.91, respectively.

MRI acquisition and scoring

MR images of the right CMC-1 and STT joints were obtained using an MSK-Extreme 1.5 T extremity MR imaging scanner (GE, Wisconsin, USA). The following sequences were acquired: coronal T1-weighted (T1-w) fast spin echo (FSE) images (repetition time [TR]/echo time [TE] 575/≤11 ms), axial T1-w FSE images (TR/TE 575/≤10.5 ms), coronal T2-w FSE images with frequency selective fat saturation (fat sat) (TR/TE 3000/61.8 ms), and axial T2-w FSE fat sat images (TR/TE 3000/60 ms). Images had a field of view of 100 mm; 18 coronal slices (slice thickness 2 mm, slice gap 0.2 mm) and 20 axial slices (slice thickness 3 mm, slice gap 0.3 mm) were obtained in a total acquisition time of 20 min. No contrast enhancement was used.

After calibration using 10 randomly selected cases, MR images were scored independently by readers FPBK and SvB (both PhD candidates with extensive training in reading hand MR images), blinded for demographic, clinical and radiography data, using TOMS[11]

- osteophytes, defined as abnormal bone protuberance at joint margins or surfaces, 0 = no osteophytes, 1 = mild (1–2 small osteophyte[s]), 2 = moderate (≥3 small osteophytes and/or ≥ 1 moderate osteophyte[s]), 3 = severe (≥1 large osteophyte[s]), scored on coronal T1w-FSE images
- cartilage space loss (CSL), defined as loss of cartilage space based on the inter-bone distance, 0 = no loss of cartilage space, 1 = mild (CSL without bone-to-bone contact), 2 = moderate (focal complete CSL with bone-to-bone contact ≤50% of the articulating area), 3 = severe (complete CSL with bone-to-bone contact >50% of the articulating area), scored on coronal T1w- and T2w-FSE fat sat images
- subchondral bone defects (SBDs), defined as subchondral bone loss, including erosions (sharply marginated bone lesions with cortical break), cysts (sharply marginated bone lesions without cortical break), and bone attrition (diffuse loss of bone contour), 0 = no bone defects, 1 = mild (≤25% of bone volume or joint surface affected), 2 = moderate (26–50% of bone volume or joint surface affected), 3 = severe (>50% of bone volume or joint surface affected), scored on coronal and axial, T1w-FSE and T2w-FSE fat sat images
- bone marrow lesions (BMLs), defined as lesions within the trabecular bone with signal characteristic consistent with increased water content (i.e., high signal intensity on fat suppressed T2w images) and with ill-defined margins, 0 = no BMLs, 1 = mild (1–33%), 2 = moderate (34–66%), 3 = severe (67–100%). Based on thirds of assessed bone volume, scored on coronal and axial, T2w-FSE fat sat images
- subluxation, defined as subluxation of the CMC-1 joint in the frontal plane, 0 = first metacarpal (MC-1) subluxed 0–25% of the MC width, 1 = MC-1 subluxed ≥26% of the MC width, scored on coronal T1w-FSE images.

Apart from subluxation, which was only scored for the CMC-1 joint, all MR features were scored for both right thumb base joints (i.e., CMC-1 and STT joints). Osteophytes, subchondral bone defects (SBDs) and bone marrow lesions (BMLs) were scored for distal and proximal joint parts separately, adding up to a sum-score for the CMC-1 (0–6) and STT (0–9) joints. Intraobserver (for reader SvB, based on 10 patients, mixed model, exact agreement, single measure, ICCs 0.76–1.00, subluxation PABAK 1.00) and interobserver (mixed model, exact agreement, average measure, ICCs 0.72–0.92, subluxation PABAK 0.73) reliability was good for all features.

Statistical analysis

For all analyses of TOMS scores, we used the average of both readers, which was rounded down to the nearest integer. Since CMC-1 subluxation was scored dichotomously, in case of disagreement images were re-evaluated ($n = 29$) and discussed to reach consensus. We combined OARSI scores for erosions and cysts into one dichotomous score (i.e., both absent vs at least one present) in order to make a comparison with SBDs on MRI. BML is an imaging feature exclusive to MRI, however studies have shown BML areas were associated with sclerotic bone on histology and histomorphometry[16–18]. Therefore we compared BML scores with subchondral sclerosis OARSI scores.

Distributions of TOMS scores were stratified for the corresponding radiographic feature scores and, depending on the number of OARSI stages (i.e., absent/present or 0–3), these were compared by Mann–Whitney U or Kruskal–Wallis test, respectively. Regarding the latter, if an overall difference was seen, pairwise comparisons were performed to investigate statistical significance of differences between consecutive OARSI stages. Similarly, osteophyte scores from both imaging methods were compared to the presence of bony swelling palpated during physical examination of the thumb base.

All tests were two-tailed and *P*-values <0.05 were considered statistically significant. Data were analysed using SPSS for Windows, version 23.0 (IBM SPSS statistics, New York, USA).The associations between TOMS and OARSI scores, and imaging and physical examination of the thumb base, were further assessed by Spearman's rank (ρ) and Phi (φ) correlation coefficients: we considered ≤0.20 poor, >0.20–<0.40 weak, ≥0.40–<0.60 moderate, ≥0.60–<0.80 strong, and ≥0.80 excellent correlated. Since SPSS does not readily provide users with confidence intervals (CIs) for correlation coefficients, we applied the method described on the IBM Support website[19]. In short, we transformed the correlation coefficient to a Fisher Z, calculated 95% CI limits for that Z, and then transformed those limits back. Therefore, correlation CIs enclosing zero indicate a *P*-value>0.05.

Results

Study population

MR imaging of the thumb base was performed in 202 patients, two patients were excluded from analysis: one due to missing of a hand radiograph and the other had undergone prior (anatomy altering) thumb base surgery. The majority of the remaining 200 eligible patients fulfilled the ACR criteria for hand OA (89.5%), were middle-aged (mean (SD) age 61.0 (8.4) years) and female (83.5%). They reported a mean (SD) VAS right hand pain of 36 (21) mm. During physical examination, 42% of the patients had tenderness on palpation of their right thumb base and in 45% a bony swelling was palpated; we found no soft swollen thumb bases.

Prevalence of imaging features

In Table I the prevalence of features for both MR imaging and PA radiography are described. Due to technical problems with the acquisition of fat sat MR images, BMLs could not be evaluated in five patients. For all studied features a higher prevalence was found with MR imaging compared to radiography. The most prominent discrepancies between TOMS and OARSI prevalence were found for erosions and osteophytes: an additional 96 out of 200 scored joints (CMC-1) and 170 out of 400 scored joints (CMC-1 $n = 79$; STT $n = 91$) were found positive with TOMS respectively, while for both features only 1 OARSI-positive CMC-1 joint scored negative with TOMS. On MR images osteophytes were detected in the vast majority of thumb bases: practically always the CMC-1 was affected, while patients with isolated STT osteophytes were quite rare for both TOMS ($n = 9$) and the OARSI ($n = 1$) scoring.

Table I
Prevalence of osteoarthritic features for radiography and MR imaging in 200 thumb base joints of the right hand in patients with hand osteoarthritis

Feature	Prevalence (score > 0)	
	On radiograph	On MRI
Osteophytes		
CMC-1	47.0%	86.0%
STT	5.5%	51.0%
TB*	47.5%	90.5%
JSN/CSL		
CMC-1	39.5%	49.5%
STT	20.0%	40.5%
TB*	46.5%	59.0%
Erosions&cysts/SBDs		
CMC-1	11.0%	58.5%
STT	n.a.	53.0%
TB*	n.a.	76.0%
Subchondral sclerosis/BMLs†		
CMC-1	22.5%	49.2%
STT	n.a.	48.7%
TB*	n.a.	63.6%
Subluxation		
CMC-1	15.0%	20.5%

* A feature is considered present in TB, when present in either or both joints.
† BMLs could not be scored in 5 TBs. BMLs = bone marrow lesions, CMC-1 = first carpometa-carpal joint, CSL = cartilage space loss, JSN = joint space narrowing, n.a. = not applicable, SBDs = subchondral bone defects, STT = scaphotrapeziotrapezoid joint, TB = thumb base.

Correlations between TOMS and OARSI scoring systems

TOMS scores were significantly higher for thumb bases that scored positive for the corresponding OARSI feature ($p < 0.001$), with increasing TOMS scores for more severe radiographic stages (stage 0 vs 1, 1 vs 2, 2 vs 3) of osteophytes (*P*-values <0.001, <0.001, 0.667) and JSN (*P*-values <0.001, 0.010, 0.355) in the CMC-1 joint (Fig. 1).

We found significant correlations (coefficient [95%CI]) between TOMS and OARSI scores for osteophytes in CMC-1 ($\rho = 0.75$ [0.69; 0.81]) and STT ($\rho = 0.30$ [0.17; 0.42]) joints; between cartilage space loss (CSL) and JSN in CMC-1 ($\rho = 0.70$ [0.62; 0.76]) and STT ($\rho = 0.53$ [0.42; 0.62]) joints; SBDs and erosions/cysts ($\rho = 0.41$ [0.29; 0.52]), BMLs and subchondral sclerosis ($\rho = 0.65$ [0.56; 0.73]), and between TOMS and OARSI defined CMC-1 subluxation ($\varphi = 0.65$ [0.57; 0.73]).

Correlations between osteophytes on imaging and physical examination

Besides comparing both imaging modalities to one another, we also compared both scoring systems to bony swellings felt during palpation of the thumb base. Bony swelling was registered for the thumb base as a whole; not for CMC-1 and STT joints separately. The osteophyte CMC-1 joint scores of both OARSI and TOMS were significantly higher in thumb bases with bony swellings compared to those without (Fig. 2, panel A and B, $p < 0.001$ in both). The associations between visualized CMC-1 osteophytes and palpated bony swelling are further supported by significant poor to weak correlations of OARSI ($\rho = 0.25$ [0.12; 0.38]) and TOMS ($\rho = 0.29$ [0.16; 0.41]) scores.

At first glance, a similar relationship appears to be true for TOMS osteophyte scores of the STT joint and bony swelling of the thumb

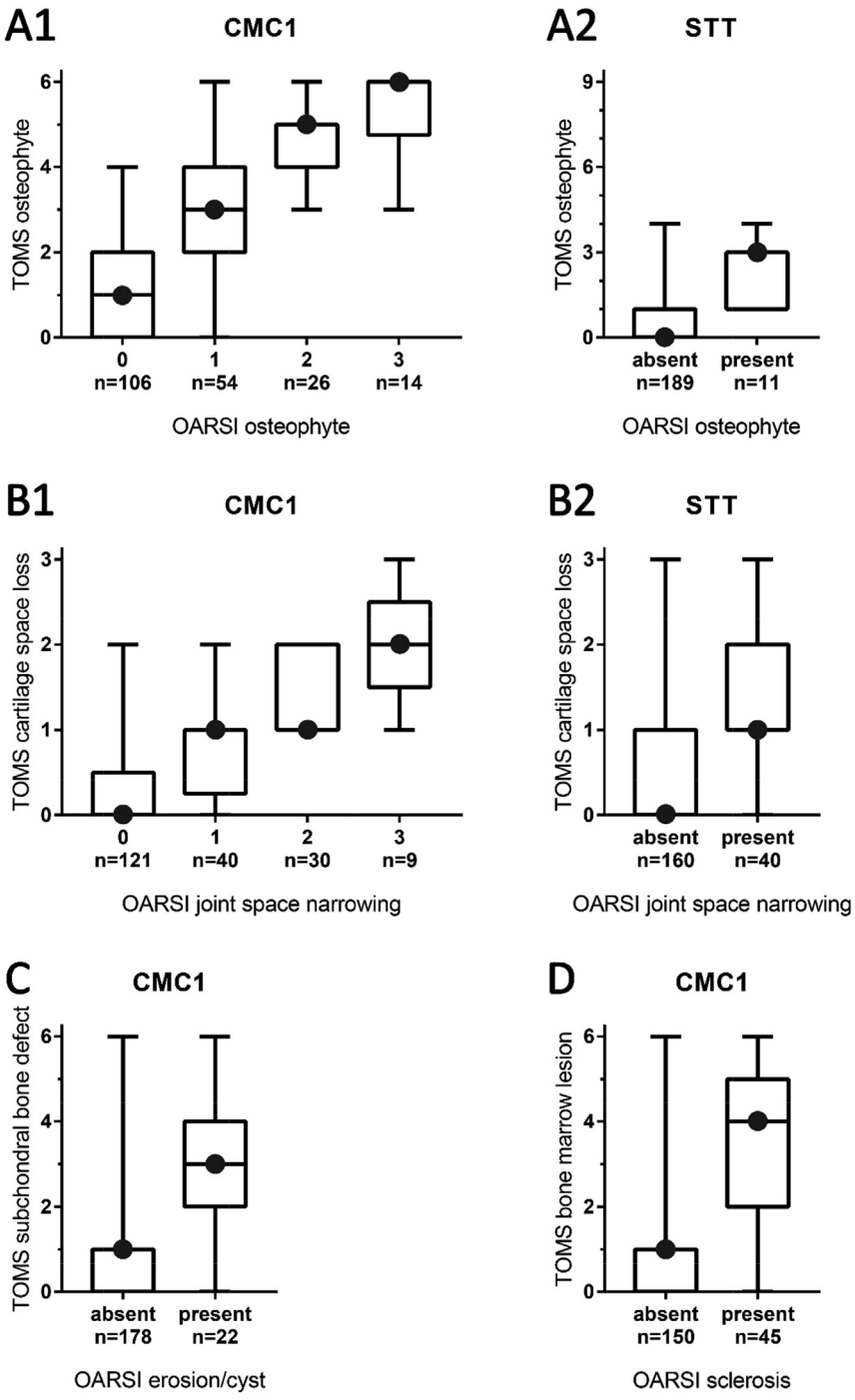

Fig. 1. The distribution of thumb base OA MRI scoring system (TOMS) scores stratified for OARSI scores in 200 thumb base joints from hand OA patients. Boxplots show the distributions of TOMS' osteophyte (A), cartilage space loss (B), subchondral bone defect (C), and bone marrow lesion ($n = 195$) (D) scores. Radiographic OARSI scoring of the STT joint only exists for osteophytes (A2) and joint space narrowing (B2). *Y*-axes are scaled to the possible scoring range; whiskers represent total range, box reflects interquartile range, dot signals median value. CMC1 = first carpometacarpal joint, OARSI = osteoarthritis research society international (radiographic atlas scoring), STT = scaphotrapeziotrapezoid joint, TOMS = thumb base osteoarthritis magnetic resonance imaging (MRI) scoring system.

base (Fig. 2, panel C1, $p = 0.059$). However, when we, by stratification, correct for the already demonstrated relationship between thumb base bony swelling and CMC-1 osteophyte score, distributions of STT osteophyte TOMS scores are not different across categories (Fig. 2, panel C2, $p > 0.999$ for both strata); nor is the distribution of OARSI osteophyte STT scores ($p = 0.548$, data not shown). Again this is reflected by low, non-significant Spearman's rank coefficients: $\rho = 0.05$ [−0.09; 0.18] and $\rho = 0.13$ [−0.005; 0.27] for the correlation of bony swelling with OARSI and TOMS osteophyte scores in STT, respectively.

Discussion

This study shows significant positive correlations between the newly developed TOMS scores and radiographic OARSI scores for corresponding OA features, indicating good construct validity of

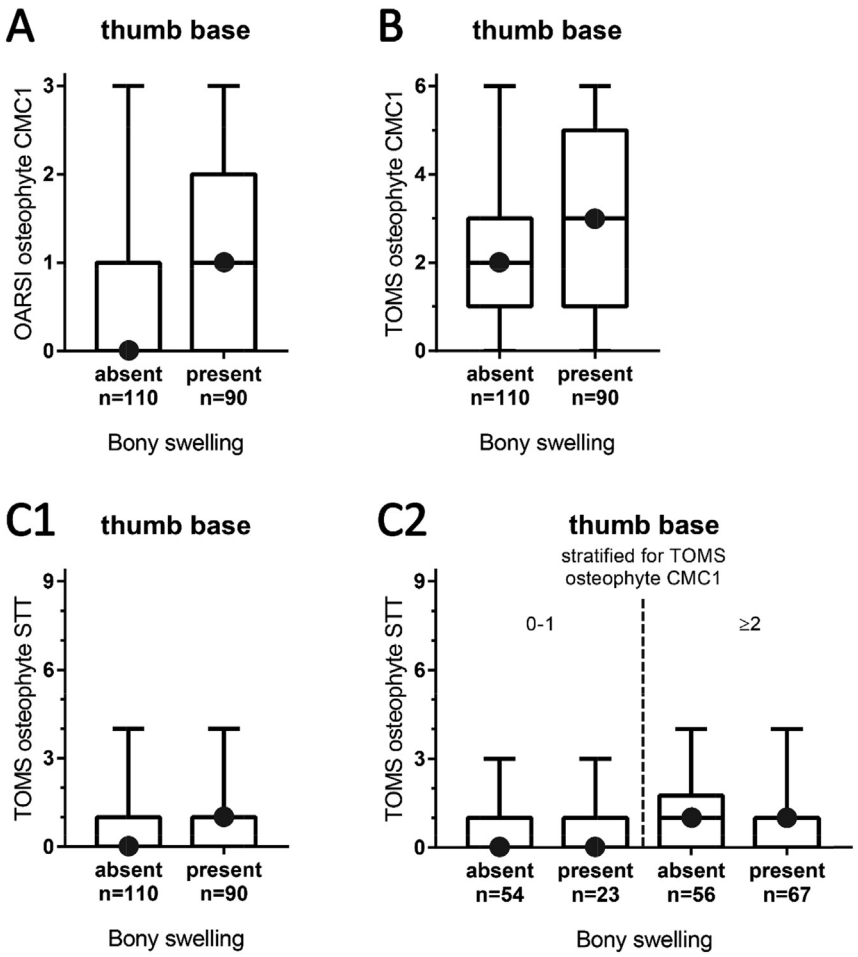

Fig. 2. The distribution of osteophyte imaging scores stratified for the presence of bony swelling during physical examination of the thumb base. Boxplots show the distributions of OARSI osteophyte scores of the CMC1 joint (A), and TOMS osteophyte scores of the CMC1 (B) and STT (C) joints; STT scores are further stratified for TOMS osteophyte CMC1 scores (C2). *Y*-axes are scaled to the possible scoring range; whiskers represent total range, box reflects interquartile range, dot signals median value. CMC1 = first carpometacarpal joint, OARSI = osteoarthritis research society international (radiographic atlas scoring), STT = scaphotrapeziotrapezoid joint, TOMS = thumb base osteoarthritis MRI scoring system.

TOMS in patients diagnosed with hand OA. Correlations between TOMS and OARSI scores in the CMC-1 joint were stronger for osteophytes and JSN than for erosions (0.75; 0.70; 0.41), which was previously also shown for correlations between Oslo HOA MRI and OARSI scores for these features in IP joints (0.53; 0.68; 0.32)[20] in a similar population of hand OA patients. In addition, osteophyte scores from both MR imaging and radiography were positively correlated with bony swelling of the thumb base as assessed by physical examination.

We found an increased detection rate for osteophytes with MR imaging compared to radiography. This finding is in accordance with previous studies in knee OA[21], IP joint OA[20,22], and veterinary OA[23,24]. Javaid *et al.* scored MR images of 164 symptom free knees without radiographic osteophytes according to the Whole-Organ MRI Score (WORMS) and only one knee had no MR-detected osteophytes. When comparing prevalence of radiographic osteophytes (41%) in IP joints with the Oslo HOA scoring method for MR-defined osteophytes (77%), a similar situation is apparent[20]. Likewise, compared to the OARSI scoring method for CMC-1 osteophytes, we found a higher prevalence of osteophytes using TOMS, with relatively higher scores. Therefore, we hypothesize that MR imaging has a better sensitivity to detect even small, subclinical osteophytes that are missed with standard radiography scoring, which is further emphasized by the findings on the associations with physical examination. A popular interpretation for this better sensitivity is the tomographic nature of MR imaging that is not limited by superimposition of overlying structures[23–25]. However, another possible explanation is the lack of ossification in early stage osteophytes[26], rendering them radiolucent. Therefore, longitudinal thumb base imaging studies are required to investigate whether the osteophytes that were solely detected with TOMS can predict future radiographic or clinical progression, or whether they have no further implications and might be considered to be merely background noise.

The plots in Fig. 1 show quite clearly that TOMS scores can discriminate between the equivalent OARSI categories, which is further supported by the outcome from formal non-parametric testing of between-group differences. In light of these results, one might expect to find higher values for the Spearman's correlation coefficients, however this statistic is negatively influenced by the high number of tied ranks in the data, which is inherent to the ordinal nature of the scoring systems. When comparing only individuals with different OARSI scores, TOMS can reliably distinguish these differences in 66–83 percent of the cases (data not shown).

Apart from a comparison between both scoring systems, we also investigated the associations of osteophyte scores with the presence of bony swellings at physical examination. For the

interphalangeal joint subset of hand OA, Cicuttini *et al.* demonstrated a poor agreement between Heberden's nodes and distal interphalangeal joint osteophytes detected with radiography[27]. Thereafter, several others studied the relation between palpable nodes and radiographic OA in finger joints[28–30]. However, to our knowledge, we are the first to investigate this relation between osteophytes on imaging and bony swelling during physical examination of the thumb base joints. We found that thumb bases with palpable bony swellings had significantly higher CMC-1 osteophyte scores for both scoring methods; STT osteophyte scores did not differ on the other hand. Possibly this indicates that the distal part of the thumb base lends itself better to physical examination than the proximal part. Another explanation could be that OA alters the anatomy in such a way that CMC-1 osteophytes can be more easily palpated than STT osteophytes, for example through the co-occurrence of CMC-1 subluxation, with radial translation of the base of the first metacarpal bone.

A strength of our study is the great number of patients studied and the variety of thumb base OA disease stages. By including patients with hand OA, but not necessarily thumb base OA, we were able to compare scores for all stages of disease. Moreover, thumb base OA often coincides with interphalangeal joint OA of the fingers[5] and that is why our cohort reflects the intended population for TOMS future use well. Finally, we used a radiographic scoring method, the OARSI atlas, which grades each individual radiographic feature per joint separately, allowing us to investigate associations for the different TOMS features with corresponding OARSI features.

Several limitations of this study have to be considered. First, for OARSI scoring only PA hand radiographs were used and, even though this is in accordance with the OARSI atlas and standard clinical practice, this might be less sensitive for examining thumb base OA than using a protocol with two orthogonal planes or additional views added, such as stress[31,32] and Robert's (i.e., hyperpronated hand position with anteroposterior beam)[33–35] views. Second, OARSI CMC-1 scores were skewed: relatively small group sizes for OARSI stages 2 and 3 resulted in low statistical power to detect differences in TOMS scores between these stages. Third, we possibly have misclassified cartilage loss by using a suboptimal MR imaging protocol. The advised MR sequence best used for TOMS cartilage assessment is a T1w fat sat 3D gradient-echo (GRE) sequence[11], because this allows for direct visualisation of the cartilage. When unavailable, other sequences can be used to assess loss of cartilage space, based on the inter-bone distance, instead. Since 3D GRE sequences were not part of our MR imaging protocol, we used CSL as substitute for true cartilage loss. Fourth, BMLs can exclusively be seen on MR images, making a direct comparison between both scoring systems impossible. Since previous studies linked BMLs to areas of sclerosis on histology[16,18], we decided to compare TOMS BMLs with OARSI subchondral sclerosis scores, which indeed showed a strong correlation. However, merely based on this finding, it is impossible to determine whether both scores truly reflect the same underlying physiological changes or that these features just happen to often co-occur. Previous studies also pointed out many other histologically and histomorphometrically changes, that may underlie the MR detected BMLs[18]. Fifth, for the STT joint only osteophytes and JSN are scored following the OARSI atlas, therefore we could not compare the other TOMS features for this joint.

As mentioned before, longitudinal studies can help unravelling the importance of radiographically undetected MR-defined osteophytes, yet simultaneously should be used to assess the reliability of TOMS change scores and its responsiveness, in order for TOMS to possibly be recommended as a core instrument according to the OMERACT filter[36]. In addition to a longitudinal approach, future studies to validate TOMS should also include other imaging modalities, such as ultrasonography and computed tomography, they should include a healthy control group, and they should use appropriate MR sequences to compare all six, including synovitis, TOMS features with the best other available imaging technique. Alternatively, cadaveric studies could use histology as a true golden standard, albeit only in a cross-sectional design.

Author contributions

SvB, FPBK and MK designed the study. WD and RL included patients in the HOSTAS cohort. MK supervised the HOSTAS cohort. SvB and HMK scored the radiographs. SvB and FPBK scored the MR images. JLB and MR supervised the MR imaging protocol and scoring. SvB and MK were involved in data analysis. SvB drafted the manuscript. All authors reviewed the manuscript and approved the final version.SvB and MK take responsibility for the integrity of the work as a whole, from inception to finished article.

Conflict of interest

None declared.

Role of the funding source

Dutch Arthritis Foundation (Reumafonds): 10-1-405 for the MR imaging and LLP-24 for the Hostas cohort. This funding source had no role in the design of this study, nor during its execution, analyses, interpretation of the data, or decision to submit results.

Acknowledgements

We thank the patients of the HOSTAS cohort for participation in this study, research nurses, Mrs BAMJ van Schie-Geyer, Mrs S Wongsodihardjo and Mrs SS Verhaar-Verdel, and datamanagers, Mrs JWM van Krol-Berkel and Mr CH Kromme, in the rheumatology department of the LUMC and technicians in the radiology department of the LUMC for support in data collection.

References

1. Zhang W, Doherty M, Leeb BF, Alekseeva L, Arden NK, Bijlsma JW, *et al*. EULAR evidence-based recommendations for the diagnosis of hand osteoarthritis: report of a task force of ESCISIT. Ann Rheum Dis 2009 Jan;68(1):8–17, https://doi.org/10.1136/ard.2007.084772.
2. 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 Nov;13(11):953–7, https://doi.org/10.1016/j.joca.2005.06.007.
3. Jónsson H, Valtýsdóttir ST. Hypermobility features in patients with hand osteoarthritis. Osteoarthritis Cartilage 1995 Mar;3(1):1–5.
4. Kraus VB, Li Y-J, Martin ER, Jordan JM, Renner JB, Doherty M, *et al*. Articular hypermobility is a protective factor for hand osteoarthritis. Arthritis Rheum 2004 Jul;50(7):2178–83, https://doi.org/10.1002/art.20354.
5. Bijsterbosch J, Visser W, Kroon HM, Stamm T, Meulenbelt I, Huizinga TWJ, *et al*. Thumb base involvement in symptomatic hand osteoarthritis is associated with more pain and functional disability. Ann Rheum Dis 2010 Mar 1;69(3):585–7, https://doi.org/10.1136/ard.2009.104562.
6. Kloppenburg M, Kwok W-Y. Hand osteoarthritis–a heterogeneous disorder. Nat Rev Rheumatol 2011 Nov 22;8(1):22–31, https://doi.org/10.1038/nrrheum.2011.170.

7. Zhang W, Doherty M, Leeb BF, Alekseeva L, Arden NK, Bijlsma JW, *et al.* EULAR evidence based recommendations for the management of hand osteoarthritis: report of a task force of the EULAR Standing Committee for International Clinical Studies Including Therapeutics (ESCISIT). Ann Rheum Dis 2007 Mar 1;66(3):377–88, https://doi.org/10.1136/ard.2006.062091.
8. Mathiessen A, Cimmino MA, Hammer HB, Haugen IK, Iagnocco A, Conaghan PG. Imaging of osteoarthritis (OA): what is new? Best Pract Res Clin Rheumatol 2016;30(4):653–69.
9. Haugen IK, Ostergaard M, Eshed I, McQueen FM, Bird P, Gandjbakhch F, *et al.* Iterative development and reliability of the OMERACT hand osteoarthritis MRI scoring system. J Rheumatol 2014 Feb;41(2):386–91, https://doi.org/10.3899/jrheum.131086.
10. Haugen IK, Eshed I, Gandjbakhch F, Foltz V, Østergaard M, Bøyesen P, *et al.* The longitudinal reliability and responsiveness of the OMERACT Hand Osteoarthritis Magnetic Resonance Imaging Scoring System (HOAMRIS). J Rheumatol 2015 Dec;42(12):2486–91, https://doi.org/10.3899/jrheum.140983.
11. Kroon FPB, Conaghan PG, Foltz V, Gandjbakhch F, Peterfy C, Eshed I, *et al.* Development and reliability of the OMERACT thumb base osteoarthritis magnetic resonance imaging scoring system. J Rheumatol 2017 Nov;44(11):1694–8, https://doi.org/10.3899/jrheum.161099.
12. Damman W, Liu R, Kroon FPB, Reijnierse M, Huizinga TWJ, Rosendaal FR, *et al.* Do comorbidities play a role in hand osteoarthritis disease burden? Data from the hand osteoarthritis in secondary care cohort. J Rheumatol 2017 Nov;44(11):1659–66, https://doi.org/10.3899/jrheum.170208.
13. Altman R, Alarcon G, Appelrouth D, Bloch D, Borenstein D, Brandt K, *et al.* The American College of Rheumatology criteria for the classification and reporting of osteoarthritis of the hand. Arthritis Rheum 1990 Nov 1;33(11):1601–10, https://doi.org/10.1002/art.1780331101.
14. Altman RD, Gold GE. Atlas of individual radiographic features in osteoarthritis, revised. Osteoarthritis Cartilage 2007;15(Suppl A):A1–A56, https://doi.org/10.1016/j.joca.2006.11.009.
15. Byrt T, Bishop J, Carlin JB. Bias, prevalence and kappa. J Clin Epidemiol 1993 May 1;46(5):423–9, https://doi.org/10.1016/0895-4356(93)90018-V.
16. Hunter DJ, Gerstenfeld L, Bishop G, Davis AD, Mason ZD, Einhorn TA, *et al.* Bone marrow lesions from osteoarthritis knees are characterized by sclerotic bone that is less well mineralized. Arthritis Res Ther 2009;11:R11, https://doi.org/10.1186/ar2601.
17. Taljanovic MS, Graham AR, Benjamin JB, Gmitro AF, Krupinski EA, Schwartz SA, *et al.* Bone marrow edema pattern in advanced hip osteoarthritis: quantitative assessment with magnetic resonance imaging and correlation with clinical examination, radiographic findings, and histopathology. Skeletal Radiol 2008 Feb 15;37(5):423–31, https://doi.org/10.1007/s00256-008-0446-3.
18. Loef M, van Beest S, Kroon FPB, Bloem JL, Dekkers OM, Reijnierse M, *et al.* Comparison of histological and morphometrical changes underlying subchondral bone abnormalities in inflammatory and degenerative musculoskeletal disorders: a systematic review. Osteoarthritis Cartilage 2018 Aug 1;26(8):992–1002, https://doi.org/10.1016/j.joca.2018.05.007.
19. IBM [Internet]. Confidence Intervals for Correlations - United States 2016 [cited 2017 Nov 28] Available from: https://www-01.ibm.com/support/docview.wss?uid=swg21478368.
20. Kortekaas MC, Kwok W-Y, Reijnierse M, Wolterbeek R, Bøyesen P, van der Heijde D, *et al.* Magnetic resonance imaging in hand osteoarthritis: intraobserver reliability and criterion validity for clinical and structural characteristics. J Rheumatol 2015 Jul;42(7):1224–30, https://doi.org/10.3899/jrheum.140338.
21. Javaid MK, Lynch JA, Tolstykh I, Guermazi A, Roemer F, Aliabadi P, *et al.* Pre-radiographic MRI findings are associated with onset of knee symptoms: the most study. Osteoarthritis Cartilage 2010 Mar;18(3):323–8, https://doi.org/10.1016/j.joca.2009.11.002.
22. Haugen IK, Bøyesen P, Slatkowsky-Christensen B, Sesseng S, Bijsterbosch J, van der Heijde D, *et al.* Comparison of features by MRI and radiographs of the interphalangeal finger joints in patients with hand osteoarthritis. Ann Rheum Dis 2012 Mar 1;71(3):345–50, https://doi.org/10.1136/annrheumdis-2011-200028.
23. Olive J, D'anjou M-A, Alexander K, Laverty S, Theoret C. Comparison of magnetic resonance imaging, computed tomography, and radiography for assessment of noncartilaginous changes in equine metacarpophalangeal osteoarthritis. Vet Radiol Ultrasound 2010 May 1;51(3):267–79, https://doi.org/10.1111/j.1740-8261.2009.01653.x.
24. D'Anjou M-A, Moreau M, Troncy E, Martel-Pelletier J, Abram F, Raynauld J-P, *et al.* Osteophytosis, subchondral bone sclerosis, joint effusion and soft tissue thickening in canine experimental stifle osteoarthritis: comparison between 1.5 T magnetic resonance imaging and computed radiography. Vet Surg VS 2008 Feb;37(2):166–77, https://doi.org/10.1111/j.1532-950X.2007.00363.x.
25. Peterfy CG, Guermazi A, Zaim S, Tirman PF, Miaux Y, White D, *et al.* Whole-organ magnetic resonance imaging score (WORMS) of the knee in osteoarthritis. Osteoarthritis Cartilage 2004 Mar;12:177–90, https://doi.org/10.1016/j.joca.2003.11.003. 1063-4584 (Print).
26. Junker S, Krumbholz G, Frommer KW, Rehart S, Steinmeyer J, Rickert M, *et al.* Differentiation of osteophyte types in osteoarthritis - proposal of a histological classification. Jt Bone Spine Rev Rhum 2016 Jan;83(1):63–7, https://doi.org/10.1016/j.jbspin.2015.04.008.
27. Cicuttini FM, Baker J, Hart DJ, Spector TD. Relation between Heberden's nodes and distal interphalangeal joint osteophytes and their role as markers of generalised disease. Ann Rheum Dis 1998 Apr 1;57(4):246–8, https://doi.org/10.1136/ard.57.4.246.
28. Thaper A, Zhang W, Wright G, Doherty M. Relationship between Heberden's nodes and underlying radiographic changes of osteoarthritis. Ann Rheum Dis 2005 Aug 1;64(8):1214–6, https://doi.org/10.1136/ard.2004.031450.
29. Jones G, Cooley HM, Bellamy N. A cross-sectional study of the association between Heberden's nodes, radiographic osteoarthritis of the hands, grip strength, disability and pain. Osteoarthritis Cartilage 2001 Oct 1;9(7):606–11, https://doi.org/10.1053/joca.2001.0460.
30. Rees F, Doherty S, Hui M, Maciewicz R, Muir K, Zhang W, *et al.* Distribution of finger nodes and their association with underlying radiographic features of osteoarthritis. Arthritis Care Res 2012 Apr 1;64(4):533–8, https://doi.org/10.1002/acr.21586.
31. Eaton RG, Littler JW. Ligament reconstruction for the painful thumb carpometacarpal joint. J Bone Joint Surg Am 1973 Dec;55(8):1655–66.
32. Wolf JM, Oren TW, Ferguson B, Williams A, Petersen B. The carpometacarpal stress view radiograph in the evaluation of

trapeziometacarpal joint laxity. J Hand Surg 2009 Oct;34(8): 1402–6, https://doi.org/10.1016/j.jhsa.2009.06.030.
33. Robert P. La radiographie de l'articulation trapezo-metacarpienne. Les arthroses de cette join-ture. Bull Mem Soc Radiol Medicale Fr 1936;24:687–90.
34. Robert M. The classic: radiography of the trapeziometacarpal joint. Degenerative changes of this joint. 1936. Clin Orthop 2014 Apr;472(4):1095–6, https://doi.org/10.1007/s11999-013-2930-x.
35. Oheb J, Lansinger Y, Jansen JA, Nguyen JQ, Porembski MA, Rayan GM. Radiographic assessment of the Robert and lateral views in trapeziometacarpal osteoarthrosis. Hand Surg Int J Devoted Hand Up Limb Surg Relat Res J Asia-Pac Fed Soc Surg Hand. 2015;20(2):251–9, https://doi.org/10.1142/S0218810415500203.
36. Boers M, Kirwan JR, Tugwell P, Beaton D, Bingham 3rd CO, Conaghan PG, et al. OMERACT Handbook, updated November-18-2017 [Internet]. [cited 2017 Nov 27].