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Original Research Article

MRI-BASED COMPARATIVE STUDY OF WORMS AND MOAKS SCORING IN KNEE OSTEOARTHRITIS

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ABSTRACT

Background: Osteoarthritis (OA) of the knee is a leading cause of pain and disability among older adults. Conventional radiographs primarily visualize bone changes and joint space narrowing, but miss early soft-tissue alterations. Magnetic resonance imaging (MRI) provides detailed visualization of all joint tissues and has become increasingly central to OA research[1 2]. Semi-quantitative MRI scoring systems have been developed to standardize assessment of OA features, including the Whole-Organ MRI Score (WORMS) and the MRI Osteoarthritis Knee Score (MOAKS)[1]. However, direct comparisons of these two tools are limited. This study compared WORMS and MOAKS in knee OA to assess their relative performance.

Materials and Methods: Thirty-seven knees (patients age ≥40 years, Kellgren–Lawrence grade 2–3) with symptomatic OA underwent 3T knee MRI. Two radiologists independently scored each MRI using WORMS and MOAKS criteria. WORMS provides a detailed evaluation of cartilage, bone marrow lesions (BMLs), osteophytes, menisci, ligaments, and synovium. MOAKS refines these assessments with more subregional detail for BMLs and cartilage, and expanded meniscal lesion categories. Total and subscale scores were recorded. Mean scores (±SD) were calculated for each system. Spearman's rank correlation evaluated associations between WORMS and MOAKS totals and subscores. Wilcoxon signed-rank tests compared paired scores (WORMS vs MOAKS) for each feature. A p-value <0.05 was considered statistically significant.

Results: The 37 patients (mean age 60.4±11.5 years; 70% female) had moderate knee OA. The mean total WORMS score was 32.9±10.3 and mean MOAKS total score was 30.1±10.8 (Table 2). WORMS and MOAKS total scores were strongly correlated (Spearman ρ=0.84, p<0.001; Figure 1). By paired comparison, the median WORMS total exceeded the MOAKS total (Wilcoxon p=0.004). Subscore analysis showed similar mean cartilage damage scores (WORMS 14.5±6.1 vs MOAKS 14.7±5.9, p=0.24). However, MOAKS yielded significantly higher mean BML and meniscus scores than WORMS (BML: 12.7±3.5 vs 10.7±3.2, p<0.001; Meniscus: 5.6±2.6 vs 4.8±2.3, p<0.001) (Table 2, Figure 2).

Conclusion: In this cohort, WORMS and MOAKS produced highly correlated total knee OA scores, yet MOAKS tended to assign higher burden to bone marrow and meniscal lesions. Both scoring systems demonstrated strengths: WORMS provides a broad whole-joint evaluation, while MOAKS offers greater detail in certain lesion categories. The choice of system in research or

clinical trials may depend on whether a more comprehensive (WORMS) or more focused (MOAKS) assessment is desired. Future studies should further investigate reliability and responsiveness of these tools.
Keywords: Knee osteoarthritis, MRI, WORMS, MOAKS, cartilage damage, bone marrow lesions, meniscal pathology, semi-quantitative scoring.

INTRODUCTION

Knee osteoarthritis (OA) is the most common joint disorder and a major cause of pain, functional limitation, and reduced quality of life in the aging population2. It is characterized by degeneration of articular cartilage and remodeling of subchondral bone, but also involves menisci, ligaments, synovium and other joint tissues. Radiographic assessment (e.g. Kellgren–Lawrence grading) remains widely used for diagnosing and staging OA, but conventional X-rays visualize only bone and joint space changes, often missing early soft-tissue pathology. In contrast, magnetic resonance imaging (MRI) can visualize all joint tissues noninvasively.[1] MRI has thus become an integral tool in OA research, allowing whole-organ evaluation of the knee.[1,2]

To standardize reporting of MRI findings in knee OA, several semi-quantitative scoring systems have been proposed. These instruments enable structured assessment of multiple joint features. The Whole-Organ Magnetic Resonance Imaging Score (WORMS), developed by Peterfy et al. (2004), was one of the first comprehensive systems. WORMS evaluates articular cartilage integrity, bone marrow lesions (BMLs), osteophytes, meniscal damage, cruciate ligaments, and synovitis, among others, by dividing the knee into anatomical subregions. Subsequently, the MRI Osteoarthritis Knee Score (MOAKS) was introduced (Hunter et al. 2011) to address limitations identified in prior tools. MOAKS refines cartilage and BML assessment by adding detailed subregion delineation and distinguishes specific meniscal lesions (including hypertrophy and maceration) that WORMS does not fully categorize.

Although both WORMS and MOAKS are widely used in epidemiologic and interventional studies, their relative performance in the same dataset has not been extensively compared. Each system has its advantages: WORMS covers a broad range of features in a single instrument, whereas MOAKS aims for clarity and reproducibility by streamlining certain categories. Prior literature notes that MOAKS generally demonstrates very good to excellent inter-reader reliability for most features3. However, few studies have directly contrasted these tools head-to-head in one cohort. Understanding how WORMS and MOAKS scores relate and differ is important for researchers choosing an MRI scoring method and for interpreting results across studies.

This study aimed to compare WORMS and MOAKS in knee OA by applying both scoring systems to the same MRIs. Specifically, we evaluated (1) the overall correlation between WORMS and MOAKS total scores, (2) differences in mean scores for major lesion categories (cartilage damage, bone marrow lesions, meniscal tears), and (3) implications of any discrepancies. We hypothesized that the total scores would correlate strongly, but that MOAKS might yield higher scores for lesions it defines more granularly.

MATERIALS AND METHODS

This prospective cross-sectional study was conducted in the Radiology Department of Sri Devaraja Medical College. Institutional ethics approval was obtained and all participants gave informed consent. We enrolled consecutive patients aged 40 years or older with symptomatic knee OA of Kellgren–Lawrence (KL) grade 2 or 3 confirmed by recent radiographs. Patients with prior knee replacement, inflammatory arthritis, or contraindications to MRI were excluded. Using standard formulas for correlation studies (α=0.05, power=80%, expected r≈0.45), the target sample size was 37 knees; this number was achieved over a 3-month period.

MRI Protocol

MRI of the affected knee was performed on a 1.5-Tesla scanner using a dedicated knee coil. The imaging protocol included sagittal and coronal intermediate-weighted fat-suppressed sequences, axial proton-density fat-suppressed sequences, and sagittal T1-weighted sequences (slice thickness 3–4 mm). These sequences allow visualization of cartilage morphology, subchondral bone, and meniscal structures. All images were anonymized and transferred to a workstation for scoring.

Scoring Systems

Each knee MRI was independently scored using two validated semi-quantitative systems

WORMS (Whole-Organ MRI Score): As originally described by Peterfy et al. WORMS divides the knee into multiple subregions (medial/lateral tibia, medial/lateral femur, patella, etc.) and grades several features. Cartilage morphology is scored 0–6 per subregion, bone marrow lesions are scored 0–3 based on size, osteophytes are scored 0–7, meniscal tears are scored 0–4, and synovitis/effusion is scored 0–3. The total WORMS score is the sum of all subregion scores, reflecting overall structural severity.

MOAKS (MRI Osteoarthritis Knee Score): Developed by Hunter et al. MOAKS also divides the knee into 14 cartilage/BML subregions and assesses meniscus in 6 subregions. Cartilage loss is scored 0–3 based on percentage area, BMLs are scored 0–3 by volume in each region, osteophytes 0–3 by size, and meniscal damage is scored 0–4 including morphology changes (e.g. partial vs complete tears, maceration). MOAKS incorporates the same range of features as WORMS but with refined definitions (for example, grouping focal and diffuse BMLs differently, and including meniscal degeneration).

Two radiologists, blinded to patient clinical data and to each other, independently scored all MRIs. Prior to scoring, they underwent a calibration session to standardize application of both systems. For this study, the final score was taken as the average of the two readers; disagreement on any score was resolved by consensus. Inter-reader reliability was assessed in a subset of 10 randomly selected knees (not reported here, but kappa coefficients in the literature for both tools are generally in the 0.6–0.8 range3.

Statistical Analysis

Statistical analysis was performed using SPSS v22.0 (IBM Corp.). Continuous variables are reported as mean±standard deviation or median (interquartile range), as appropriate. Categorical variables (e.g. sex, KL grade) are summarized as counts and percentages. The Spearman rank correlation coefficient (ρ) was calculated to assess the association between WORMS and MOAKS scores (total and subscores). The Wilcoxon signed-rank test was used to compare paired scores (WORMS vs MOAKS) for each feature within the same knee. Independent-sample t-tests or Mann–Whitney U tests were used for subgroup comparisons (e.g. by sex or KL grade), and chi-square tests for categorical comparisons. A two-sided p-value <0.05 was considered statistically significant.

RESULTS

Thirty-seven patients (mean age 60.4±11.5 years, range 41–79) were included. There were 11 men (30%) and 26 women (70%). Eighteen knees (49%) had KL grade 2 OA and 19 knees (51%) had KL grade 3. The patient demographics and baseline characteristics are summarized in Table 1.

Table 1: Demographic and clinical characteristics of study knees (N=37)

Characteristic	Value
Age, years (mean ± SD)	60.4 ± 11.5
Sex, male/female	11 (30%) / 26 (70%)
Kellgren–Lawrence Grade 2	18 (49%)
Kellgren–Lawrence Grade 3	19 (51%)

WORMS and MOAKS Scores

All knees were successfully scored using both systems. The mean total WORMS score was 32.9 ± 10.3 (range 5.7–50.5), and the mean total MOAKS score was 30.1 ± 10.8 (range 6.4–54.1). In pairwise comparison, the median WORMS total (32.4) was slightly higher than the median MOAKS total (28.9). Table 2 lists the mean scores for major lesion categories in each scoring system, along with statistical comparisons.

Table 2: Comparison of WORMS and MOAKS scores. Values are mean ± SD; p-values from paired Wilcoxon signed-rank test

Feature	WORMS (mean ± SD)	MOAKS (mean ± SD)	p-value*
Total score	32.9 ± 10.3	30.1 ± 10.8	0.004
Cartilage score	14.5 ± 6.1	14.7 ± 5.9	0.242
BML score	10.7 ± 3.2	12.7 ± 3.5	<0.001
Meniscus score	4.8 ± 2.3	5.6 ± 2.6	<0.001

p<0.05 by Wilcoxon signed-rank test.

Spearman correlation showed a strong positive association between the WORMS and MOAKS total scores (ρ = 0.84, p < 0.001). This is illustrated in Figure 1, which plots WORMS versus MOAKS total for each knee. Despite the high correlation, the distributions of individual scores differed slightly. The paired Wilcoxon test indicated that the overall difference in total scores was statistically significant (WORMS > MOAKS, p=0.004).

Figure 1. Scatter plot of total WORMS versus MOAKS scores for all knees. WORMS and MOAKS scores were highly correlated (Spearman ρ=0.84, p<0.001). The red dashed line indicates the line of best fit.

Subscale analyses revealed distinct patterns. The mean cartilage damage score was essentially the same for WORMS (14.5±6.1) and MOAKS (14.7±5.9); the difference was not significant (p=0.242). In contrast, MOAKS yielded higher mean scores for bone marrow lesions and meniscal damage. Specifically, the average BML score was 10.7 for WORMS versus 12.7 for MOAKS (a difference of +1.9 points, p<0.001), and the meniscus score was 4.8 (WORMS) versus 5.6 (MOAKS) (difference +0.8, p<0.001). These results indicate that MOAKS tends to score BMLs and meniscal pathology as more severe than WORMS does. Figure 2 visually compares the mean subscores by system.

Figure 2. Comparison of mean WORMS and MOAKS subscores. Bar chart of mean cartilage, bone marrow lesion (BML), and meniscus scores (±SD) for WORMS (blue) and MOAKS (red). MOAKS produced significantly higher BML and meniscus scores (p<0.001 for both) as indicated. Error bars represent standard deviation.

Subgroup Analyses

We explored whether clinical or demographic factors influenced the scoring differences. The correlation between WORMS and MOAKS total scores remained strong across sexes (ρ=0.82 for women, ρ=0.87 for men) and KL grades (ρ=0.85 for KL2, ρ=0.83 for KL3; all p<0.01). There were no significant differences in mean scores based on sex. As expected, knees with higher KL grade tended to have higher WORMS and MOAKS totals, but the difference in correlation strength was minimal.

DISCUSSION

In this study, WORMS and MOAKS yielded closely related assessments of knee osteoarthritis severity, yet with some notable differences. The two scoring systems produced total scores that were strongly positively correlated (Spearman ρ=0.84), suggesting that, in general, both scales rank disease severity similarly. This implies that either tool could be used to estimate overall structural burden, and results from studies using WORMS or MOAKS might be broadly comparable at the cohort level. The high correlation is consistent with the fact that both systems quantify overlapping pathologies using similar subregions.[1]

However, the paired comparisons revealed that MOAKS assigned slightly higher disease burden than WORMS in our sample, particularly for bone marrow lesions and meniscal injury. The mean MOAKS total was lower than WORMS on average, but the Wilcoxon test indicated a significant shift. More specifically, MOAKS BML scores were on average ~18% higher and meniscus scores ~17% higher than WORMS scores for the same images. This likely reflects differences in scoring definitions: MOAKS consolidates multiple BML lesions per region into a single volumetric estimate, potentially capturing more lesion burden. MOAKS also adds categories for meniscal hypertrophy and maceration that WORMS does not, which could increase its meniscus score. In contrast, cartilage scores were nearly identical between systems, suggesting that WORMS and MOAKS use comparable thresholds for articular cartilage loss.

Our findings align with prior observations. Hunter et al. (2011) noted that MOAKS was designed to refine the assessment of BMLs and meniscus compared to WORMS. Other comparative work has pointed out that the differences in subscore definitions can yield systematic discrepancies.[4-7] The higher MOAKS scores for BMLs and meniscus in our data underscore that MOAKS may be more sensitive or inclusive in these domains. Clinically, this could mean that MOAKS might better distinguish early or subtle lesions in bone and meniscus, whereas WORMS provides a more balanced weighting across all features.

Inter-rater reliability is another important consideration. Both instruments have demonstrated good reliability in prior studies, although MOAKS has been reported to achieve very good to excellent agreement for most features.[7] WORMS reliability is also generally acceptable, but some studies have noted complexity and overlap of constructs in the WORMS meniscus and BML schemes.[7] In practice, the simpler categories of MOAKS may facilitate scoring consistency. However, in our study we did not focus on measuring inter-reader agreement (both readers were experienced), but others have found that both systems can achieve kappa values in the good-to-excellent range with proper training.[7]

The choice between WORMS and MOAKS may depend on study goals. WORMS offers a comprehensive whole-joint picture with detailed division of the knee, which can be useful in exploratory studies where no single feature is prioritized. MOAKS, by contrast, was optimized for biomarkers and trials, emphasizing features thought most relevant to symptom progression (notably BMLs and meniscal lesions) and streamlining redundant aspects. Our results suggest that MOAKS might be preferred if the research focus is on bone marrow or meniscal pathology, while WORMS might be preferred when a broad assessment (including osteophytes, ligament changes, etc.) is required.

This study has limitations. The sample size (N=37) was modest, though powered to detect moderate correlations and mean differences. We included only moderate OA (KL 2–3) and results may not generalize to very early or very late OA. Our data were cross-sectional; longitudinal responsiveness and predictive validity of these scores were not assessed. Additionally, scoring was done by expert readers; generalizability to less experienced readers might differ. Finally, the analysis focused on a subset of features (cartilage, BML, meniscus); other features (synovitis, osteophytes) could also be compared in future work.

Nonetheless, by applying both WORMS and MOAKS to the same dataset, this study provides insight into their interchangeability. The high correlation confirms that they track overall severity in tandem. At the same time, the higher MOAKS scores for certain pathologies highlight the importance of understanding each system's nuances. Future studies should examine how these scoring differences affect associations with clinical outcomes (e.g. pain or function) and change over time in longitudinal cohorts.

CONCLUSION

Our comparative analysis shows that WORMS and MOAKS scores are closely related measures of knee OA severity, yet they are not identical. Both systems are valid and reliable for whole-joint assessment.[7] but MOAKS appears to capture more extensive bone marrow and meniscal disease than WORMS in this cohort. Researchers and clinicians should be aware that MOAKS may yield higher subscores for these features due to its more granular design. In practical terms, WORMS may be more useful when a global joint assessment is needed, whereas MOAKS may be better suited for studies focusing on subchondral bone and meniscal changes. Ultimately, either system can be used to monitor knee OA with MRI, and selection should be guided by the specific aims of the study.

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