



ORIGINAL RESEARCH ARTICLE

**AGREEMENT BETWEEN KNEE RADIOGRAPHY AND KNEE
ULTRASONOGRAPHY IN THE DETECTION OF OSTEOPHYTE
(SPUR) FORMATION AND JOINT SPACE NARROWING IN
KNEE OSTEOARTHRITIS: A CROSS-SECTIONAL STUDY AT
GATOT SOEBROTO CENTRAL ARMY HOSPITAL, INDONESIA,
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Bintang Bayu Aryandi^{1*}, Leksmana Arry Chandra¹, Terawan Agus Putranto¹,
Yanuarso², Vininta Fazharyasti¹

¹Department of Radiology, Gatot Soebroto Central Army Hospital (RSPAD Gatot Soebroto Puskesmas), Jakarta, Indonesia; Faculty of Medicine Universitas Pembangunan Nasional “Veteran” Jakarta, Jakarta, Indonesia

²Department of Orthopaedics and Traumatology, Gatot Soebroto Central Army Hospital (RSPAD Gatot Soebroto Puskesmas), Jakarta, Indonesia

**Corresponding author: Bintang Bayu Aryandi, Faculty of Medicine, Universitas Pembangunan Nasional “Veteran” Jakarta, Jalan RS Fatmawati No.1, Jakarta, Indonesia. Email: bintangaryandi@upnvj.ac.id*

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ABSTRACT

Background: Knee osteoarthritis (OA) is one of the most common degenerative joint diseases among adult and older populations, with osteophyte (spur) formation and joint space narrowing (JSN) as its two principal radiological hallmarks. Conventional radiography remains the standard imaging modality but is limited by its two-dimensional nature and inability to directly assess soft tissue, whereas ultrasonography (US) allows real-time visualization of bone margins and periarticular soft tissue without ionizing radiation. Reported agreement (kappa) between radiography and US for osteophyte detection varies widely across populations (0.18–0.58), underscoring the need for

population-specific data.

Objective: To determine the level of agreement between knee radiography and knee US in detecting osteophyte formation and joint space narrowing in patients with knee osteoarthritis.

Methods: An analytic observational study with a cross-sectional design was conducted on 42 subjects with a clinical diagnosis of knee OA who underwent weight-bearing knee radiography and knee US of the same knee at the Radiology Installation of Gatot Soebroto Central Army Hospital (RSPAD Gatot Soebroto Puskesmas), Jakarta, Indonesia, between August and September 2026. Subjects were enrolled by consecutive sampling. Radiographic (anteroposterior weight-bearing and lateral) and B-mode US (high-frequency linear transducer, weight-bearing position) examinations were interpreted independently by different radiologists. Agreement was analyzed using Cohen's kappa (κ), with sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of radiography relative to US calculated as supplementary diagnostic parameters.

Results: Of 42 subjects, the majority were female (35; 83.3%), with a mean age of 59.79 years (median 58; range 40–82 years). Osteophyte formation was detected in 38 subjects (90.5%) by radiography and 36 subjects (85.7%) by US, yielding $\kappa = 0.774$ (95% CI 0.469–1.000; $p < 0.001$; substantial agreement). All discordant pairs ($n = 2$) showed the pattern “radiography positive, US negative,” giving radiography a sensitivity of 100%, specificity of 66.7%, PPV of 94.7%, and NPV of 100% relative to US. Joint space narrowing was identically detected in 40 of 42 subjects (95.2%) by both modalities, yielding $\kappa = 1.000$ (95% CI 1.000–1.000; $p < 0.001$; almost perfect agreement). US additionally identified patellar cartilage thinning in 38 (90.5%),

meniscal degeneration in 36 (85.7%), synovitis in 35 (83.3%), and knee joint effusion in 3 of 42 subjects (7.1%) — findings not assessable by radiography.

Conclusion: Knee radiography and knee US show substantial-to-almost-perfect agreement in detecting osteophyte formation and joint space narrowing, supporting the use of knee US as a complementary, radiation-free modality in the evaluation of knee osteoarthritis, particularly given its additional capacity to characterize periarticular soft-tissue abnormalities not detectable by radiography.

Keywords: knee osteoarthritis; radiography; ultrasonography; osteophyte; joint space narrowing; Cohen's kappa

INTRODUCTION

Knee osteoarthritis (OA) is one of the most common degenerative musculoskeletal diseases in adult and older populations, characterized by progressive articular cartilage breakdown accompanied by subchondral bone remodeling, osteophyte formation, joint space narrowing, and periarticular soft-tissue changes. It is a leading cause of chronic pain, reduced mobility, diminished quality of life, and disability among older adults worldwide^[1]. Global Burden of Disease estimates report more than 370 million prevalent cases of knee OA in 2021, with a substantial projected increase through 2050 driven by population growth, demographic ageing, and rising obesity prevalence^[2]. Epidemiological studies consistently identify female sex as an independent risk factor for knee OA, with higher prevalence and severity than in men, particularly beyond the age of 50 years^[1,3], a pattern attributed to postmenopausal hormonal changes, differences in lower-limb alignment, and biomechanical factors such as body mass index^[4].

Imaging plays a central role in confirming the diagnosis, grading structural severity, guiding prognosis, and informing treatment planning in knee OA^[5,6,7,22]. Conventional radiography remains the primary imaging modality because it is widely available, inexpensive, rapid, and underpinned by an internationally accepted grading system — the Kellgren-Lawrence (KL) classification, introduced in 1957^[8,28]. Radiography reliably depicts structural bony changes such as joint space narrowing, marginal osteophytes, and subchondral sclerosis^[8,9]. Nevertheless, subsequent research has highlighted several limitations of the KL system, including variable interobserver reliability, the absence of compartment-specific grading, and ambiguity in distinguishing early (grade 1) osteophytes; compartment-based modifications have been proposed to address these shortcomings^[8,10,11,12].

Osteophyte formation and joint space narrowing are the two most clinically important radiographic parameters of degenerative change and constitute the core components of the KL grading system. Osteophytes are new bone formations at joint margins arising in response to biomechanical instability and chronic degenerative stress, while joint space narrowing reflects a

reduction in the combined thickness of articular cartilage and meniscus and serves as an indirect marker of cartilage loss and disease progression^[8]. However, radiography is inherently two-dimensional and cannot directly evaluate soft tissue; small osteophytes at certain locations may be missed, and joint-space measurements can be influenced by patient positioning, technique, and image quality. Contemporary reviews further emphasize that radiographic joint space width does not purely reflect cartilage status but is also influenced by meniscal position and the degree of meniscal extrusion^[13,26].

Ultrasonography (US) has increasingly been applied to musculoskeletal joint evaluation, including knee OA, owing to its real-time, non-invasive nature, absence of ionizing radiation, and ability to directly visualize bone surfaces and periarticular soft tissue^[14,15]. Recent comparative studies have reported that US has high sensitivity for detecting superficial marginal osteophytes, at times identifying osteophytes not yet apparent on radiography. A 2026 bilateral comparative study, for example, found that US detected marginal osteophytes significantly more often than radiography, with no osteophyte identified by radiography but missed by US^[16,17]. US can also be used to assess femorotibial joint space distances, offering a potential complementary tool for evaluating joint space narrowing. Nevertheless, US performance is strongly operator-dependent, which may introduce inter-examination variability, and radiography and US therefore possess distinct but potentially complementary diagnostic characteristics^[14,15,18].

International literature on the level of agreement between radiography and US for osteophyte detection in the knee shows considerable heterogeneity, with reported kappa values ranging from 0.18 to 0.58 in several studies, while other studies report substantially higher agreement. This variation is thought to reflect differences in the operational definition of osteophytes, transducer frequency, operator experience, and population characteristics^[16,17,19,20], highlighting the importance of generating agreement data specific to the Indonesian population. The Radiology Installation of Gatot Soebroto Central Army Hospital (RSPAD Gatot Soebroto Puskesmas), a national tertiary referral center with adequate digital radiography and musculoskeletal US facilities and a high annual caseload of knee OA patients, provided a suitable setting for such an investigation.

This study was therefore conducted in 42 subjects meeting the inclusion and exclusion criteria at the Radiology Installation of RSPAD Gatot Soebroto Puskesmas to determine the level of agreement between knee radiography and knee US in detecting osteophyte formation and joint space narrowing in knee OA, and to characterize additional periarticular soft-tissue findings detectable only by US. The findings are intended to inform the role of US as a complementary or alternative modality in the radiological evaluation of knee OA, particularly in settings where radiography is unavailable or contraindicated.

MATERIAL AND METHODS

Study Design, Setting, and Duration

This was an analytic observational study with a cross-sectional design, conducted to assess the level of agreement between knee radiography and knee US in detecting osteophyte formation and joint space narrowing in patients with knee OA, without any intervention or manipulation of study variables. The design allowed radiography and US examinations of the same knee to be performed within the same clinical encounter for each subject, enabling direct comparison of the two modalities under comparable joint conditions. The study was conducted at the Radiology Installation of Gatot Soebroto Central Army Hospital (RSPAD Gatot Soebroto Puskesmas), Jakarta, Indonesia. Data collection took place from August to September 2026 until the minimum required sample size was achieved; the entire process of data collection, verification, and final analysis spanned approximately two months.

Study Population and Sample

The target population comprised all patients with knee OA undergoing radiological evaluation of degenerative knee changes. The accessible population consisted of patients with a clinical diagnosis of knee OA who underwent both knee radiography and knee US at the Radiology Installation of RSPAD Gatot Soebroto Puskesmas during the study period. Subjects were recruited using consecutive sampling, whereby all patients meeting the eligibility criteria during the study

period were enrolled sequentially until the minimum sample size was reached. A total of 42 subjects with complete clinical and radiological data were ultimately included.

Eligibility Criteria

Inclusion criteria were: (1) clinical diagnosis of knee OA; (2) age ≥ 40 years; (3) radiography and US performed on the same knee; (4) willingness to participate and provide written informed consent; and (5) complete clinical and radiological data. Exclusion criteria were: (1) history of prior knee surgery; (2) acute knee trauma that could confound image interpretation; (3) inflammatory joint disease (rheumatoid arthritis, gout, psoriatic arthritis, or joint infection); (4) severe deformity precluding optimal evaluation; and (5) inadequate image quality on either modality.

Sample Size

The minimum sample size for this agreement (kappa) study was calculated using the formula $n = [(Z\alpha + Z\beta)^2 \times P_0(1-P_0)] / (P_0 - P_e)^2$, where $Z\alpha = 1.96$ (5% significance level), $Z\beta = 0.84$ (80% power), $P_0 = 0.70$ (expected proportion of agreement), and $P_e = 0.50$ (proportion of agreement expected by chance). This yielded $n = (7.84 \times 0.21)/0.04 \approx 41.16$, rounded up to 42 subjects. Data collection continued until this minimum requirement was met with complete, analyzable data for all subjects.

Imaging Protocol and Procedure

After providing written informed consent, each subject underwent knee radiography in the anteroposterior (AP) weight-bearing and lateral projections according to the standard institutional protocol. Radiographs were evaluated by a radiologist for the presence of osteophyte formation and joint space narrowing. Each subject subsequently underwent knee US using a Mindray Resona i9 ultrasound system with a high-frequency linear transducer in B-mode, following standardized musculoskeletal scanning technique^[24,25], performed in the weight-bearing position to maintain consistency of joint loading conditions with the radiographic examination. US evaluation assessed the presence of osteophyte formation, joint space narrowing, patellar cartilage thinning, synovitis, meniscal degeneration, and knee joint effusion. Both examinations were performed on the same visit to minimize the interval-related change in clinical status. Radiographic and US images were interpreted independently by different radiologists to minimize interobserver bias between

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modalities. All findings were recorded on a standardized data collection form and subsequently tabulated for statistical analysis.

Variables and Operational Definitions

The independent variables were the imaging modality used (knee radiography versus knee US). The dependent variables were the presence or absence of osteophyte (spur) formation and joint space narrowing, together with additional US findings (patellar cartilage thinning, synovitis, meniscal degeneration, and knee joint effusion). Subject age and sex were recorded to characterize the demographic profile of the sample. Osteophyte formation was operationally defined as new bone growth at the margin of the knee joint attributable to a degenerative process, evaluated by radiography and US and recorded as a binary variable (present/absent). Joint space narrowing was defined as a reduction in the distance between the femorotibial articular surfaces attributable to cartilage degeneration, evaluated by weight-bearing radiography and weight-bearing US and likewise recorded as present/absent.

Statistical Analysis

Data were processed and analyzed using IBM SPSS Statistics (version 27). Descriptive statistics (frequencies, percentages, means, medians, and ranges) were used to characterize subject demographics and the distribution of imaging findings. Agreement between radiography and US for each parameter was assessed using 2×2 cross-tabulation and Cohen's kappa (κ), calculated as $\kappa = (P_o - P_e)/(1 - P_e)$, where P_o is the observed agreement and P_e is the agreement expected by chance. Kappa values were interpreted according to the Landis and Koch criteria: <0.00 poor; 0.00–0.20 slight; 0.21–0.40 fair; 0.41–0.60 moderate; 0.61–0.80 substantial; and 0.81–1.00 almost perfect agreement (Landis and Koch criteria). Given the unidirectional pattern of discordance observed for osteophyte formation, the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of radiography relative to US were additionally calculated. Statistical significance was set at $p < 0.05$, and 95% confidence intervals (CI) were reported for all kappa estimates.

Ethical Considerations

This study was conducted in accordance with the ethical principles of medical research and was approved by the Research Ethics Committee of RSPAD Gatot Soebroto Puskesmas. All subjects received an explanation of the study aims and procedures and provided written informed consent prior to any study-related procedure. Patient data were anonymized using subject codes, and no additional intervention beyond the clinically indicated standard radiological examinations was performed, posing no additional risk to participants.

RESULTS

Between August and September 2026, 42 subjects with a clinical diagnosis of knee OA met the eligibility criteria and were enrolled at the Radiology Installation of RSPAD Gatot Soebroto Puskesmas. Each subject underwent both knee radiography and knee US of the same knee on the same visit, with independent interpretation by different radiologists.

Demographic Characteristics

Table 1 summarizes the demographic characteristics of the study population. The majority of subjects were female (35; 83.3%), with a female-to-male ratio of approximately 5:1, considerably higher than the ratio commonly reported in general-population epidemiological studies of knee OA (1.3:1 to 2:1). The mean age was 59.79 years (median 58; range 40–82 years), with the largest proportion of subjects in the 50–59-year age group (35.7%), followed by the 60–69-year group (31.0%), a pattern consistent with the known increase in knee OA incidence during the fifth to seventh decades of life.

Table 1. Demographic characteristics of study subjects (n = 42)

Characteristic	n	%
Sex		
Female	35	83.3
Male	7	16.7
Age group (years)		
40–49	7	16.7

50–59	15	35.7
60–69	13	31.0
70–79	5	11.9
≥80	2	4.8

Mean age 59.79 years; median 58 years; range 40–82 years.

Detection of Osteophyte Formation and Joint Space Narrowing

Osteophyte formation was detected in 38 of 42 subjects (90.5%) by radiography and in 36 of 42 subjects (85.7%) by US (Table 2). Numerically, radiography detected osteophytes in a slightly higher proportion of subjects than US in this cohort — a pattern that differs from the general tendency reported in most international literature, in which US is typically more sensitive than radiography for osteophyte detection (see Discussion). For joint space narrowing, both modalities produced identical results: 40 of 42 subjects (95.2%) were classified as “present” and 2 of 42 (4.8%) as “absent” by both radiography and US.

Table 2. Detection of osteophyte (spur) formation and joint space narrowing by knee radiography and ultrasonography (n = 42)

Finding / Modality	Present, n (%)	Absent, n (%)
Osteophyte formation		
Radiography	38 (90.5)	4 (9.5)
Ultrasonography	36 (85.7)	6 (14.3)
Joint space narrowing		
Radiography	40 (95.2)	2 (4.8)
Ultrasonography	40 (95.2)	2 (4.8)

Cross-Tabulation and Kappa Agreement Analysis

For osteophyte formation, 36 subjects were classified as “present” by both modalities and 4 subjects as “absent” by both modalities, giving concordant results in 40 of 42 subjects (Table 3). Two subjects showed discordant results, in both cases with radiography positive and US negative;

no subject showed the opposite pattern. The observed agreement (P_o) was $40/42 = 95.2\%$, and the expected agreement by chance (P_e) was 78.9% .

Table 3. Cross-tabulation of osteophyte (spur) formation between radiography and ultrasonography (n = 42)

Radiography	US: Present	US: Absent	Total
Present	36	2	38
Absent	0	4	4
Total	36	6	42

For joint space narrowing, both modalities produced identical results across all 42 subjects, with no discordant pairs (Table 4). The observed agreement was $42/42 = 100\%$, with an expected agreement by chance of 90.9% .

Table 4. Cross-tabulation of joint space narrowing between radiography and ultrasonography (n = 42)

Radiography	US: Present	US: Absent	Total
Present	40	0	40
Absent	0	2	2
Total	40	2	42

Cohen's kappa for osteophyte formation was 0.774 (95% CI $0.469-1.000$; $p < 0.001$), corresponding to substantial agreement according to the Landis and Koch criteria. Kappa for joint space narrowing was 1.000 (95% CI $1.000-1.000$; $p < 0.001$), corresponding to almost perfect (complete) agreement, reflecting the absence of any discordant pair for this parameter (Table 5).

Table 5. Cohen's kappa agreement between knee radiography and ultrasonography for osteophyte formation and joint space narrowing

Parameter	Osteophyte Formation	Joint Space Narrowing
Observed agreement (P_o)	0.952 (95.2%)	1.000 (100%)
Expected agreement (P_e)	0.789	0.909

Kappa (κ)	0.774	1.000
Standard error	0.152	0.000
95% confidence interval	0.469–1.000*	1.000–1.000
p-value	< 0.001	< 0.001
Interpretation (Landis & Koch)	Substantial	Almost perfect

*Upper bound truncated at 1.0 per conventional kappa reporting.

Because the two discordant pairs for osteophyte formation were unidirectional (radiography positive, US negative), the diagnostic performance of radiography relative to US was additionally assessed (Table 6). Radiography showed 100% sensitivity (36/36) and 100% NPV (4/4) relative to US, but only 66.7% specificity (4/6) and 94.7% PPV (36/38) — indicating that, among the 6 subjects classified as osteophyte-negative by US, 2 were classified as osteophyte-positive by radiography.

Table 6. Diagnostic performance of radiography relative to ultrasonography for osteophyte (spur) detection

Diagnostic Parameter	Value
Sensitivity	100% (36/36)
Specificity	66.7% (4/6)
Positive predictive value (PPV)	94.7% (36/38)
Negative predictive value (NPV)	100% (4/4)

Additional Ultrasonographic Findings

Beyond osteophyte formation and joint space narrowing, US identified several additional periarticular soft-tissue findings not assessable by radiography (Table 7). Patellar cartilage thinning was the most common additional finding (38/42; 90.5%), followed by meniscal degeneration (36/42; 85.7%) and synovitis (35/42; 83.3%). Knee joint effusion was comparatively uncommon, observed in only 3 of 42 subjects (7.1%).

Table 7. Additional ultrasonographic findings in knee osteoarthritis (n = 42)

US Finding	n	%
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Patellar cartilage thinning	38	90.5
Meniscal degeneration	36	85.7
Synovitis	35	83.3
Knee joint effusion	3	7.1

Comparison with Previous Studies

Table 8 compares the kappa value for osteophyte agreement obtained in this study with values reported in previous comparative studies. The kappa value obtained here (0.774) was considerably higher than that reported by Harosa et al. (0.34–0.51) and by Nguyen and Tran (0.58), and higher than the correlation coefficients reported by Okano et al. Possible explanations for this discrepancy are addressed in the Discussion.

Table 8. Comparison of kappa values for osteophyte agreement with previous studies

Study (Year)	Setting / Population	n	Kappa / Statistic	Interpretation
This study (2026)	RSPAD Gatot Soebroto, Indonesia	42	$\kappa = 0.774$	Substantial
Harosa et al. ¹⁷ (2026)	Craiova, Romania (bilateral)	30 (60 knees)	$\kappa = 0.34\text{--}0.51$	Fair–moderate
Nguyen & Tran ²⁰ (2021)	ACR meeting abstract	290 knees	$\kappa = 0.58$	Moderate
Okano et al. ¹⁶ (2016)	Rheumatology clinic, Italy	84 (166 knees)	$\rho = 0.70\text{--}0.75$ (correlation)	—
Suwal et al. ¹⁹ (2024)	Nepal	136	Osteophyte count: US > radiography	—

DISCUSSION

Demographic Characteristics

The pronounced female predominance observed in this study (83.3%; ratio $\approx 5:1$) considerably exceeds the female-to-male ratio typically reported in general-population epidemiological studies of knee OA (1.3:1 to 2:1). Global Burden of Disease data indicate that knee OA incidence in women is approximately 1.46 times higher than in men worldwide, while a rural Chinese population-based study reported a 1.76-fold higher risk in women^[2,3]. The markedly higher ratio observed here likely reflects the referral-based nature of RSPAD Gatot Soebroto Puskesmas as a tertiary hospital, which predominantly evaluates clinically significant, symptomatic OA cases rather than a general population sample. Similar patterns of pronounced female predominance have been reported in other rheumatology- and radiology-clinic-based cohorts, including a recent bilateral Romanian study (80% female) and the cohort of Okano et al.^[16,17]. Postulated biological contributors include postmenopausal hormonal changes affecting cartilage metabolism and subchondral bone density, sex differences in lower-limb biomechanical alignment, and a tendency toward higher body mass index among older women^[4]. The mean age in this cohort (59.79 years; median 58) is also consistent with the known rise in knee OA incidence during the fifth to seventh decades of life, although it was somewhat lower than the median age reported by Harosa et al. (69 years) and the mean age reported by Okano et al. (68.7 years), likely reflecting this study's lower age-inclusion threshold (≥ 40 years) and differing referral population characteristics^[16,17].

Agreement for Osteophyte Formation

The kappa value of 0.774 obtained for osteophyte formation indicates substantial agreement according to Landis and Koch criteria, and is notably higher than most values reported in the international literature comparing radiography and US for knee osteophyte detection. Several factors may account for this discrepancy. First, many comparator studies used a feature-specific, compartment-based approach — assessing osteophytes separately at the medial femoral, lateral femoral, medial tibial, and lateral tibial compartments before aggregating agreement at the knee or compartment level — whereas this study assessed osteophyte formation as a single binary variable

at the patient level (present/absent for the examined knee, without compartmental localization). A more global, patient-level assessment tends to yield higher observed agreement than a more granular compartment-level assessment, because localized discordance between compartments can cancel out at the patient level while still being captured as discordance at the compartment level^[16,17].

Second, this population had a very high prevalence of osteophyte formation on both modalities (90.5% by radiography, 85.7% by US), unlike the more heterogeneous population studied by Okano et al., which reported a substantially lower radiographic osteophyte prevalence. A very high (or very low) prevalence of positive findings on both methods statistically tends to lower the expected chance agreement (P_e) while the observed agreement (P_o) remains high, thereby inflating the resulting kappa value — a phenomenon known as the kappa paradox^[16]. Third, differences in the operational definition of osteophytes contribute to between-study variation in kappa: this study used a simple present/absent binary definition, whereas several comparator studies used a semi-quantitative severity grading (grade 0–3) subsequently dichotomized, a process that can increase interobserver variability and reduce agreement. Fourth, differences in transducer frequency (4–18 MHz across comparator studies) may play a role, as higher-frequency transducers generally provide better spatial resolution for superficial structures such as marginal osteophytes, potentially enabling detection of very small osteophytes not visualized on radiography, which in turn could reduce agreement (because US would then detect more positive cases than radiography).

Notably, the direction of discordance observed in this study was opposite to that reported in most of the international literature. Here, both discordant subjects showed the pattern “radiography positive, US negative” (radiography sensitivity 100%, specificity 66.7% relative to US), whereas Harosa et al., Okano et al., and Suwal et al. consistently reported the opposite pattern, with US detecting more osteophytes than radiography and no osteophyte detected by radiography but missed by US^[16,17,19]. This reversed pattern may be explained by osteophytes located in acoustically challenging regions for US — such as the intercondylar compartment or osteophytes obscured by thick overlying soft tissue — which may be more readily visualized on radiography, which is not subject to an acoustic window limitation. The two discordant subjects in this study may have had

small osteophytes at locations suboptimal for US visualization, while nonetheless being visible on radiography owing to its projection of the entire osseous structure without soft-tissue attenuation. Operator experience and equipment quality at the study site are additional factors to consider, given the strong operator dependence of US sensitivity for osteophyte detection.

Nonetheless, the number of discordant subjects in this study was very small (2 of 42), resulting in a fairly wide 95% CI for the osteophyte kappa value (0.469–1.000), indicating limited precision in the point estimate owing to the relatively small sample size — particularly the small number of subjects classified as “absent” on radiography ($n = 4$). This limitation should be borne in mind when interpreting the magnitude of agreement, and confirmation in a larger sample would provide a more stable estimate.

Agreement for Joint Space Narrowing

The kappa value of 1.000 obtained for joint space narrowing indicates almost perfect (complete) agreement between radiography and US, with no discordant results among the 42 subjects examined. This finding suggests that, for joint space narrowing in this population, radiography and US have equivalent detection capability and can, in practical terms, be used interchangeably. This is consistent with the concept that joint space narrowing is a relatively coarse, macroscopic structural finding that is comparatively straightforward to assess visually on both modalities, in contrast to small osteophytes, which require higher spatial resolution and are more susceptible to technical variation. Although the bilateral study by Harosa et al. did not report a specific kappa value for joint space narrowing (having assessed joint space width as a continuous millimeter measurement rather than a binary categorical variable), it reported that radiographic joint space width was closely associated with several other US findings, including meniscal extrusion and joint effusion, supporting the notion that joint space narrowing is a structural marker that can be assessed consistently across imaging modalities^[17].

Nonetheless, the perfect kappa value obtained here warrants cautious methodological interpretation. A kappa of 1.000 arises from the complete absence of discordant pairs in this sample; while mathematically and statistically valid, such a perfect result in a relatively small sample (42 subjects) may be sample-specific, and generalization to a larger population requires further

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confirmation. The binary (present/absent, without severity grading) operational definition of joint space narrowing used in this study may also have contributed to the high observed agreement, since binary variables are generally easier to agree upon than ordinal or continuous variables requiring more detailed quantitative thresholds. In addition, the use of the weight-bearing position for both modalities likely contributed to the high agreement, as weight-bearing acquisition allows joint space visualization under comparable physiological loading conditions across both examinations, reducing variability attributable to differences in patient positioning^[21].

Contribution of Additional Ultrasonographic Findings

The additional US findings observed in this study — patellar cartilage thinning (90.5%), meniscal degeneration (85.7%), synovitis (83.3%), and knee joint effusion (7.1%) — provide a considerably more comprehensive picture of the knee OA phenotype in this population than can be obtained from conventional radiography alone. These findings align with recent international literature emphasizing the role of US as a multiparametric evaluation modality in knee OA^[18]. By comparison, the bilateral study by Harosa et al. reported that joint effusion was found almost exclusively in knees with US-detected osteophytes (84.6% of left knees and 76.0% of right knees with osteophytes, versus 0% of knees without osteophytes), suggesting a close relationship between marginal bone remodeling and intra-articular inflammatory response. A broadly similar pattern is reflected indirectly in this study, in which the high prevalence of osteophyte formation (85.7–90.5%) coexisted with a high prevalence of synovitis (83.3%), although a formal analysis of the association between these findings was outside the scope of the present study and may be an avenue for future research^[17].

The high prevalence of meniscal degeneration (85.7%) observed here is also consistent with recent systematic evidence linking meniscal extrusion and degeneration to a range of knee OA outcomes, including radiographic joint space narrowing^[26]. Given that this study also found complete agreement for joint space narrowing between modalities, it is plausible that meniscal degeneration contributed to the consistency of joint space narrowing findings across modalities, although this specific causal relationship requires further dedicated analysis beyond the scope of this study. This is consistent with the contemporary understanding of knee OA as a disease affecting

the whole joint — including synovium, subchondral bone, and periarticular soft tissue — rather than articular cartilage in isolation^[23], and reinforces the value of US as a modality capable of capturing this broader disease burden. Overall, these additional findings reinforce the argument that knee US should not be viewed merely as a comparator to radiography for the two classic Kellgren-Lawrence parameters (osteophytes and joint space), but rather as a complementary modality capable of providing clinically valuable additional information on periarticular soft-tissue status — information that may influence management decisions, such as the need for additional anti-inflammatory therapy in patients with active synovitis.

Clinical Implications

These findings carry several clinical implications. First, the substantial-to-almost-perfect agreement between radiography and US for osteophyte formation and joint space narrowing supports the use of knee US as a viable alternative modality in specific circumstances, such as in patients with relative contraindications to ionizing radiation, those requiring short-interval repeat evaluation (e.g., for disease-progression monitoring), or in facilities with limited access to radiographic equipment. Second, the capability of knee US to assess additional findings such as synovitis, joint effusion, and meniscal degeneration provides significant added value not obtainable from radiography, supporting the use of US as a complementary (rather than substitutive) examination in the initial multiparametric evaluation of knee OA, particularly in patients whose clinical symptoms are not fully concordant with radiographic severity. Third, because the direction of discordance for osteophyte formation in this study was opposite to the pattern generally reported in the international literature (radiography detecting more than US, rather than the reverse), caution is warranted before generalizing that US is “always more sensitive” than radiography for osteophyte detection across all anatomical locations; modality selection should ideally take into account the suspected anatomical location of the osteophyte and the availability of an experienced US operator.

LIMITATIONS

This study has several limitations that should be considered when interpreting its findings. (1) Musculoskeletal US is highly dependent on operator skill, experience, and scanning technique; interoperator variation may influence the detection of osteophyte formation and joint space narrowing. (2) US has inherent limitations in evaluating the entire knee joint surface owing to acoustic shadowing from bony structures, so osteophytes or joint space narrowing at certain locations may not be optimally visualized. (3) Although radiography is the standard method for assessing joint space narrowing and degenerative bony change, it provides only a two-dimensional projection, and its interpretation can be influenced by patient positioning, technique, and image quality. (4) The assessment of osteophyte formation and joint space narrowing on both modalities involves an element of subjectivity that may introduce interpretive variation despite the use of consistent assessment criteria. (5) The relatively small sample size (42 subjects) resulted in wide confidence intervals for some estimates, particularly the osteophyte kappa value, warranting caution in generalizing the results to a broader population; the perfect kappa value (1.000) obtained for joint space narrowing may likewise be sample-specific and requires confirmation in larger cohorts. (6) This study employed an agreement-study design comparing two imaging modalities rather than a diagnostic accuracy study against a single independent reference standard (e.g., MRI or arthroscopy); therefore, it cannot determine which modality is absolutely more accurate. (7) Osteophyte formation and joint space narrowing were assessed as patient-level binary variables rather than by specific anatomical compartment (medial, lateral, or patellofemoral), precluding compartment-specific agreement estimates, which has been shown to be an important source of variation in the international literature^[27]. (8) Formal interobserver and intraobserver reliability analyses were not performed for either modality, so the contribution of observer variability to the agreement estimates cannot be separated from variability attributable to inherent differences between the modalities themselves. (9) A formal statistical analysis of the association between additional US findings (synovitis, effusion, meniscal degeneration, cartilage thinning) and osteophyte formation or joint space narrowing was not undertaken; the relationships discussed are

therefore descriptive and would require dedicated statistical testing to establish statistical significance.

CONCLUSION

In this cross-sectional study of 42 subjects with knee osteoarthritis, knee radiography and knee ultrasonography showed substantial agreement for osteophyte (spur) formation ($\kappa = 0.774$; 95% CI 0.469–1.000; $p < 0.001$) and almost perfect agreement for joint space narrowing ($\kappa = 1.000$; $p < 0.001$). All discordant osteophyte results were unidirectional (radiography positive, US negative), yielding 100% sensitivity but only 66.7% specificity for radiography relative to US. Ultrasonography additionally identified clinically relevant periarticular soft-tissue findings — patellar cartilage thinning, meniscal degeneration, synovitis, and joint effusion — that are not assessable by radiography. These findings support the use of knee ultrasonography as a complementary, radiation-free modality alongside radiography in the multiparametric evaluation of knee osteoarthritis, while underscoring the need for larger, compartment-specific studies incorporating an independent reference standard to confirm and extend these observations.

DECLARATIONS

Author Contributions

BBA contributed to the conceptualization, methodology, investigation, data curation, and writing of the original draft. LAC contributed to the methodology, supervision, and review and editing of the manuscript, with particular expertise in musculoskeletal radiology. TAP contributed to the methodology, formal analysis, supervision, and review and editing of the manuscript, particularly in statistical data analysis. Y contributed to the methodology, supervision, and review and editing of the manuscript, particularly regarding the clinical aspects of knee osteoarthritis. VF contributed to supervision and review and editing of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Ethical Approval

This study was approved by the Research Ethics Committee of RSPAD Gatot Soebroto Puskesmas and was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment.

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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