

Ultrasonographic Assessment of Canine Arthritis with Genetic and Microbiological Context: An Integrative Diagnostic Imaging Approach

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<https://doi.org/10.65723/RMSP2735>

Abstract:

Background: Canine arthritis is a common chronic musculoskeletal disorder that reduces mobility, causes pain, and impairs quality of life. Radiography remains widely used in clinical practice but is relatively insensitive for early soft-tissue and inflammatory changes. Ultrasonography can provide real-time visualization of synovial thickening, joint effusion, periarticular soft tissue changes, and Doppler vascularity. Because arthritis is multifactorial, imaging findings should also be interpreted in relation to genetic susceptibility and potential microbiological or microbiome-related inflammatory mechanisms.

Aim: This study evaluated the diagnostic contribution of ultrasonography in dogs with clinical signs of arthritis and interpreted the observed imaging patterns within an integrative framework that includes genetic and microbiological considerations.

Methods: A retrospective longitudinal clinical case series of 30 dogs examined at the Small Animal Clinic, Faculty of Veterinary Medicine, Omar Al-Mukhtar University, was reviewed. Dogs were recruited between 2023 and 2025 and followed by serial ultrasonography. Joint evaluation was performed using a Mindray ultrasound system and a high-frequency linear probe (7.5–12 MHz). Synovial membrane thickening, joint effusion, cartilage surface irregularity or erosion, periarticular soft tissue changes, and Doppler hypervascularity were recorded. Radiographic findings were compared descriptively with ultrasonographic findings. Genetic testing and microbiological or microbiome profiling were not performed and are discussed as contextual mechanisms and future research directions.

Results: The dogs were 8.3 ± 2.2 years old (median 8; range 5–12 years). Ultrasonography detected synovial inflammation in 90% of dogs, Doppler hypervascularity in 85%, joint effusion in 78%, and cartilage erosion in 62%. Early ultrasonographic inflammatory changes were reported in 72% of dogs

before radiographic abnormalities were evident, whereas radiographic changes such as osteophyte formation or joint-space alteration were detected in 60% of cases. Older dogs, larger-breed dogs, and overweight dogs showed faster progression according to the clinical summaries.

Conclusion: Ultrasonography is a valuable non-invasive tool for early assessment and follow-up of canine arthritis, particularly when soft-tissue inflammation precedes radiographically visible bone change. The study supports the use of serial ultrasonographic monitoring in clinical management. Future prospective studies should combine imaging with standardized clinical scoring, radiographic grading, genetic screening, synovial fluid culture or 16S rRNA PCR, and fecal microbiome profiling to develop predictive models for disease progression.

Keywords: canine arthritis; osteoarthritis; ultrasonography; Doppler imaging; synovial inflammation; joint effusion; radiography

1. Introduction

Arthritis is among the most clinically important causes of chronic pain and reduced mobility in dogs. Osteoarthritis and other chronic joint disorders are particularly common in older animals, large-breed dogs, dogs with previous joint trauma, and dogs with excessive body weight. The condition affects welfare, activity, owner-perceived quality of life, and long-term treatment requirements.

Conventional diagnosis is commonly based on clinical examination and radiography. Radiographs are valuable for detecting osteophytes, subchondral sclerosis, joint-space alteration, and advanced degenerative remodeling. However, early inflammatory changes may remain radiographically occult because synovial thickening, mild effusion, cartilage surface irregularity, and periarticular soft tissue changes are not always visible on plain radiographs.

Ultrasonography has become increasingly useful in the evaluation of superficial and accessible joints because it provides real-time, non-invasive assessment of synovial structures, joint capsule contour, effusion, tendon and periarticular tissues, and cartilage surface abnormalities. Doppler ultrasound can add functional information by identifying synovial hypervascularity, which may reflect active inflammation. Compared with magnetic resonance imaging, ultrasonography is less expensive and more accessible in routine veterinary practice, although it is operator-dependent and cannot evaluate all intra-articular structures equally.

Canine arthritis is not driven by imaging findings alone. Genetic background influences structural joint vulnerability, especially in breeds predisposed to hip dysplasia, elbow dysplasia, cranial cruciate ligament disease, and secondary osteoarthritis. Candidate genes involved in cartilage matrix integrity and skeletal development, including COL2A1, COL11A2, ACAN, and other loci identified in breed-based studies, may influence disease onset, severity, and progression.

A microbiological dimension is also relevant. Septic arthritis may mimic or accelerate degenerative joint disease and is usually investigated through synovial fluid cytology and culture, with molecular approaches such as 16S rRNA PCR used in selected cases. In addition, the gut-joint axis has emerged as a potential contributor to chronic joint inflammation, with intestinal dysbiosis, obesity-associated inflammation, and altered systemic cytokine profiles being proposed as mechanisms that may affect joint tissues. Therefore, an integrative diagnostic approach should consider imaging, host predisposition, and inflammatory or infectious mechanisms.

2. Objectives

To evaluate the diagnostic yield of ultrasonography in dogs with clinical signs compatible with arthritis.
To compare ultrasonographic findings descriptively with radiographic abnormalities.
To identify the most frequent ultrasonographic signs associated with canine arthritis.
To interpret breed-, age-, and body-condition patterns in relation to published genetic susceptibility literature.
To discuss microbiological and microbiome-related mechanisms that may contribute to joint inflammation and atypical progression.

3. Materials and Methods

3.1 Study design and clinical setting

This study was designed as a retrospective longitudinal clinical case series. Medical and imaging records were reviewed for dogs presented with clinical signs suggestive of arthritis at the Small Animal Clinic, Faculty of Veterinary Medicine, Omar Al-Mukhtar University, Al-Bayda, Libya. Dogs were recruited between January 2023 and June 2025 and were followed by serial ultrasonographic examinations when follow-up visits were available. The last follow-up records in the supplied case schedule extended to December 2027.

3.2 Animals and inclusion criteria

Thirty dogs were included. Eligible dogs had clinical signs consistent with joint disease, such as lameness, pain on manipulation, reduced range of motion, joint swelling, reluctance to exercise, or chronic mobility impairment. Dogs with incomplete imaging records were excluded from comparative interpretation. Age was recorded for all dogs. Breed, sex, body weight, and body-condition score should be included in the final dataset before journal submission because they are essential covariates for arthritis progression analysis.

3.3 Ultrasonographic imaging protocol

Ultrasonographic examinations were performed using a Mindray ultrasound system equipped with a high-frequency linear probe (7.5–12 MHz). The stifle and/or affected joints were scanned in longitudinal and transverse planes. The probe frequency and depth were adjusted according to animal size and joint depth. When clinically indicated, Doppler imaging was used to evaluate synovial and periarticular vascularity.

The main ultrasonographic criteria were: synovial membrane thickening, anechoic or hypoechoic joint effusion, cartilage surface irregularity or erosion, periarticular soft tissue echogenicity changes, osteophyte visualization when accessible, and Doppler hypervascularity. Doppler activity was graded descriptively as absent, mild, moderate, or marked; future studies should use a standardized semi-quantitative Doppler scale.

3.4 Radiographic assessment

Radiographic records were reviewed when available. Radiographic abnormalities included osteophyte formation, joint-space narrowing or irregularity, subchondral sclerosis, and advanced degenerative remodeling. Because radiography and ultrasonography evaluate different tissue compartments, the comparison was descriptive rather than treated as a direct gold-standard sensitivity analysis.

3.5 Genetic and microbiological scope

Genetic testing, candidate-gene screening, synovial fluid culture, 16S rRNA PCR, and fecal microbiome sequencing were not performed in this case series. Genetic and microbiological mechanisms are therefore discussed as contextual explanatory factors and as directions for future prospective investigation. The title was revised to reflect this limitation and avoid overclaiming direct genetic or microbiological testing.

3.6 Statistical analysis

Age was summarized as mean $\pm$ standard deviation, median, interquartile range, and range. Detection rates were summarized as percentages. Because only aggregate percentages were provided, approximate case counts were derived by rounding to the nearest whole dog for construction of Wilson 95% confidence intervals; these rounded counts must be verified against original clinical records before journal submission. Yearly ultrasonographic rates were presented graphically as descriptive trends only. With a complete paired dataset, ultrasonography versus radiography should be compared using McNemar's test, and associations with age, breed size, sex, weight, body-condition score, and follow-up duration should be assessed using logistic regression or mixed-effects models.

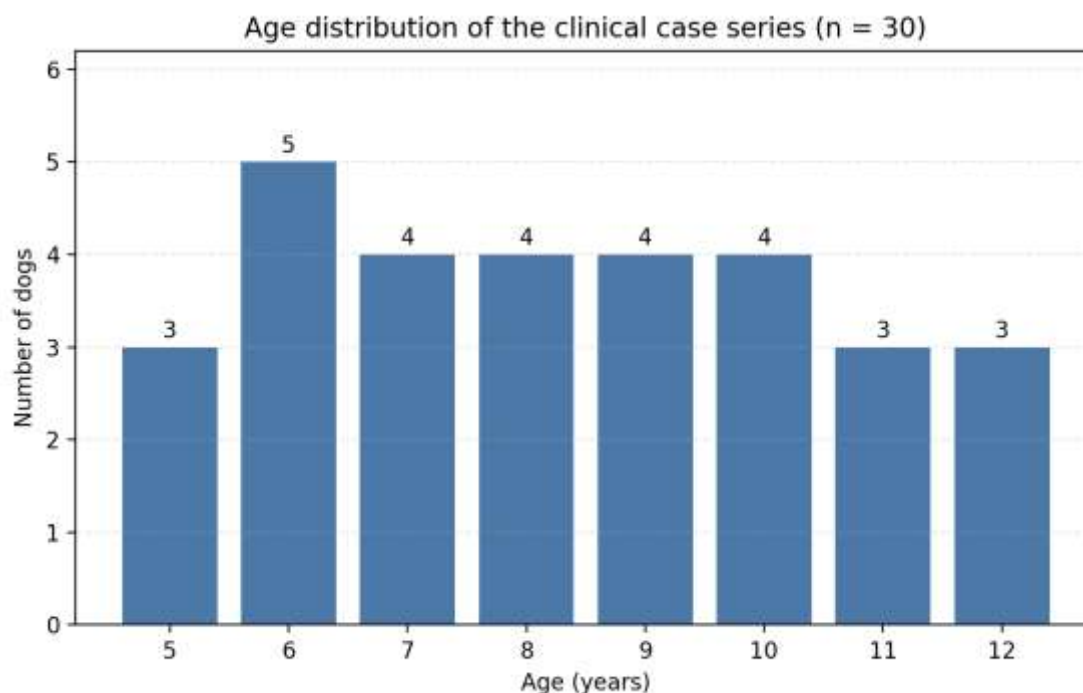
4. Results

4.1 Study population

The case series included 30 dogs aged 5–12 years. The mean age was 8.3 ± 2.2 years, and the median age was 8 years (interquartile range 6.2–10.0). Fourteen dogs (46.7%) were nine years or older.

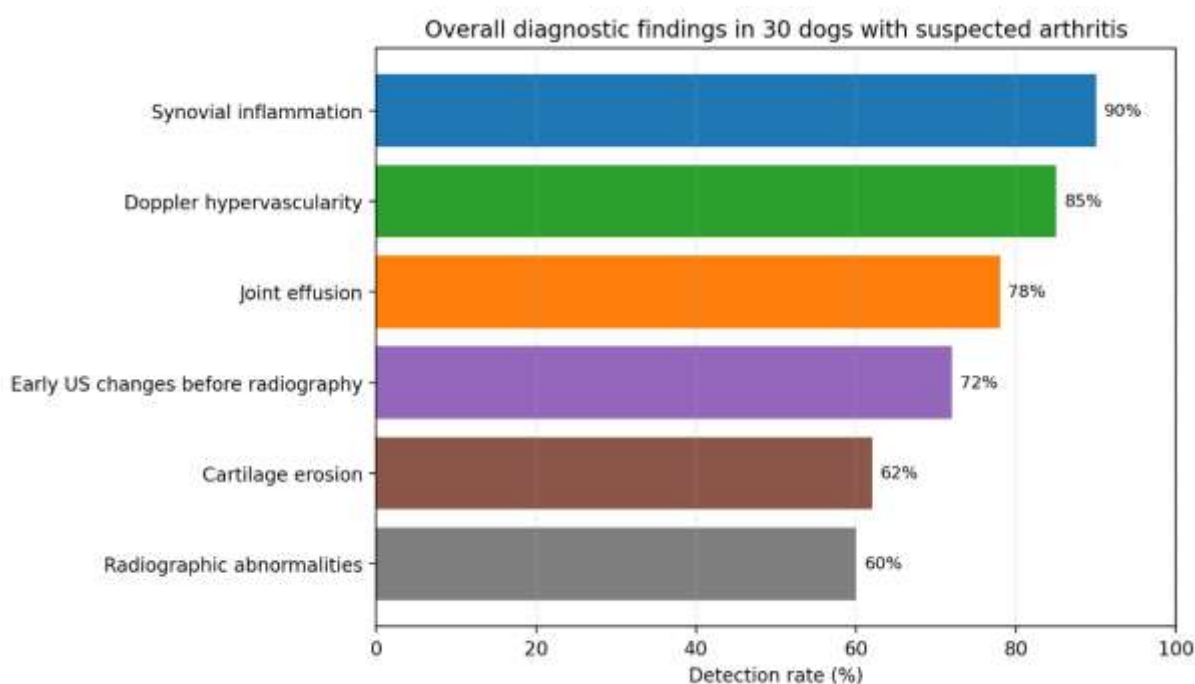
Age group	Number of dogs	Percentage
5–6 years	8	26.7%
7–8 years	8	26.7%
≥ 9 years	14	46.7%

Figure 1. Age distribution of the clinical case series.



4.2 Overall ultrasonographic and radiographic findings

Finding	Supplied rate	Rounded count*	Approx. 95% CI*
Synovial inflammation	90%	27/30	74.4–96.5%
Doppler hypervascularity	85%	26/30	70.3–94.7%
Joint effusion	78%	23/30	59.1–88.2%
Early US changes before radiography	72%	22/30	55.6–85.8%
Cartilage erosion	62%	19/30	45.5–78.1%
Radiographic abnormalities	60%	18/30	42.3–75.4%

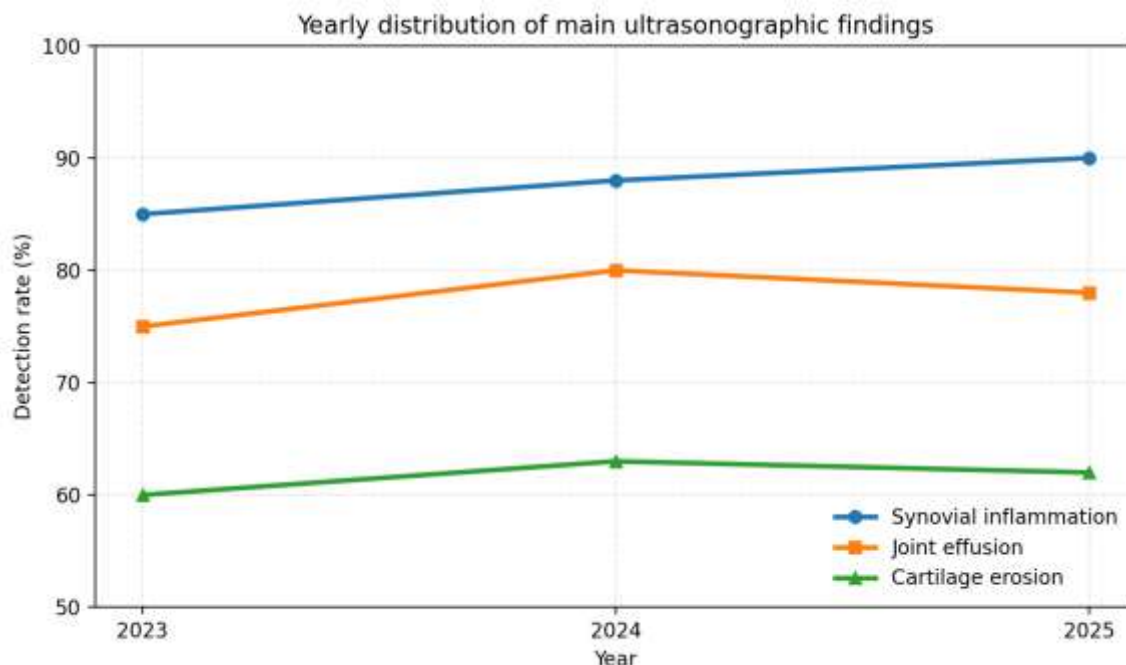


4.3 Yearly distribution of ultrasonographic findings

Year	Synovial inflammation	Joint effusion	Cartilage erosion
2023	85%	75%	60%
2024	88%	80%	63%
2025	90%	78%	62%

Synovial inflammation and joint effusion remained the most frequent ultrasonographic abnormalities across the observation period. The yearly percentages should be interpreted descriptively because each year included a small number of cases and the original individual-level data were not supplied.

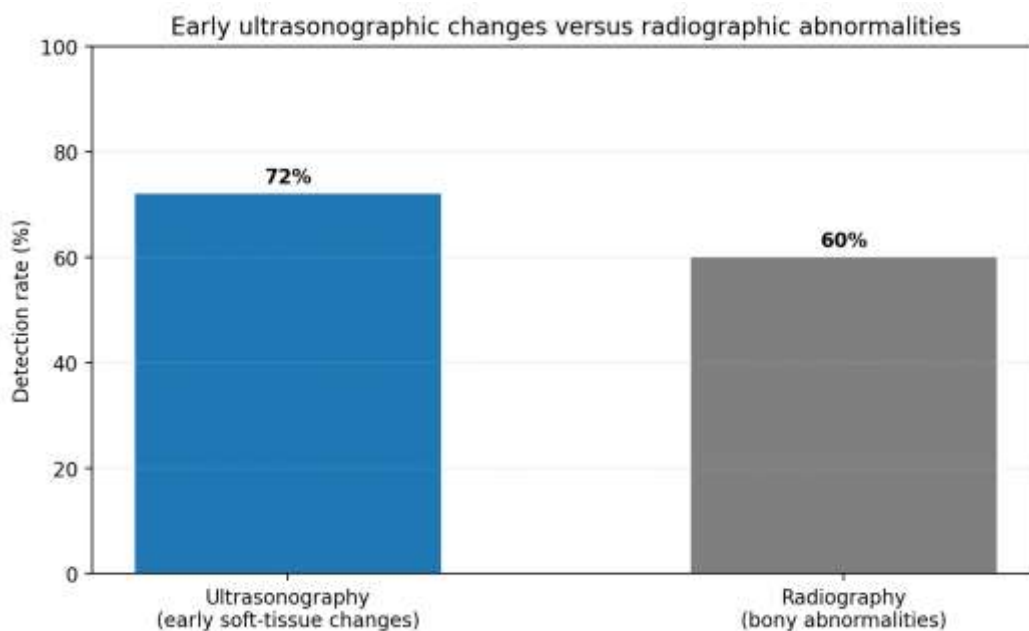
Figure 3. Yearly distribution of main ultrasonographic findings.



4.4 Ultrasonography compared with radiography

Early ultrasonographic inflammatory changes were reported in 72% of dogs before radiographic abnormalities were evident. In contrast, radiographic changes such as joint-space alteration and osteophyte formation were reported in 60% of cases. These findings support the clinical role of ultrasonography in detecting soft-tissue inflammation before advanced bony changes become visible. However, because the paired dog-level radiographic and ultrasonographic results were not provided, this comparison should be considered descriptive rather than a formal sensitivity analysis.

Figure 4. Early ultrasonographic changes versus radiographic abnormalities.



4.5 Representative clinical cases

Case	Signalment	Main imaging findings	Clinical interpretation
Case 1: early ultrasonographic detection	Dog ID 07; age 5 years	Mild synovial thickening and increased Doppler vascularity; radiographs initially normal.	Radiographic joint-space narrowing became visible during follow-up.
Case 2: advanced degenerative arthritis	Dog ID 12; age 12 years	Marked cartilage irregularity, synovial thickening, effusion, and radiographic osteophytes.	Long-term analgesia, weight management, and joint-support therapy were recommended.
Case 3: rapid progression in an overweight dog	Dog ID 21; age 12 years	Severe synovial inflammation and moderate-to-marked effusion at early follow-up.	Within one year, cartilage deterioration and osteophyte formation became more evident.
Case 4: slower progression in a younger dog	Dog ID 26; age 5 years	Mild effusion and minor synovial thickening without initial radiographic abnormality.	Clinical stability was maintained with weight control and joint-support treatment.

4.6 Sonographic follow-up pattern of the stifle joint

A representative stifle-joint follow-up showed an early-to-moderate arthritic pattern characterized by synovial effusion, synovial membrane thickening, and mild surrounding soft tissue changes without advanced bony erosion at the first examination. After three weeks, a longitudinal suprapatellar view showed a hyperechoic region in the suprapatellar bursa, nearly anechoic effusion, mild uneven articular cartilage thickening, preserved joint space, and increased synovial thickness medially. At two months, the medial and anteromedial joint spaces showed persistent effusion, thickened cartilage, hyperechoic change within the infrapatellar fat pad, early osteophyte development, and mild irregular synovial thickening. At three months, transverse ultrasonography of the flexed stifle showed loss of the normal hypoechoic cartilage pattern, thickened synovium, an anechoic effusion pocket, focal echogenic material within the joint space, and irregular cartilage consistent with progressive degenerative change.

Figure 5. Longitudinal ultrasonographic image demonstrating mild synovial membrane thickening with moderate anechoic joint effusion, consistent with early inflammatory arthritis.

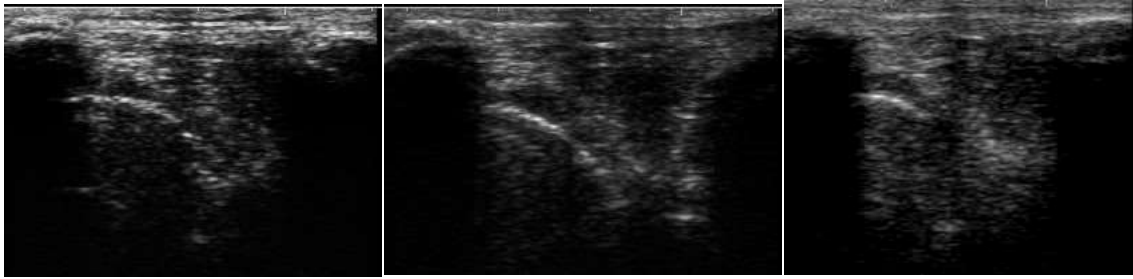


Figure 6. Ultrasonographic image showing progressive synovial hypertrophy with early cartilage surface irregularity.

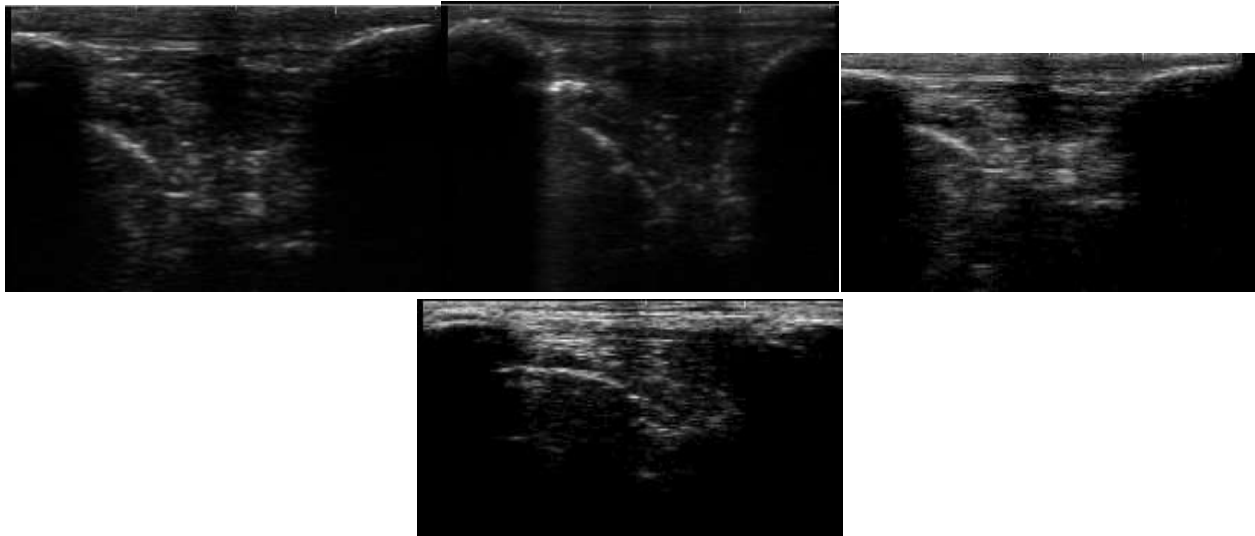


Figure 7. Color Doppler image demonstrating increased synovial vascularity indicating active inflammation (use only if Doppler image is present).

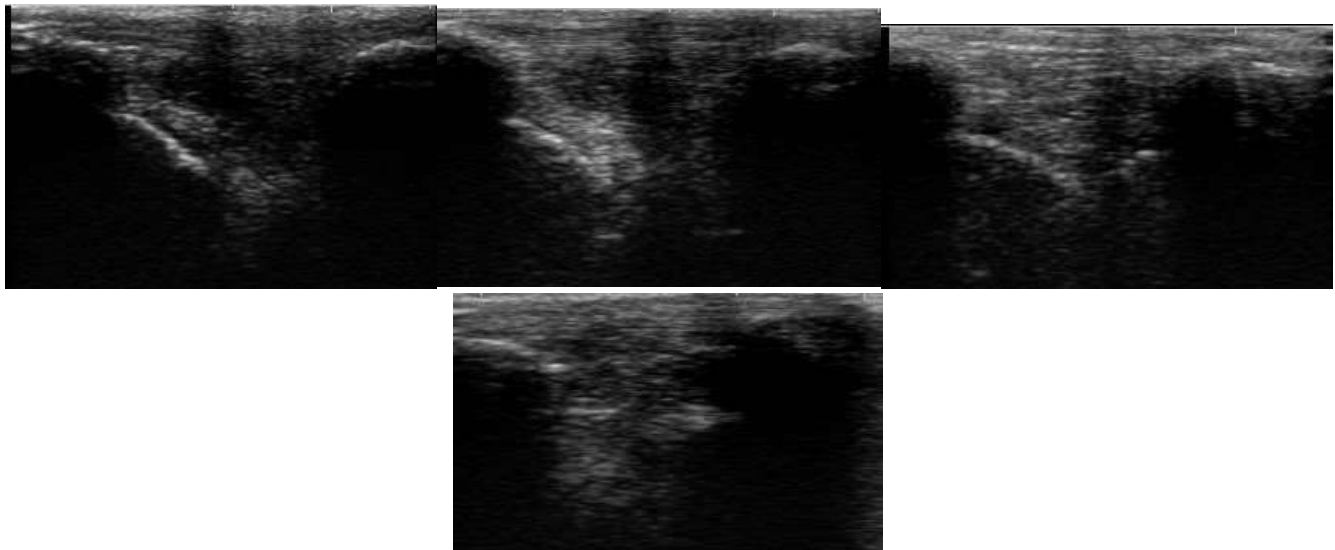


Figure 7. Sonographic evidence of marginal osteophyte formation and irregular cartilage contour compatible with chronic osteoarthritis.

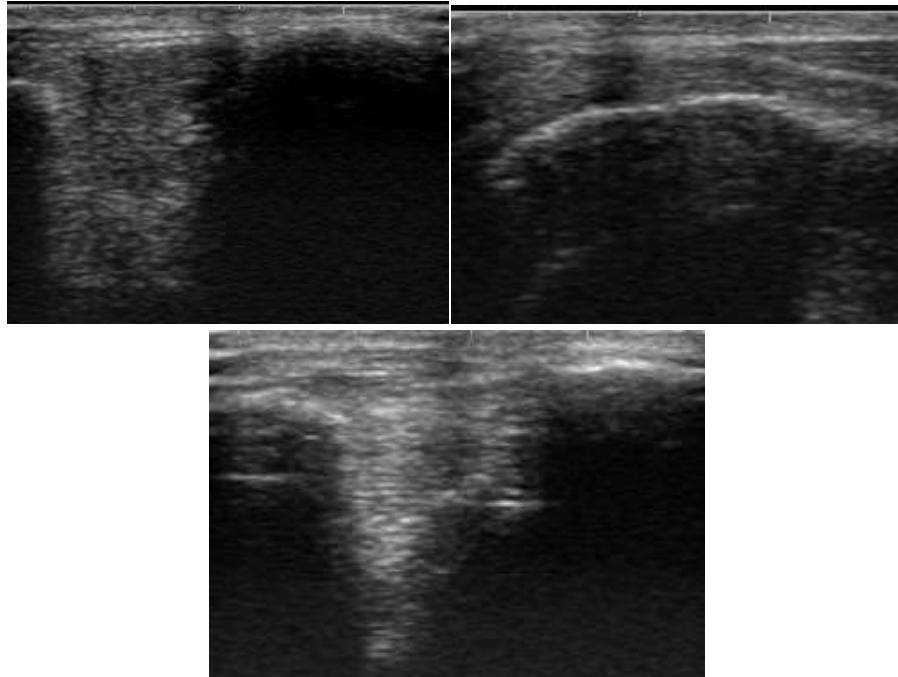


Figure 8. Advanced degenerative joint disease characterized by marked synovial thickening, cartilage irregularity, and extensive joint effusion with osteophyte formation.



Figure 9. Follow-up ultrasonographic examination demonstrating reduction of joint effusion after treatment with persistent synovial thickening.

5. Discussion

This revised case series indicates that ultrasonography can identify clinically relevant soft-tissue and inflammatory changes in dogs with suspected arthritis. Synovial inflammation, Doppler hypervascularity, and joint effusion were the most frequent findings, whereas cartilage erosion was less frequent and likely reflected more advanced or progressive disease. These observations are consistent with the practical value of ultrasonography for early evaluation of superficial joints, especially when radiographs do not yet show advanced bony remodeling.

The comparison with radiography should be interpreted carefully. Radiography remains essential for detecting osteophytes, subchondral bone changes, fractures, luxation, and advanced degenerative remodeling. Ultrasonography, by contrast, is better suited to assessing synovial structures, effusion, accessible cartilage surfaces, periarticular soft tissues, and Doppler vascularity. Therefore, the two modalities are complementary rather than mutually exclusive. In clinical practice, radiography can provide a structural overview, while ultrasonography can improve early inflammatory assessment and guide follow-up.

The age profile of this case series also supports the known importance of age in canine arthritis. Nearly half of the dogs were nine years or older, and older dogs were described clinically as showing more pronounced cartilage degradation and effusion. Increased body weight and larger breed size were also identified in the clinical summaries as factors associated with faster progression, which agrees with current knowledge that mechanical loading, joint instability, and breed-associated skeletal conformation contribute to degenerative joint disease.

The genetic context is important for interpretation. Breed-associated developmental disorders such as hip dysplasia and elbow dysplasia predispose dogs to secondary osteoarthritis, and genome-wide studies have shown that hip dysplasia and osteoarthritis can be regulated by partly distinct genetic mechanisms. Cartilage-matrix genes, including COL2A1 and ACAN, may influence cartilage resilience and susceptibility to degeneration. Although this study did not perform genotyping, the observed variation in progression among dogs of similar age suggests that future work should integrate breed records and candidate-gene or genome-wide screening with serial imaging.

The microbiological context should also be considered. Septic arthritis can present with effusion, synovial thickening, pain, and lameness, and it may be difficult to exclude on imaging alone. Synovial fluid culture remains clinically important, although culture-negative cases may occur; molecular testing such as 16S rRNA PCR may be helpful in selected cases. Beyond overt infection, the gut-joint axis has become an emerging area of interest in both human and veterinary osteoarthritis research. Obesity, gut dysbiosis, intestinal permeability, and systemic inflammatory mediators may influence joint inflammation and pain. The rapidly progressive overweight case in this series is compatible with the need to investigate metabolic and microbiome-related pathways, although no direct microbiome data were available here.

A major strength of this work is its longitudinal clinical perspective and the use of serial ultrasonographic follow-up. However, several limitations must be addressed before submission to a high-impact journal. The study is limited by the small sample size, retrospective design, absence of a healthy control group, lack of standardized pain and lameness scoring, absence of exact paired ultrasonographic and radiographic raw data, and lack of direct genetic or microbiological testing. Future prospective studies should include standardized case definitions, blinded image interpretation, repeated-measures statistical

modeling, synovial fluid cytology and culture, 16S rRNA PCR where indicated, fecal microbiome profiling, and genetic or breed-risk analysis.

6. Conclusion

Ultrasonography was useful for detecting early synovial inflammation, effusion, Doppler vascularity, and accessible cartilage abnormalities in dogs with clinical signs of arthritis.

Radiography remains important for bony and advanced degenerative changes, but ultrasonography provides complementary information on early soft-tissue pathology.

Serial ultrasonographic monitoring may support earlier intervention, including analgesia, anti-inflammatory therapy, physiotherapy, joint-support supplements, and weight management.

Age, body weight, and breed-related predisposition should be included in future predictive models of canine arthritis progression.

Direct genetic screening and microbiological or microbiome testing are required before claims can be made about genetic or microbial causation in this clinical population.

7. Required Improvements Before Submission to a Scopus-Indexed Journal

Prepare a complete dog-level dataset including dog ID, breed, sex, neuter status, age, body weight, body-condition score, affected joint, clinical score, radiographic score, ultrasonographic score, treatment, and follow-up duration.

Use standardized ultrasonographic scoring for synovial thickness, effusion depth, cartilage irregularity, osteophytes, and Doppler vascularity.

Have images reviewed by at least two blinded observers and report interobserver agreement using Cohen's kappa or intraclass correlation coefficients.

Use McNemar's test for paired ultrasonography-versus-radiography detection data and regression or mixed-effects models for progression analysis.

Add ethical approval number and owner consent statement.

Replace rounded counts with exact raw counts and report exact P-values and 95% confidence intervals.

If the title includes genetic or microbiological assessment, perform direct testing; otherwise, keep these as contextual discussion only.

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