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Research article
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Articular changes in patellar luxation afflicted canine stifle joints

P. Sharma,[1]* A. Anand,[1] V. Sangwan[1]

[1]Department of Veterinary Surgery and Radiology, College of Veterinary Science
Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India, 141004

ABSTRACT: Patellar luxation alters the alignment of the stifle joint and predisposes affected stifles to articular and peri-articular changes that may progress to secondary osteoarthritis. This study documented the radiographic and intra-operative macroscopic alterations in 14 stifle joints of dogs with Grades 2–4 patellar luxation and evaluated the prognostic value of radiographic scoring in relation to postoperative functional outcomes. Radiographic lesions were scored at ten predetermined points, and a scoring system was used to determine the correlation between luxation grade and radiographic lesions. The prevalence of articular cartilage erosions in different subdivisions was recorded. Functional outcomes were graded postoperatively and correlated with preoperative radiographic severity using Spearman rank correlation. Radiographically, distal patella was the most common site of osteophytosis or lytic change (86%), and pseudo- or flat trochlear grooves were frequently observed in higher luxation grades. Intra-operatively, articular cartilage erosions were present in 57% of stifles, most often affecting the distal patella and lateral trochlear surfaces. Radiographic scores increased significantly with luxation grade (ANOVA, $p < 0.05$). A strong negative correlation was detected between radiographic severity and functional recovery ($\rho = -0.73$, $p = 0.003$), indicating that higher preoperative radiographic scores predicted poorer postoperative outcomes. These findings support the use of radiographic scoring as an objective prognostic indicator to guide clinical decision-making, case management, and client counselling in dogs with patellar luxation.

Keyword: Dogs; patellar luxation; radiography; osteoarthritis; surgery

Correspondence author:
P. Sharma
Department of Veterinary Surgery and Radiology, College of Veterinary Science Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India, 141004
E-mail address: palkhisharma28@gmail.com

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INTRODUCTION

Patellar luxation (PL) is a common orthopaedic disorder causing pelvic limb lameness in canines (Ness et al., 1996). It is reported to have a 1.3% (O'Neill et al., 2016) to 9.2% (Bosio et al., 2017) prevalence amongst canine orthopaedic conditions. The condition is most frequently observed in small-breed dogs, particularly Chihuahuas, Poodles, Pomeranians, Maltese, and Bull Terriers. Medial patellar luxation (MPL) occurs more often in small breed dogs (Alam et al., 2011). PL is usually considered a developmental disorder with a complex aetiology, however congenital and traumatic factors are the two most common pathophysiological processes associated with PL in dogs (L'Eplattenier and Montavon, 2002). It is also considered a predisposing factor for the development of secondary osteoarthritis, which can be diagnosed radiographically and confirmed intraoperatively (Jahrupatrakorn, 2017). The present study is based on the hypothesis that displacement of the patella outside the trochlear groove could lead to structural changes in the stifle joint, which can be detected radiographically and observed macroscopically during corrective surgery. Additionally the study aims to evaluate whether radiographic scoring can serve as a useful prognostic tool by correlating preoperative radiographic severity with postoperative functional outcomes.

MATERIALS AND METHODS

The prospective study included 14 stifle joints of dogs affected with Grades 2, 3, or 4 of PL presented in a period of one year (March 2024 - February 2025) at the Teaching Veterinary Hospital. This clinical research study was duly approved by the Institutional Animal Ethics Committee (IAEC) and the Committee for Control and Supervision of Experiments on Animals (CCSEA) (GADVASU/2024/IAEC/71/05).

The signalment and clinical presentation was noted and the dogs were categorized into three groups depending upon the grade of PL as per Putnam's grading (Putnam, 1968) of PL, modified by Singleton (Singleton, 1969).

All dogs were subjected to cranio-caudal, lateral and skyline radiographic views of the stifle joint using a Wipro GE Dx300 radiography machine and Specialized Master View Dx software, followed by surgical management. All stifles underwent a standardized surgical correction, including abrasion trochleosulcoplasty, retinacular imbrication sutures, and anti-rotational sutures. One case of concurrent cranial cruciate ligament rupture was repaired by extracapsular suture stabilization. Dogs with higher preoperative radiographic scores (Groups II-III) received adjunctive joint-support medications such as chondroprotective agents to aid recovery. The data collected in this study were organised into the following assessment components:

Radiographic assessment

Stifle radiographs were evaluated and changes were recorded. The radiographic appearance of trochlea in skyline view was classified using three study-defined descriptive categories, based upon the visual appearance of groove depth and contour:

- Shallow groove: A trochlear groove that is present but reduced in depth, with mild flattening of the trochlear ridges.
- Flat groove: A markedly reduced or nearly absent trochlear depression, resulting in minimal concavity and poor patellar engagement.
- Pseudo-trochlear groove: An apparent "groove" created by chronic luxation or periarticular bone remodeling, giving the impression of a sulcus despite lacking true anatomical depth.

Radiographic scoring

A scoring system was applied based on the presence of osteophyte formation, cartilage erosive lesions or subchondral sclerosis at ten predefined anatomical points; six on lateral view [proximal patella (PPa), distal patella (DPa), proximal trochlear sulcus (PTS), distal trochlear sulcus (DTS), cranial tibial plateau (CrTP), caudal tibial plateau (CdTP)] and four on cranio-caudal view [Lateral femoral condyle (LFC), medial femoral condyle (MFC), lateral tibial condyle (LTC), Medial tibial condyle (MTC)]. Each site was graded from 0 to 3.

- 0=no osteophyte formation (±subchondral sclerosis),
- 1=mild osteophyte formation (±subchondral sclerosis),
- 2= moderate osteophyte formation and
- 3=severe osteophyte formation (±subchondral sclerosis).

A maximum score of 30 was assigned to each stifle affected with PL (Frost-Christensen et al., 2008; Wessely et al., 2017). Mean radiographic scores were compared between groups using one way ANOVA with a 95% confidence interval.

Lesion frequency distribution

The frequency distribution of radiographic lesion at each assessment site was recorded and summarized.

Gross, macroscopic assessment
Intraoperative gross alterations were recorded. The frequency of articular cartilage erosive lesions was recorded and their distribution across six anatomical subdivisions of stifle were assessed.

Functional outcome assessment
Post-operative functional recovery was evaluated using a combination of clinician assessment and owner-reported observations during follow-up. Functional outcomes were graded as Excellent, Good, Fair, or Poor based on limb use, gait, pain, and overall activity. For correlation analysis, these categorical outcomes were numerically coded (Excellent = 4, Good = 3, Fair = 2, Poor = 1).

Statistical Analysis
Descriptive statistics were calculated for radiographic scores and functional outcomes. To assess the relationship between preoperative radiographic severity and postoperative functional recovery, Spearman rank correlation was performed. Ranks were assigned to both radiographic scores and numerically coded functional outcomes using standard ranking methods, with tied values receiving average ranks. The Spearman correlation coefficient (ρ) and corresponding p-value were calculated to quantify the strength and significance of the association. A negative ρ indicates that higher radiographic scores were associated with poorer functional recovery. Statistical analyses were performed using GraphPad Prism 6 (PISM® ver. 6.01, GraphPad, Inc.) and Microsoft Excel.

RESULTS

A total of 14 stifle joints from 12 dogs (6 males and 6 females) were evaluated. Eight stifles were affected with lateral PL and six with medial PL. Distribution by grading showed that 5 stifles (36%) had Grade 2 luxation (Group I), another 5 stifles (36%) had Grade 3 (Group II), and 4 stifles (28%) had Grade 4 luxation (Group III). The mean age and body weight did not differ significantly among the groups. The age ranged between 5-42 months.The median ages for the Groups I, II, and III being 24, 11, and 18 months respectively. The body weight ranged between 3–40 kg with the medians of 4.9, 13 and 8.3 kg for Groups I, II and III respectively. The Pomeranian was the most frequently affected breed (50%) followed by single cases of Labrador, Golden retrievers, Cane Corso, Pug, and Shih Tzu. Similar chronicity of the condition was observed among all three groups.

Radiographic assessment
The skyline view was confirmatory for diagnosing PL (8 lateral and 6 medial luxation). The radiographic appearance of the trochlear groove in skyline view is summarised in Table 1 with representative images provided in Figure 1.

Group I: Most stifles (80%) had a shallow groove with one showing a flat groove.
Group II: Stifles presented with a shallow groove (40%), pseudo-trochlear groove (40%) and flat groove (20%).
Group III: Most stifles (75%) exhibited a flat groove while one showed pseudo-trochlear groove (Fig. 1).

On the medio-lateral view, mild to moderate osteophytosis was visible in five of the 14 stifles. Erosions and lytic lesions at the caudal pole of the patella were detected in two stifles (14%) of Group II. Mild angulation of the distal femur was identified in one stifle (21%) from each group. Displacement of the patella was evident in two cases from Group II and three cases from Group III on the medio-lateral view (Fig. 2C). In one case from Group II, the tibia was positioned cranial to the femur, accompanied by mild stifle joint effusions – findings consistent with cranial cruciate ligament rupture. One stifle joint in Group III, exhibited thickening or mild ossification of the periarticular soft tissue along with patellar displacement.

The cranio-caudal view revealed medial or lateral luxation in ten of the fourteen cases (71.43%). However, accurate positioning of the patient was critical for obtaining a diagnostic ventrodorsal pelvic

Table 1. Radiographic evaluation of the trochlear groove in skyline view

Radiographic appearance of trochlear groove	Groups		
	Group I (Grade 2 PL)	Group II (Grade 3 PL)	Group III (Grade 4 PL)
Shallow groove	4	2	-
Flat groove	1	1	3
Pseudo-trochlear groove	-	2	1
Total	5	5	4

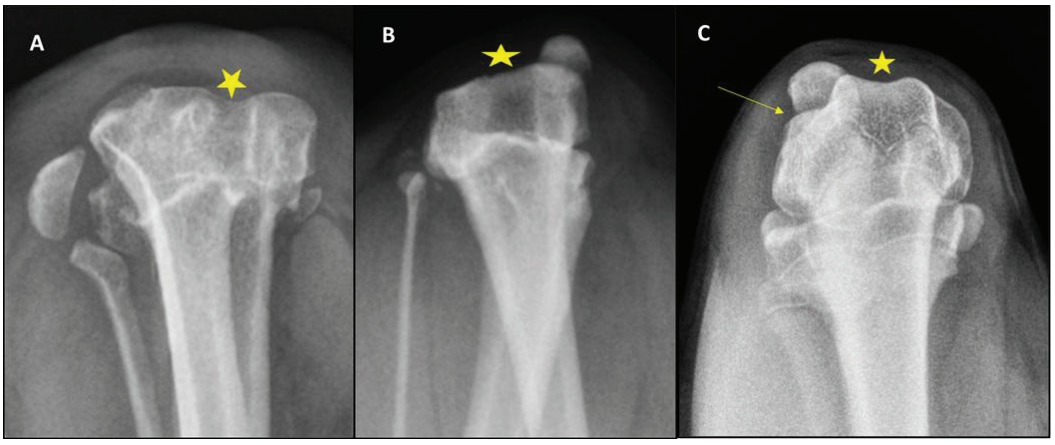

Figure 1. Skyline radiographic views of patellar luxation affected stifle joints: (A) Shallow trochlear groove (B) Flat trochlea (C) Pseudo-trochlear groove (yellow arrow) and a normal trochlear groove (yellow star).

view (Marino and Loughin, 2010). Enthesophytes or joint mice were observed in 2 stifles (Fig. 2A), one each from Groups I and III. Three stifle joints of Group II exhibited lytic lesions and subchondral bone exposure on the femoral condyles (Figure 2D).

Radiographic scoring (Table 2)

The radiographic score was assigned to each case out of 30. Group III recorded the highest mean radiographic score, followed by Group II, while Group I recorded the lowest. A statistically significant difference was observed between Groups I and III at the 5% level.

Frequency of radiographic lesion at different assessment points

The highest frequency (80%) of osteophyte formation was observed at DPa followed by the LTC and MFC. There was no osteophyte formation recorded at the proximal pole of patella in any case. The frequency of radiographic lesions at different stifle joint landmarks on cranio-caudal and medio-lateral views is presented in Table 3. Representative examples of these lesions are shown in Figure 3.

Gross macroscopic alterations observed intra-operatively

A shallow trochlear groove was present in all stifles, flat in five (35.71%), pseudo-trochlear groove in three cases (21.43%) and completely deformed trochlea in two stifles. Osteophyte formations were observed on the femoral groove and the distal aspect of patella in seven stifles (50%), with mild osteophytosis in four stifles and moderate to severe in three.

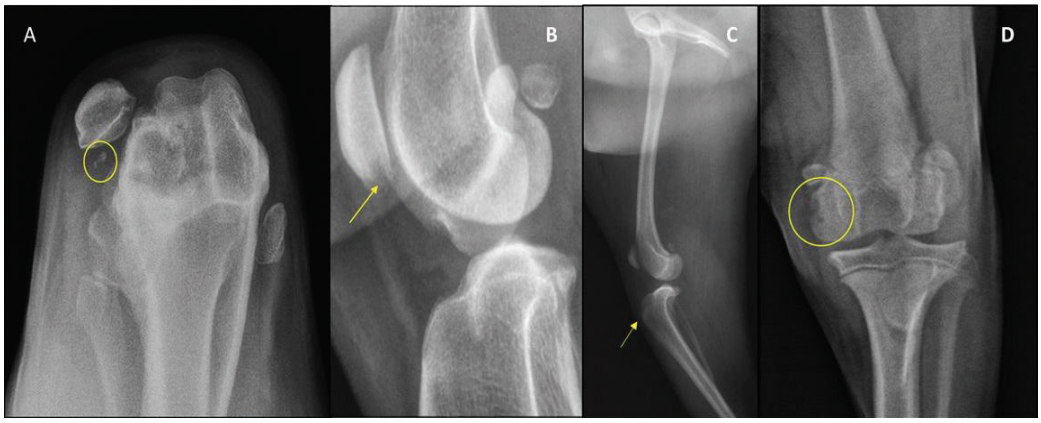

Figure 2. Radiographs in various views showing stifle joint changes due to patellar luxation; (A) Skyline view with joint mice (yellow circle), (B) Lateral view with lytic lesion on the distal aspect of patella (yellow arrow), (C) lateral view with cranial displacement of tibia, indicating cranial cruciate ligament rupture, (D) Cranio-caudal view with subchondral sclerosis and erosive lesion in medial femoral condyle (yellow circle).

Table 2. Mean ± SE pre-operative radiographic score of dogs with PL

Groups	Mean ± SE (Range)	Median
Group I	2.8 ± 0.58[a] (1 – 4)	3
Group II	5.8 ± 1.2[ab] (3 – 9)	7
Group III	7.25 ± 0.85[b] (5 – 9)	7.5
Total	5.14 ± 0.70 (1 – 9)	4.5

{SE = Standard Error of the mean. Groups with different superscript letters (a, b) differ significantly at $p < 0.05$ (one-way ANOVA).}

Thickening of the joint capsule was recorded in six stifles (43%).Cartilage erosions were identified in eight stifles (57%) (Table 4).

Two stifles exhibited a single erosive site, while the other six had multiple erosive lesions. The distal patellar and lateral trochlear surfaces were the most commonly affected sites each in four stifles (29%). The proximal patella and femoral groove showed erosions in three stifles each (21%), while medial trochlear surfaces and central patellar surfaces showed the lowest prevalence, being affected in two stifles (14%) and one stifle (7%) respectively (Table 5). The gross macroscopic erosive lesions observed intra-operatively (Fig. 4) were highly comparable to the radiographic lesions described previously.

Functional outcome

All the stifles in Group I (n=5) achieved 'excellent' functional recovery. Four stifles in Group II (n=5)

Table 3. The frequency of radiographic lesions in the stifle joints of dogs affected with PL in medio-lateral and cranio-caudal views

	Medio-lateral view (n = 14)						Cranio-caudal view (n = 14)			
Groups	**PPa**	**DPa**	**PTS**	**DTS**	**CrTP**	**CdTP**	**LFC**	**MFC**	**LTC**	**MTC**
Group I (n = 5)	0% (0/5)	80% (4/5)	20% (1/5)	20% (1/5)	40% (2/5)	20% (1/5)	0% (0/5)	40% (2/5)	60% (3/5)	0% (0/5)
Group II (n = 5)	0% (0/5)	80% (4/5)	40% (2/5)	20% (1/5)	20% (1/5)	80% (4/5)	60% (3/5)	80% (4/5)	80% (4/5)	20% (1/5)
Group III (n = 4)	0% (0/4)	100% (4/4)	100% (4/4)	75% (3/4)	50% (2/4)	50% (2/4)	100% (4/4)	75% (3/4)	50% (2/4)	25% (1/4)
Total	**0% (0/14)**	**86% (12/14)**	**50% (7/14)**	**36% (5/14)**	**36% (5/14)**	**50% (7/14)**	**50% (7/14)**	**64% (9/14)**	**64% (9/14)**	**14% (2/14)**

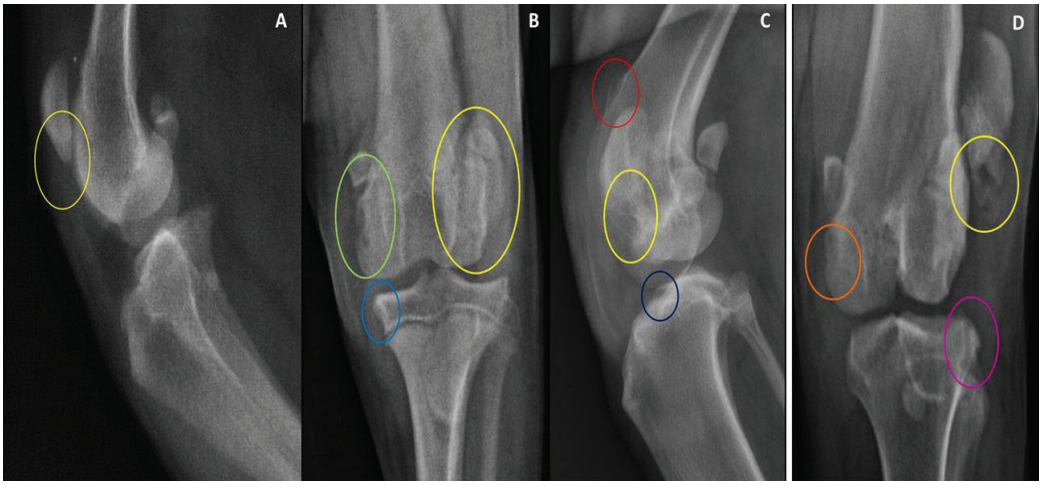

Figure 3. Radiographs in various views showing site of stifle joint changes due to patellar luxation; (A) Distal patella, (B) Lateral femoral condyle (yellow ellipse), Medial femoral condyle (green ellipse), & Medial tibial condyle (blue ellipse), (C) Proximal trochlear sulcus (red ellipse), Distal trochlear sulcus (yellow ellipse), Caudal tibial plateau (blue ellipse), (D) Medial femoral condyle (orange ellipse), Lateral tibial condyle (purple ellipse), distal patella (yellow ellipse).

Table 4. Frequency of intraoperative findings of stifles affected with PL

Intra-operative findings		Frequency of cases	
		Number	%
Shallow trochlear groove		6	42.85%
Flat trochlear groove		5	35.71%
Pseudo-trochlear groove		3	21.43%
Completely deformed trochlea		2	14.28%
Osteophyte formation	Mild osteophytosis	4	28.57%
	Moderate osteophytosis	3	21.43%
Thickened joint capsule		6	42.85%
Articular cartilage erosions		8	57.14%

Table 5. Frequency distribution of stifles showing cartilage erosions at different sub-divisions of the stifle joint.

Groups	Distal patella	Proximal patella	Center of patella	Medial trochlea	Lateral trochlea	Femoral groove
I (n=5)	0% (0)	20% (1)	0% (0)	0% (0)	0% (0)	20% (1)
II (n=5)	40% (2)	20% (1)	0% (0)	40% (2)	40% (2)	0% (0)
III (n=4)	50% (2)	25% (1)	25% (1)	0% (0)	50% (2)	50% (2)
Total	29% (4)	21% (3)	7% (1)	14% (2)	29% (4)	21% (3)

{Values represent the percentage of affected stifles within each group (n given per group), with the number of affected stifles in parentheses. Percentage in all rows (Groups I-III and Total) were calculated as (number of stifles with erosions at a given site ÷ **total number of stifles in that group, or in all groups for the Total row). Overall, n = 14 stifles}**

had excellent recovery while one stifle had 'good'. In Group III (n=4), one stifle achieved 'good' outcome, two had 'fair' and one had 'poor' outcome (Table 6).

Correlation between radiographic severity and functional outcome

Spearman rank correlation analysis demonstrated a significant negative correlation between preoperative radiographic scores and postoperative functional outcome ($\rho = -0.73$, $p = 0.003$).

DISCUSSION

Radiography is a valuable ancillary diagnostic tool for evaluating PL utilizing cranio-caudal, lateral and skyline views. The cranio-caudal and lateral projections provide useful information on patellar position, trochlear morphology, and secondary degenerative changes. The skyline view is particularly useful for assessing the depth of trochlear groove distinguishing between normal and shallow conformations (Marino and Loughin, 2010). Radiographic features of osteoarthritis in the canine stifle joint include osteophyte formation, joint effusions, narrowed joint space, enthesophyte development, and subchondral sclerosis (Morgan, 1968; Bennett et al., 1988).

A clear trend emerged in our results, with radiographic severity increasing progressively with the grade of luxation. Group III stifles consistently exhibited flat or pseudo-trochlear grooves and the highest radiographic scores. Although Jahrupatrakorn (2017) reported no significant difference in radiographic scores between normal dogs and those with MPL, our findings demonstrate that within clinically affected animals, higher luxation grades were associated with more pronounced radiographic degeneration. Distal patella was the most common site of osteophytosis in our study, consistent with reports that distal patellar and trochlear surfaces experience abnormal mechanical loading during patellar displacement and hence, an increased extent of cartilage erosions. The absence of osteophytes at the proximal patella in our cases also aligns with previously published patterns of lesion distribution (Jahrupatrakorn, 2017; Kim et al., 2024).

Intra-operative observations supported the radiographic findings. Articular cartilage erosions were present in 57% of stifles, comparable to previous reports (Daems et al., 2009; Kim et al., 2024). The distal patella and lateral trochlea were the most frequently affected surfaces, in agreement with earli-

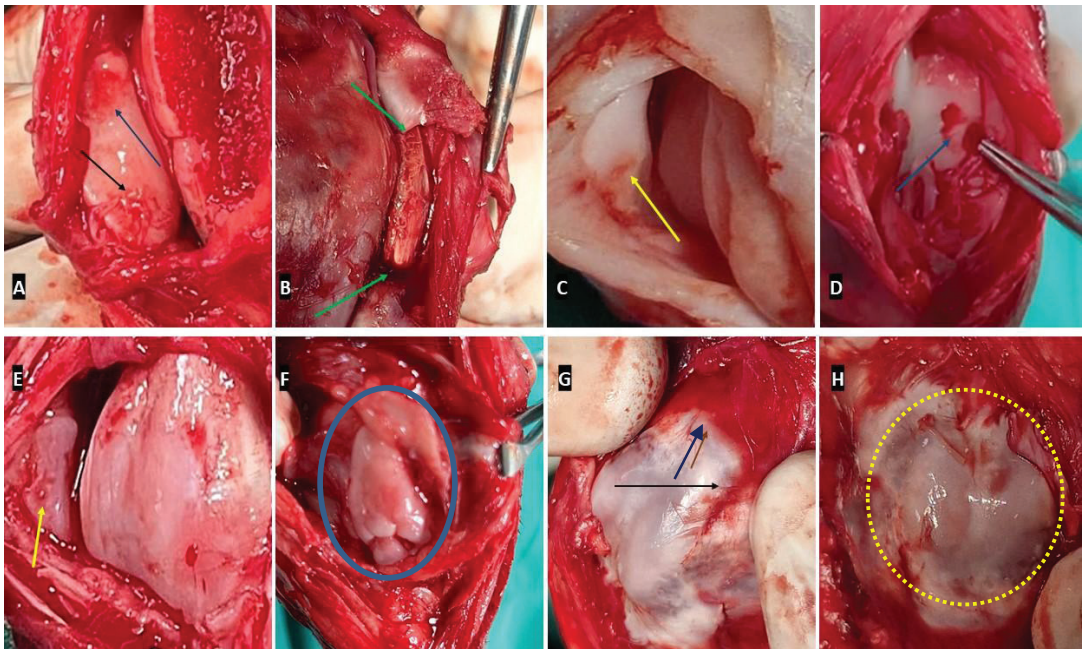

Figure 4. Gross, macroscopic intra-operative alterations; **(**A) Erosive lesion at proximal (blue arrow) and distal patella (black arrow) (B) Eroded proximal and distal patellar edges (green arrow) (C) Erosion at distal patella (yellow arrow) (D) Erosion at lateral femoral trochlea (Blue arrow) (E) Articular cartilage erosive lesion at center of patella (yellow arrow) (F) Osteophytosis at femoral groove (blue circle) (G) Erosion (black arrow) and neovascularisation (blue arrow) at proximo-lateral trochlea (H) Flat, deformed trochlear groove (yellow, dotted circle).

Table 6. Functional outcome of surgically operated stifles

Groups	Excellent	Good	Fair	Poor
I (n=5)	5 (100%)	0 (0%)	0 (0%)	0 (0%)
II (n=5)	4 (80%)	1 (20%)	0 (0%)	0 (0%)
III (n=4)	0 (0%)	1 (25%)	2 (50%)	1 (25%)
Total (n=14)	9 (64.28%)	2 (14.29%)	2 (14.29%)	1 (7.14%)

er studies identifying these regions as particularly susceptible to wear in patellar luxation. Variations in erosive lesion distribution between medial and lateral patellar luxation have been described previously (Lara et al., 2018). The close correspondence between radiographic abnormalities and intra-operative changes reinforces the usefulness of radiographs in anticipating the extent of joint pathology.

A key outcome of this study was the significant negative correlation between radiographic score and postoperative functional recovery. Stifles with higher radiographic scores had less favourable functional outcomes, despite receiving similar surgical procedures. This supports the prognostic value of radiographic scoring, indicating that radiographic severity may reflect the extent of irreversible cartilage and peri-articular damage, which in turn influences postoperative recovery potential. Such an association highlights the clinical relevance of radiographic evaluation in treatment planning and in counselling dog owners regarding expected recovery.

Although radiography remains the most accessible imaging tool for evaluating patellar luxation, it has recognised limitations when compared with advanced modalities such as CT or MRI. Radiographs provide excellent information on bony alignment, trochlear morphology, and osteophytic changes, but they are less sensitive for detecting early cartilage degeneration, subtle subchondral defects, and soft-tissue abnormalities such as retinacular thickening or periarticular fibrosis. CT offers greater anatomical detail and has been shown useful for

assessing stifle alignment and postoperative changes in patellar luxation, including confirmation of trochlear deepening and improved quadriceps alignment after surgery (Marino and Loughin, 2010).

Despite these limitations, the radiographic changes documented in this study had direct clinical relevance. Identifying marked osteophytosis, pseudo-trochlear grooves, or subchondral lysis may prompt earlier surgical intervention rather than conservative management, particularly in dogs with progressive luxation. Radiographic severity also helped guide postoperative care in this study, as dogs with higher preoperative scores received adjunctive joint-support medications. Finally, recognising the extent of preoperative degeneration allows clinicians to provide more accurate prognostic counselling, especially in cases where advanced osteoarthritic changes may limit functional recovery.

Functional outcomes in this study were assessed using clinician evaluation and owner feedback. Although subjective, this method reflects real-world clinical practice in client-owned dogs and is commonly reported in veterinary orthopaedic literature. Future studies incorporating objective tools such as gait analysis or force-plate measurements would help validate and strengthen the prognostic ability of radiographic scoring.

Overall, the results demonstrate that radiographic scoring provides meaningful insight into both disease severity and expected functional recovery, supporting its use as a practical and objective prognostic indicator in dogs with patellar luxation.

CONCLUSIONS

This study reports the radiographic and macroscopic changes associated with PL in canine stifles. Distal patella was the most frequent site of osteophyte formation or lytic changes. Pseudo-trochlear groove formation, evident both radiographically and intra-operatively was observed in three affected stifles. Higher grades of luxation were significantly associated with higher radiographic scores and articular cartilage erosive lesions were present in 57% of affected stifles, with distal patella and lateral trochlea being the most frequently impacted sites. A strong negative correlation between radiographic score and postoperative functional outcome ($\rho = -0.73$, $p = 0.003$) further demonstrated that greater radiographic severity is associated with less favourable recovery. These findings highlight the value of preoperative radiographic scoring as an objective indicator of stifle joint health and postoperative prognosis.

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Conflicts of interest

The authors have no conflicts of interest with anyone.

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