Radiographic Evaluation of the Femur and Tibia in Pomeranian Dogs with Medial Patellar Luxation: Insights into Angular Deformities and the Need for Breed-Specific Reference Values

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ABSTRACT

Medial Patellar Luxation (MPL) is highly prevalent in small breed dogs, including Pomeranians. Although radiographic evaluation guides surgical planning, the lack of breed-specific angular reference values for small dogs complicates the assessment of femoral and tibial deformities. This study aimed to radiographically evaluate femoral and tibial angles in Pomeranian dogs with varying grades of MPL and discuss the implications for establishing specific reference standards. Thirty-five pelvic limbs from 19 Pomeranian dogs were prospectively evaluated and categorized into MPL grades I (n=12), II (n=20), and III (n=3). Craniocaudal femoral radiographs and caudocranial/mediolateral tibial radiographs were obtained under sedation. Femoral angles (including ICA, FVA, aLPFA, aLDFA, mLPFA, mLDFA) and tibial angles (mMPTA, mMDTA, mCrPTA, mCrDTA, TPA) were measured using standardized techniques. Angles were compared between MPL grades using the Kruskal-Wallis test ($p<0.05$). The mean age of the dogs was 41.5 ± 26.3 months, and the mean weight was 4.3 kg ± 1.4 kg. Bilateral MPL was present in 84% of the dogs. A trend toward increased femoral angles with higher MPL grades was observed; however, only the mechanical lateral proximal femoral angle (mLPFA) showed a statistically significant difference ($p=0.046$) among the grades, being higher in Grade III compared to Grade I. No significant differences were found for other femoral angles or for any tibial angles between the groups. In conclusion, significant angular differences were not detected for most

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parameters between MPL grades I, II, and III in this Pomeranian cohort, except for mLPFA. These findings highlight the potential limitations of applying large-breed reference values to small breeds and underscore the need to establish breed-specific radiographic standards for femoral and tibial alignment in small dogs like Pomeranians. Such standards are essential for accurate deformity assessment and improved surgical planning for MPL.

Keywords: Angular deformities; Canine femur; Medial patellar luxation; Orthopedics; Radiography; Small breed dogs; Stifle joint

INTRODUCTION

Medial Patellar Luxation (MPL) is one of the most prevalent orthopedic conditions in small animal practice, primarily affecting small and toy breed dogs [1,2]. Among the most predisposed breeds, the Pomeranian stands out [3,4]. MPL is frequently bilateral and may manifest as intermittent or persistent lameness, significantly impacting the animal's quality of life [5,6]. The condition is believed to have a genetic component and is associated with congenital anatomical alterations, including angular and rotational deformities of the long bones of the pelvic limb, such as the femur and tibia, as well as misalignment of the extensor mechanism [7-9].

Conventional radiographic evaluation remains the primary diagnostic tool for identifying and quantifying these skeletal deformities, guiding surgical planning and prognostic assessment [1,10]. Several surgical techniques have been described for the treatment of MPL, aiming to realign the extensor mechanism and stabilize the patella within the femoral trochlea [7,11]. However, failure to accurately identify the underlying deformities can lead to unsatisfactory surgical outcomes and recurrences [6].

Previous studies have established reference values for various femoral and tibial angles in large-breed dogs, aiding in the identification of angular deviations and indications for corrective osteotomies [12,13]. However, these reference standards are not well defined for small-breed dogs, and the direct application of large-breed values may be inappropriate due to intrinsic conformational differences related to size [3,14]. Recent literature even explores advanced imaging techniques such as Computed Tomography (CT) and three-dimensional (3D) reconstructions for more precise measurements, particularly in complex or multiplanar deformities, reinforcing the need for breed- and size-specific parameters [15,16].

Despite the high frequency of MPL in small breeds, few studies have systematically quantified femoral and tibial angular deformities in specific populations such as Pomeranians [3]. The lack of specific reference values for these breeds complicates the interpretation of radiographic findings and clinical decision-making, especially in lower-grade cases (Grades I and II), where surgical indication may be controversial [17].

Given this scenario, the present study aimed to radiographically evaluate femoral and tibial angles in Pomeranian dogs diagnosed with varying grades of MPL. Additionally, it seeks to discuss the clinical relevance of these findings and highlight the need to establish breed-specific angular reference standards for small dogs. The initial hypothesis was that more severe angular deformities would be present in dogs with higher grades of MPL; however, the results alongside the existing literature suggest greater complexity and emphasize the urgent need to define what constitutes 'normal' in these patients, opening a new and necessary line of research in veterinary orthopedics.

MATERIALS AND METHODS

Study design and ethical approval

This prospective study was conducted at the Veterinary Hospital of the Federal University of Mato Grosso between 2022 and 2023. All procedures involving animals adhered to the ethical principles established by the Brazilian National Council for Animal Experimentation Control (CONCEA) and were approved by the Ethics Committee on the Use of Animals (CEUA) of the same institution under protocol number 23108.009863/2022-63. Written informed consent was obtained from all owners prior to inclusion of their dogs in the study.

Inclusion criteria and experimental groups

Pomeranian dogs (German Spitz), regardless of sex or age, diagnosed with Medial Patellar Luxation (MPL) through routine or specific orthopedic examination, were included. A total of 19 dogs corresponding to 35 pelvic limbs were evaluated. Limbs were classified and allocated into three groups according to MPL grade, based on the Singleton classification [18]:

- **Grade I:** Patella luxates manually with the stifle extended and reduces spontaneously.
- **Grade II:** Patella luxates during flexion or manual manipulation and remains luxated until extension manual reduction.
- **Grade III:** Patella remains continuously luxated but can be manually reduced.

Dogs with Grade IV MPL were excluded due to the potential difficulty in achieving accurate radiographic positioning and identifying anatomical landmarks, as previously discussed in the literature [19]. Dogs with prior surgery on the affected limb or with concomitant orthopedic conditions that could interfere with measurements were also excluded.

Pre-anesthetic evaluation and radiographic protocol

All animals underwent pre-anesthetic evaluation, including complete blood count, creatinine and alanine aminotransferase tests. Sedation was achieved using acepromazine (0.02 mg/kg SC) and methadone (0.035 mg/kg SC) administered at the Yintang acupoint, followed by induction and maintenance with propofol (1 mg/kg IV–5 mg/kg IV) as needed to ensure proper and motionless positioning.

Digital radiography equipment was used to obtain images. For femoral assessment in the frontal plane, craniocaudal projections were taken of each femur individually, with the dog seated and the femur parallel to the radiographic table. An image was considered adequate when femoral cortices were bisected by the fabellae, the lesser trochanter was partially visible medially, and the intercondylar lines were parallel [3,19].

For tibial assessment, caudocranial projections (frontal plane) were taken in sternal recumbency and mediolateral projections (sagittal plane) in dorsal recumbency. In the sagittal view, the stifle and tarsus were kept parallel to the radiographic film. The X-ray beam was centered on the mid-diaphysis of the bone in all projections. All images were reviewed immediately after acquisition to assess quality and positioning.

Radiographic measurements

Angular measurements were performed by a single experienced evaluator using specific software (Digimizer). In the frontal plane of the femur (craniocaudal projection), the following angles were measured.

Table 1. Medium and standard deviations, minimum and maximum values, and p-values of femoral alignment angles in Pomeranian dogs affected by medial patellar luxation.

-	-	Grade I	Grade II	Grade III	p-value
Femur	aLPFA (°)	111.0 ± 7.1	112.0 ± 7.1	121.6 ± 5.7	0.1
		(100.1-125.8)	(99.7-128.4)	(116.8-127.9)	
	aLDFA (°)	95.2 ± 2.8	96.1 ± 2.7	96.9 ± 3.6	0.639
		(90.3-99.6)	(90-102)	(94-101)	
	mLPFA (°)	107.1 ± 7.1	109.5 ± 7.1	120.1 ± 7.2	0.046
		(94.8-123.2)	(95.5-126.1)	(113.2-127.5)	
	mLDFA (°)	99.0 ± 3.0	98.7 ± 2.5	99.9 ± 1.5	0.665
		(96.5-103.9)	(94.1-103.4)	(98.4-101.3)	
	FVA (°)	5.3 ± 2.6	5.7 ± 2.6	6.4 ± 4.4	0.902
		(1.5-9.6)	(0.7-12)	(2.3-11)	
	ICA (°)	131.0 ± 6.0	128.2 ± 6.8	123.7 ± 3.4	0.162
		(104.1-138.7)	(111.1-140.6)	(120-126.7)	
Tibia	mMPTA (°)	93.8 ± 1.4	94.6 ± 1.9	95.7 ± 1.5	0.188
		(91.2-96.3)	(91-98.8)	(94.4-97.3)	
	mMDTA (°)	96.9 ± 2.1	96.7 ± 2.8	97.8 ± 2.1	0.553
		(94.4-100.8)	(93.2-104.7)	(95.9-100.1)	
	mCrPTA (°)	111.4 ± 3.7	111.8 ± 3.7	109.9 ± 2.3	0.739
		(107.6-117.3)	(105.3-118.9)	(108.5-112.6)	
	mCrDTA (°)	87.4 ± 2.1	87.4 ± 3.5	86.1 ± 1.5	0.77
		(82.6-91.3)	(80.9-94.8)	(85-87.8)	
	TPA (°)	21.4 ± 3.7	21.8 ± 3.7	19.9 ± 2.3	0.738
		(17.3-20.6)	(15.3-28.9)	18.5-22.6)	

Note: Inclination Angle (ICA); Femoral Varus Angle (FVA); PROXIMAL lateral Femoral Anatomical Angle (aLPFA); Distal Lateral Femoral Anatomical Angle (aLDFA); Distal Lateral Femoral Mechanical Angle (mLDFA)

- **Inclination of the Femoral Head (ICA):** Angle between the femoral neck axis and the anatomical axis of the femur.
- **Femoral Varus Angle (FVA):** Angle between the proximal and distal anatomical axes of the femur.
- **Anatomical Lateral Proximal Femoral Angle (aLPFA):** Angle between the anatomical axis and the proximal joint orientation line.
- **Anatomical Lateral Distal Femoral Angle (aLDFA):** Angle between the anatomical axis and the distal joint orientation line.
- **Mechanical Lateral Proximal Femoral Angle (mLPFA):** Angle between the mechanical axis and the proximal joint orientation line.

- **Mechanical Lateral Distal Femoral Angle (mLDFA):** Angle between the mechanical axis and the distal joint orientation line.

For the tibia, the following measurements were obtained (see Table 2):

Table 2. Comparison of femoral angles in dogs with medial patellar luxation of different breeds, obtained through craniocaudal radiographies.

-	Pomeranian dogs (present study)			Pomeranian dogs (2)			Chihuahua (18)			Yorkshire Terrier (17)			Toy Poodle (7)	Small Breeds (14)		
MPL Grade	I	II	III	I	II	III	I	II	III	I	II	III	II	I	II	III
ICA (°)	131 ± 6	128.2 ± 6.8	123.7 ± 3.4	136.7 ± 6	136.7 ± 6	139 ± 9	134.1 ± 3.5	132.4 ± 4.4	135.2 ± 8.4	125 ± 3.6	123.8 ± 7	126.5 ± 4.1	124.6 ± 7.1	127.2 ± 3.3	125.3 ± 4.7	130.4 ± 6.2
FVA (°)	5.3 ± 2.6	5.7 ± 2.6	6.4 ± 4.4	9.3 ± 3.7	9.3 ± 3.7	13.1 ± 5.5	-	-	-	6.1 ± 2	6.9 ± 2.7	10.5 ± 2	4.3 ± 4.8	-	-	-
aLPFA (°)	111 ± 7.1	112 ± 7.1	121.6 ± 5.7	-	-	-	111.2 ± 6.2	115.9 ± 7.7	113.8 ± 8.3	120.4 ± 1.8	118.2 ± 6.5	119.6 ± 3.5	107.6 ± 6.3	114 ± 9.1	109.7 ± 8	110.6 ± 8.2
aLDFA (°)	95.2 ± 2.8	96.1 ± 2.7	96.9 ± 3.6	98.8 ± 3.8	98.8 ± 3.8	103.2 ± 5.9	99.8 ± 4.8	100.7 ± 3	102.7 ± 2.6	96.1 ± 2	97.1 ± 3.4	100.5 ± 2	94.3 ± 4.8	100 ± 4	95.6 ± 6	98.6 ± 7
mLPFA (°)	107.1 ± 7.1	109.5 ± 7.1	120.1 ± 7.2	-	-	-	111.2 ± 6.2	115.9 ± 7.7	113.8 ± 9.7	-	-	-	101.5 ± 7.7	107.6 ± 7.7	104.6 ± 7.7	106 ± 7.6
mLDFA (°)	99 ± 3	98.7 ± 2.5	99.9 ± 1.5	101.6 ± 3.1	101.6 ± 3.1	104.4 ± 4.3	101 ± 6.1	103.2 ± 2	104.6 ± 2.2	-	-	-	99.3 ± 3.9	103.3 ± 3	99.8 ± 4.5	103.5 ± 6.2

Note: Inclination Angle (ICA); Femoral Varus Angle (FVA); Proximal Lateral Femoral Anatomical Angle (aLPFA); Distal Lateral Femoral Anatomical Angle (aLDFA); Distal Lateral Femoral Mechanical Angle (mLDFA)

Frontal plane (Caudocranial projection)

- **Mechanical Medial Proximal Tibial Angle (mMPTA):** Angle between the mechanical axis and the proximal joint orientation line.
- **Mechanical Medial Distal Tibial Angle (mMDTA):** Angle between the mechanical axis and the distal joint orientation line.

Sagittal plane (Mediolateral projection)

- **Mechanical Cranial Proximal Tibial Angle (mCrPTA):** Angle between the mechanical axis and the proximal joint orientation line.

- **Mechanical Cranial Distal Tibial Angle (mCrDTA):** Angle between the mechanical axis and the distal joint orientation line.
- **Tibial Plateau Angle (TPA):** Determined by the proximal joint orientation line, the tibial mechanical axis, and a line perpendicular to this axis.

Anatomical and mechanical axes, as well as joint orientation lines, were defined according to previous descriptions in the literature as shown in Table 3 [12,20,21].

Table 3. Comparison of tibial angles in dogs with medial patellar luxation (MPL) from different breeds, obtained through radiographs.

	Pomeranian dogs			Chihuahua (18)			Toy Poodle (7)	Small Breeds (14)		
MPL Grade	I	II	III	I	II	III	II	I	II	III
TPA°	21.4 ± 3.7	21.8 ± 3.7	19.9 ± 2.3	-	-	-	28.4 ± 5.3	24.6 ± 3.9	23 ± 3.7	23.2 ± 10.4
mCrDTA°	87.4 ± 3.7	87.4 ± 3.5	86.1 ± 1.5	92.2 ± 4	88 ± 2.3	91.8 ± 4.1	88.8 ± 2	84.6 ± 2.7	82.6 ± 1.5	86.8 ± 2.1
mMPTA°	93.8 ± 1.4	94.6 ± 1.9	95.7 ± 1.5	96.9 ± 3.2	97.1 ± 3.3	98.4 ± 2.7	96.9 ± 3.5	95.1 ± 2.5	94.8 ± 2	97.1 ± 4.7
mMDTA°	96.9 ± 2.1	96.7 ± 2.8	95.7 ± 1.5	94.8 ± 3.5	93.3 ± 2.4	95 ± 2.4	94.2 ± 4.4	96 ± 3.3	97.2 ± 3.9	97.1 ± 3.8

Note: Tibial Plateau Angle (TPA); Mechanical Distal Cranial Tibial Angle (mCrDTA); Mechanical Proximal Medial Tibial angle (mMPTA); Mechanical Distal Medial Tibial Angle (mMDTA)

Statistical analysis

Data were analyzed using statistical software (GraphPad Prism 9). Angular values were expressed as mean ± standard deviation. Data normality was assessed using the Shapiro-Wilk test. As data did not follow a normal distribution, the nonparametric Kruskal-Wallis test was applied to compare angular measurements among the three MPL grades (I, II, and III). When significant differences were found ($p<0.05$), post-hoc analyses were performed using Dunn's test with Bonferroni correction for multiple comparisons. A significance level of 5% ($p<0.05$) and a 95% confidence interval were adopted [22-27].

CONCLUSION

The present study revealed no statistically significant correlation between most femoral and tibial angular deformities and the severity of Medial Patellar Luxation (MPL) in Pomeranian dogs, except for a single parameter the mechanical Lateral Proximal Femoral Angle (mLPFA) which increased significantly in Grade III MPL compared to Grade I ($p=0.046$). However, this finding should be interpreted with caution due to the small sample size of the Grade III group.

All other angular measurements including the commonly used Femoral Varus Angle (FVA), Anatomical Distal Lateral Femoral Angle (aLDFA), and Tibial Plateau Angle (TPA) did not show significant variation across MPL grades. These findings are consistent with previous literature suggesting that angular deviations measurable via two-dimensional radiographs may not fully explain clinical MPL severity in small breeds.

Furthermore, the comparison with other small-breed dogs (chihuahua, toy poodle, yorkshire terrier) reinforces the variability and overlap in angular values, even in non-affected individuals, and underscores the limitations of extrapolating angular norms from large-breed dogs (e.g., labrador retrievers), where reference values are better defined.

This study supports the notion that small breeds, such as Pomeranians, may require distinct radiographic reference values, as their joint anatomy and bone conformation differ significantly from both large breeds and even among other small breeds. Therefore, caution is advised when using angular parameters alone to guide surgical decisions for MPL correction in small dogs. Future studies should focus on multiplanar imaging techniques (e.g., CT/3D reconstructions) and establish breed-specific thresholds to improve diagnostic accuracy and surgical outcomes.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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