Short Communication

Sex-associated differences in patellotrochlear morphology in small-breed dogs

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Abstract

The purpose of this study was to make a between-sex comparison of trochlear groove and patellar metrics in healthy dogs on tangential radiographs. A total of 38 stifle joints from 19 healthy dogs (9 males; 10 females) from three small breeds (Pomeranian, Pinscher, Chihuahua) were evaluated. The following morphometric parameters of patella and trochlear groove were measured: trochlear sulcus angle (SA), lateral and medial trochlear inclination angles (LTI; MTI), trochlear groove depth (TD), retropatellar angle of Wiberg (WA), lateral and medial patellar facet angles (LFA, MFA), lateral and medial facet lengths (LF, MF), horizontal and vertical patellar diameters. In the studied joints, both patellar diameters, LF, MF, MF/LF ratio, MTI, LFA and MFA were found to be statistically significantly lower in females. The Wiberg angle and sulcus angle tended to be higher in females yet the differences were not consistent. The results suggest that the smaller patellar thickness, respectively the reduced communication time between the patella and the trochlear groove together with the shorter medial femoral condyle letting the kneecap to escape from the trochlear groove, are anatomical features that may explain the greater predisposition of small-breed female dogs to medial patellar luxation.

Keywords: medial patellar luxation, small-breed dogs, sex, patellar morphology, trochlear morphology

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Introduction

The prevailing number of reports on canine patellar luxation suggest that this condition was more common in males from large breeds and females from small breeds (Gibbons *et al.*, 2006; Garnoeva *et al.*, 2016; Perry *et al.*, 2017). The more robust pelvic limb muscles of male dogs is a better stabiliser of the patella within the trochlear groove (Linney *et al.*, 2011). Hormonal and genetic factors may predispose to this condition and explain its higher incidence in females (Priester, 1972). An experimental study in 14 Beagle dogs demonstrated that the application of estradiol benzoate resulted in trochlear groove hypoplasia (Gustafsson *et al.*, 1969) due to inhibition of articular cartilage growth and growth hormones.

Trochlear morphology is essential for the selection of operative technique in dogs with medial patellar luxation, associated either with trochlea deepening (trochleoplasty) or change of kneecap shape (patelloplasty) (Wangdee *et al.*, 2015; Katayama *et al.*, 2016). Only a few reports provide information on canine trochlear groove and patellar shapes from the point of view of patellar luxation etiology (Nicetto *et al.*, 2020; Garnoeva, 2021; Matchwick *et al.*, 2021). So far, data referring to sexual dimorphism in patellotrochlear morphology have not been reported.

Because of the important role of trochlear and patellar morphology in the etiopathogenesis of medial patellar luxation in dogs, the aim of this study was to evaluate morphometric trochlear and patellar parameters in sound small-breed dogs from both sexes on tangential radiographs and to seek an explanation for the greater susceptibility of females to this common orthopaedic disease.

Materials and Methods

A total of 38 stifle joints from 19 healthy dogs (9 males; 10 females) from three small breeds (5 Pomeranians, 11 Pinschers, and 3 Chihuahuas) were included in the study. The median age of the animals was 18 months (range 11-72 months) and the median body weight – 1.9 kg (range 0.9-4.0 kg). The dogs were examined to confirm that they had no orthopaedic or neurological disorders affecting the musculoskeletal system. The orthopaedic exam consisted of a patellar displacement test and dancing patella test, both of which were negative in the examined dogs. Palpation of hindlimbs showed no asymmetry of femoral and gluteal muscles. Neurological status exams consisted of proprioceptive positioning by flexing the paw so that the dorsal surface was on the floor; all dogs responded with immediate return to normal position. The lack of worn nails or trophic ulcers provided evidence of the absence of long-term proprioceptive dysfunction. The patellar and withdrawal reflexes were normal.

After deep sedation with 0.075 mg/kg medetomidine hydrochloride (Dorbene vet®, 1 mg/ml, Syva, Spain) and 7.5 mg/kg ketamine hydrochloride (Anaket®, 100 mg/ml, Richter Pharma, Austria) applied intramuscularly, radiographs in tangential (skyline) views were taken. The dogs were positioned in sternal recumbency with pelvic limbs flexed as much as possible. The central X-ray beam was focused between the femoral condyles on the patella.

The following trochlear groove parameters were determined (Fig. 1): trochlear sulcus angle, lateral and medial trochlear inclination angles and trochlear groove depth (Garnoeva, 2021).

Morphometry of the patella (Fig. 2) included measurement of retropatellar angle of Wiberg (Wiberg, 1941); lateral and medial patellar facet angles (LFA, MFA) (Jimenez *et al.*, 2021); lateral and medial facet lengths (LF, MF) (Wiberg, 1941); horizontal and vertical patellar diameters (Staubli *et al.*, 1999).

Between-sex differences were evaluated by the non-parametric Mann-Whitney test.

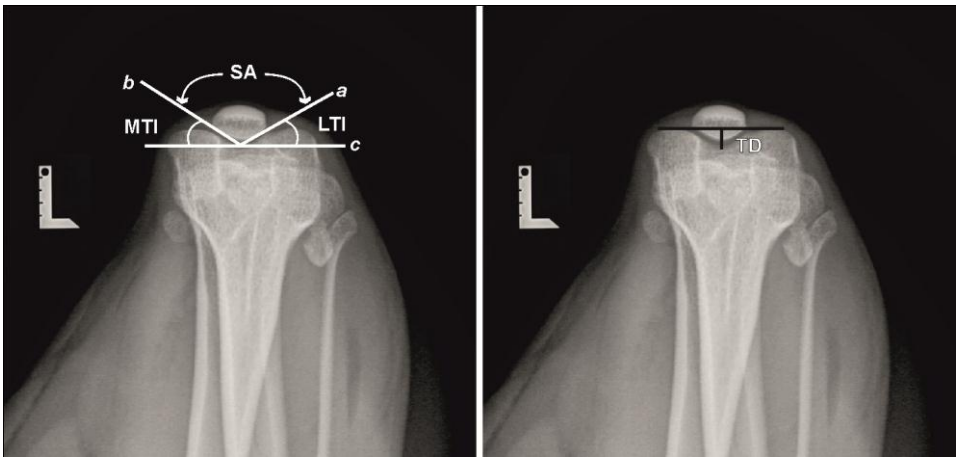

Figure 1 Trochlear sulcus angle (SA) is formed by lines connecting each of the lateral and medial condyles with the deepest point of the trochlea (a, b); lateral and medial trochlear inclination angles (LTI; MTI) are formed between the line tangential to the posterior condyles (c) and the lines passing from the sulcus bottom to the lateral and medial condyles, respectively; the trochlear depth (TD) is the distance from the trochlear groove bottom to a tangential line passing through both femoral condyles.

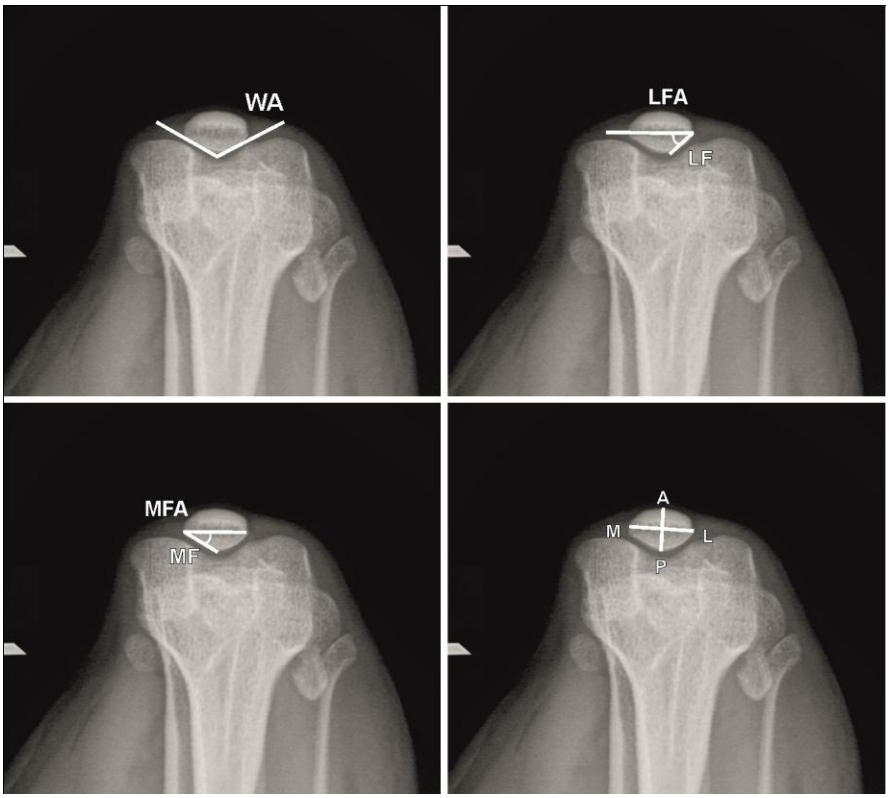

Figure 2 The Wiberg angle (WA) is formed by the medial and the lateral patellar facet tangents. The lateral and medial patellar facet angles (LFA, MFA) are formed between the patellar horizontal diameter and the lateral and medial patellar facet tangent, respectively. The lateral and medial patellar facet lengths (LF, MF) are measured by passing a line from the most lateral and medial edge of the patella, respectively, to its apex. The horizontal diameter is the length between the most medial (m) to the most lateral (l) patella edges and the vertical diameter (thickness) – between the farthest patellar anterior (a) and posterior (p) poles.

Results and Discussion

In veterinary medicine literature, there are only two reports on trochlear shape and depth in healthy dogs from medium-size and large breeds (Nicetto *et al.*, 2020; Matchwick *et al.*, 2021) and one in dogs from small breeds (Garnoeva, 2021), but to our best knowledge, no sex-associated anatomic trochlear and kneecap differences have been reported.

In female stifles, the medial trochlear inclination angle (MTI) was smaller (26°) compared to male stifles (28°; $P<0.05$). A similar trend was observed for the sex-related differences in the lateral inclination angle (LTI), which was significantly smaller in stifles of females than in those of males (28° vs 30.5°) (Table 1). The trochlear sulcus angle was higher in female dogs (125°) compared to males (122°), yet statistically insignificantly. In men, reported differences in sulcus angle, lateral and medial inclination angles and Wiberg angle with respect to the sex were not substantial (Li *et al.*, 2021).

Table 1 Trochlear and patellar morphological parameters of stifles from female and male dogs, measured on tangential radiographs. Data is presented as median (range).

	Female dogs (n=20 stifles)	**Male dogs (n=18 stifles)**
Trochlear morphology parameters		
Sulcus angle, °	125.0 (116-153)	122 (112-149)
LTI, °	28.0 (12-37)	30.5 (22-39)
MTI, °	26.0* (14-35)	28.0 (19-37)
Trochlear depth, mm	2.05 (0.7-3.1)	2.0 (0.8-3.1)
Patellar morphology parameters		
MF, mm	2.00** (1.6-3.7)	2.7 (2.0-4.8)
LF, mm	2.25* (1.7-3.9)	2.65 (1.9-4.4)
MF/LF	0.91** (0.83-1.00)	1.04 (0.90-1.42)
LFA, °	34.5** (26-46)	40.5 (30-52)
MFA, °	31.0** (18-45)	36 (30-51)
Horizontal diameter, mm	4.85* (2.7-7.1)	5.25 (3.8- 7.6)
Patellar thickness, mm	2.75** (1.8- 4.3)	3.25 (2.8-5.0)
Wiberg angle, °	127.5 (112-136)	122 (116-135)

*$P<0.05$; **$P<0.01$ between sexes; LTI; MTI: lateral and medial trochlear inclination angles; LF, MF: lateral and medial patellar facet lengths; LFA, MFA: lateral and medial facet angles.

The trochlear depth (TD) of studied stifle joints showed no consistent sex-related difference. A meta-analysis of human trochlear morphology (Pringfle *et al.,* 2019) showed a general trend toward shallower sulcus, greater sulcus angle and greater asymmetry suggesting trochlear dysplasia in females. Trochlear condyles' height was significantly higher in males (Hsu *et al.,* 2021) in agreement with results from this study in male small-breed dogs. This may be attributed to the greater pressure of the kneecap on the trochlea exerted by the more robust femoral muscles of male dogs. The established trochlear shape asymmetry of females in this study (indicated by the statistically significantly lower medial trochlear inclination angle, $P<0.05$) may account for the greater predisposition of small-breed bitches to medial patellar luxation.

Statistically significant between-sex differences were observed for the vertical patellar diameter (patellar thickness). It was lower in female (2.75 mm) vs male stifles (3.25 mm) ($P<0.01$). The horizontal patellar diameter was also shorter ($P<0.05$) in females than in males – 4.85 mm vs 5.2 mm (Table 1). The ratio of medial to lateral facet lengths (MF/LF) was substantially more decreased in female patellae than in those of males (0.91 vs 1.04; $P<0.01$), proving existing asymmetry between medial and lateral patellar facets and thus, increased susceptibility to patellar instability. The majority of studies evaluating the patella morphology in humans reviewed by Pringfle *et al.* (2019), also showed greater patellar metrics in males after adjustment for height and weight.

The patellar lateral and medial facet angles (LFA and MFA) were significantly ($P<0.01$) lower in female canine stifle joints. The opposite tendency was found for the Wiberg angle that tended to be higher in females (127.5°) vs males (122°). These parameters suggest sharper patellar apex in male dogs and thus, higher pressure of the patella on trochlear groove. The possible reason may be sought in the different bone density in male and female subjects. The thinner patella of females is associated with the shorter time of communication with the trochlea which consequently results in a shallower groove.

In conclusion, despite the small number of measured stifles, the results from this preliminary study suggest that the morphology of knee osseous structures and that demonstrated between-sex differences in patellotrochlear metrics may partly explain the existing predisposition of female small-breed dogs to medial patellar luxation. The smaller patellar thickness reduces the time of patella-trochlear groove communication, whereas the shorter medial femoral condyle facilitates the displacement of the kneecap out of the trochlear groove. Investigations on a larger cohort of dogs from both sexes would determine with more confidence whether the trochlear depth, patellar thickness and the height of trochlear condyles of sound small-breed dogs are predictors for the occurrence of medial patellar luxation.

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