Proximodistal Alignment of the Canine Patella:
Radiographic Evaluation and Association with Medial and Lateral Patellar Luxation

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Objectives—To evaluate the contribution of proximodistal alignment of the patella to patellar luxation, and to evaluate the structures contributing to proximodistal alignment of the patella relative to the femoral trochlea.

Study Design—Retrospective study using a convenience sample.

Animals—Medium to giant breed dogs (n = 106).

Methods—Medical records and stifle radiographs of 106 dogs were reviewed. Radiographic measurements evaluated the proximodistal alignment of the patella with respect to the femoral trochlea, distal aspect of the femur, and proximal aspect of the tibia. Measurements were compared between dogs with clinically normal stifles (controls; n = 51 dogs, 66 stifles), and dogs with a clinical diagnosis of medial patellar luxation (MPL, n = 46 dogs, 65 stifles) or lateral patellar luxation (LPL, n = 9 dogs, 11 stifles) using ANOVA.

Results—In dogs with MPL, the ratio of patellar ligament length (PLL) to patellar length (PL) was increased, as was the ratio of the distance from the proximal aspect of the patella to the femoral condyle (A) to PL (P < .0001). Dogs with LPL had a decreased A:PL (P = .003) and an increased ratio of the proximal tibial length (PTL) to distal tibial width (DTW; P = .009).

Conclusions—MPL is associated with a relatively long patellar ligament and patella alta in medium to giant breed dogs. LPL is associated with a relatively long proximal tibia and patella baja. Values for PLL:PL > 2.06 and A:PL > 2.03 are suggestive of the presence of patella alta, whereas a value for A:PL < 1.92 is suggestive of patella baja.

Clinical Relevance—Measurements of both PLL:PL and A:PL are recommended in dogs with patellar luxation, and surgical correction should be considered in those with abnormal values.

INTRODUCTION

MEDIAl PATELLAR luxation (MPL) is a common orthopedic disease in dogs with ~ 95% of affected dogs having related structural abnormalities.1,2 Lateral patellar luxation (LPL) occurs less frequently than MPL.2 Recurrence of patellar luxation is one of the most common complications associated with surgical management of MPL or LPL. Complications develop in 18–29% of dogs, and more likely in dogs weighing > 20 kg.3,4 Reluxation accounts for 30–48% of these postoperative complications3,5 and 65–86% of the major complications after surgical repair of patellar luxation in dogs.3,4 The relatively high frequency of patellar reluxation may be related to inadequate evaluation of underlying skeletal deformities leading to incomplete surgical correction.4 Although proximodistal transposition of the tibial crest has been proposed in dogs, its indications and...
effects remain undetermined. Surgical treatment of patellar luxation traditionally includes desmotomy, contralateral imbrication of soft tissue, trochleoplasty, and transposition of the tibial crest. When combined, these techniques restore the quadriceps alignment and adequately deepen the trochlear groove of the femur; however, these procedures do not address proximodistal malalignment of the patella relative to the femoral trochlea, which may contribute to postoperative recurrence of patellar luxation.

Proximodistal malalignment of the patella includes patella alta and baja, which refer to a patella located too proximally (high riding patella) or distally (low riding patella) within the femoral trochlea, respectively. Among the radiographic techniques described to evaluate the proximodistal alignment of the patella in humans, Insall’s index provides the most applicable and convenient method of diagnosing patella alta in humans. Insall’s index is obtained by dividing the greatest diagonal length of the patella by the length of the patellar ligament to calculate a ratio, which is normally equal to 1.0. An Insall’s index value < 0.80 is consistent with patella alta, whereas a ratio > 1.20 indicates the presence of patella baja.

Insall’s index has been modified in humans to overcome the artifact created by long distal patellar facets that artificially increase the ratio and may mask the presence of patella alta. Insall’s modified index is obtained by dividing the distance between the inferior pole of the patella to a line drawn across the distal aspect of the femoral condyles is > 20 mm. Evaluations of the proximodistal alignment of the canine patella have been limited to the application of Insall’s index to large breed dogs. The ratio of patellar ligament length (PLL) to patellar length (PL) was increased in 30 large breed dogs with MPL, with ratios > 1.97 being consistent with patella alta. Based on the association between increased PLL:PL and MPL, patella alta was suspected to play a role in the development of MPL in large breed dogs.

Most studies in humans and animals have focused on the diagnosis of patella alta and baja using techniques relying on the length of the patellar ligament, but have ignored the potential effects of distal femoral or proximal tibial abnormalities on the position of the patella in relationship with the femoral trochlea. Although several authors have described anomalies of the distal portion of the femur and proximal portion of the tibia in dogs, the relationship of these anomalies to the extensor mechanism has not been characterized. Incomplete knowledge of the anatomic structures contributing to the proximodistal alignment of the patella may limit the success of surgical management of patellar luxation.

The impetus for this study was our observation that measurements of PLL and PL in clinical cases were influenced by the presence of enthesiophytes on the distal patella and proximal tibia. In addition, reliance on PLL:PL ignores the potential effect that distal femoral or proximal tibial abnormalities could exert on the position of the patella in relationship to the femoral trochlea. We hypothesized that a proximal or distal position of the patella contributes to medial or LPL in medium, large, and giant breed dogs. We also hypothesized that structures other than the patellar ligament contribute to a proximodistal malalignment of the patella. Our 1st objective was to evaluate the reproducibility of radiographic measurements characterizing the proximodistal alignment of the patella in medium to giant-breed dogs. The 2nd objective was to evaluate the potential contribution of patellar position (alta or baja) to the side of patellar luxation (medial or lateral) in medium to giant-breed dogs and our 3rd objective was to evaluate structures contributing to the proximodistal alignment of the patella relative to the femoral trochlea.

MATERIALS AND METHODS

Dogs

Medical records and stifle radiographs of medium (minimum body weight, 11 kg) to giant-breed dogs, ≥5 months of age admitted between March 1997 and February 2006, were retrieved. The control group consisted of dogs with no history of stifle disease and normal stifle radiographs. Dogs with displaced diaphyseal femoral fractures were excluded from study. The case definition for a diagnosis of MPL or LPL did not require a radiograph and was based on a history of intermittent pelvic limb lameness and the presence of a grade I–IV patellar luxation on orthopedic examination of the affected pelvic limb. Additional inclusion criteria for dogs with patellar luxation included no history of trauma, no detectable evidence or knowledge of previous stifle surgery, and no evidence of pathologic changes in the stifle joint other than patellar luxation with or without cranial cruciate ligament (CCL) rupture and degenerative joint disease (DJD).

All radiographs included in the study were approved in terms of quality and positioning by a board certified radiologist. Positioning was judged as satisfactory if both femoral condyles were superimposed on lateral projections and if both fabellae symmetrically bisected the femoral cortices in cranial views and the patella was centered over the trochlear groove.
(in the control group). Dogs were included in this study if the lateral projection of the stifle extended to the diaphysis of the femur and tibia, allowing all the measurements required.

**Radiographic Measurements (Table 1)**

All radiographs were evaluated to study the proximodistal alignment of the patella, the conformation of the distal aspect of the femur and proximal aspect of the tibia, the presence and severity of joint effusion, and the presence and degree of DJD. Radiographic signs of DJD were graded as 0 (no enthesiophytes), 1 (1 mm enthesiophytes), 2 (2–3 mm enthesiophytes), and 3 (>3 mm enthesiophytes), based on a previous scoring system. Radiographic measurements were obtained from 3 populations of medium to giant-breed dogs: normal dogs, dogs with MPL, and dogs with LPL.

The reproducibility of radiographic measurements was evaluated by calculating intra-observer repeatability using the coefficient of variation (CV) for each variable and by determining the effect of stifle flexion on measurements. CV was based on evaluations performed by the same investigator (AM) on 3 separate days of 20 randomly (using a simple random sample) selected dogs with patellar luxation.

The PLL was indexed to the greatest PL on a mediolateral radiograph (Fig 1) and the modified PLL:PL calculated. The PLL represented the distance from the point of origin of the ligament on the distal aspect of the patella to its insertion on the proximal extent of the tibial crest (tibial tuberosity). Measurement of PL in dogs with DJD was problematic because of the presence of enthesiophytes at the distal aspect of the patella. Enthesiophytes were excluded from the measurement of PL in these dogs by extrapolating the normal contour of the patella. When contralateral radiographs were available, this extrapolation was based on superimposition of the normal patella.

**Evaluation of the Position of the Patella in Relation to the Transcondylar Axis of the Femur (A:PL)**

The length of a vertical line (A) connecting the proximal pole of the patella and the transcondylar axis of the distal femur, measured from a caudocranial or cranio-caudal radiograph (Fig. 2), was indexed to the PL to provide A:PL. The value for PL was measured on the corresponding mediolateral view of the stifle because superimposition over the distal aspect of the patella prevented adequate observation of the distal pole of the patella on caudocranial and cranio-caudal projections.

**Evaluation of the Distal Aspect of the Femur**

The femoral condylar length (FCL) was the length of a vertical line extending between the distal aspect of the femoral condyles and the proximal extent of the femoral trochlear ridges (X; Fig 3). This value was normalized by the femoral width (FCL:FW) to mitigate the effects of size and magnification. The femoral trochlea length (FTL, Fig. 4) was the distance between a line across the proximal extent of the femoral trochlear ridges (X) and the cranial distal femoral physis or the extensor fossa (Z). The (FW, Fig 3) was defined as the width of the femur measured at a distance equal to FCL from the proximal aspect of the trochlea (X). The greatest diagonal PL was measured as described previously. The lengths of the femoral condyle (FCL) and trochlea (FTL) were expressed relative to the length of the patella (FCL:PL, FTL:PL) and compared between groups.

### Table 1. Definitions of the Abbreviations of the Radiographic Measurements

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>PL</td>
<td>Patellar length</td>
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<tr>
<td>PLL</td>
<td>Patellar ligament length</td>
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<tr>
<td>A</td>
<td>Vertical distance between the proximal pole of the patella and transcondylar axis of the distal femur</td>
</tr>
<tr>
<td>FCL</td>
<td>Femoral condylar length</td>
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<tr>
<td>FW</td>
<td>Femoral width</td>
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<tr>
<td>PTW</td>
<td>Proximal tibial width</td>
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<tr>
<td>DTW</td>
<td>Distal tibial width</td>
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<tr>
<td>PTL</td>
<td>Femoral trochlear length</td>
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<tr>
<td>J</td>
<td>Distance between proximal extent of femoral trochlear ridges and tibial tuberosity</td>
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**Fig 1.** Mediolateral radiograph of a clinically normal canine stifle illustrating the measurements made to determine patellar length (PL) and patellar ligament length (PLL).
Evaluation of the Proximal Aspect of the Tibia

The proximal tibial length (PTL) was measured as the distance between the cranial point of the medial articular surface of the tibial plateau (I) and the tibial tuberosity (O; Fig 5). The proximal tibial width (PTW) was measured as the distance between the point of insertion of the patellar ligament on the tibial tuberosity (O) and the caudal point of the medial articular surface of the tibial plateau (point of insertion of caudal cruciate ligament; S). The distal tibial width (DTW) was measured at a distance equal to twice the proximal tibial width (PTW) from the cranial aspect of the tibial plateau (I). The ratios of PTL to DTW (PTL:DTW) and PTW to DTW (PTW:DTW) were calculated.

Relationship Between the Patellar Mechanism, Distal Aspect of the Femur, and Proximal Aspect of the Tibia

This relationship was evaluated with measurements that spanned the distal femur and proximal tibia. The measurement “J” was defined as the distance between a line extending from the proximal extent of the femoral trochlear ridges (point “X”) to the proximal aspect of the tibial crest “O” (Fig 4). The following femorotibial ratios were evaluated: the proximal tibial width to the FCL (PTW:FCL), the sum of PL and PLL to the sum of FTL and PTL (PLL + PL)/(PTL + FTL), and the sum of PL and PLL to the distance between the proximal trochlea and the insertion of the patellar ligament (PLL + PL)/J.
Angle of Flexion of the Stifle

The angle of the stifle joint was defined as the angle formed between the long axis of the distal femur and proximal aspect of the tibia (Fig 6). This angle was determined by drawing a segment (FW) between the femoral cortices at a distance equal to the length of the femoral condyle from the proximal extent of the trochlea “X”. A segment “D” parallel to FW was drawn 20 mm proximal to FW. A line was drawn from joining the centers of the 2 segments (FW and D) to define the long axis of the distal femur. The long axis of the proximal tibia was drawn by connecting the cranial point of the medial articular surface of the tibial plateau to the midpoint of the segment used to measure DTW. The stifle joint angle was measured at the intersection of these 2 axes.

Statistical Analysis

Data are reported as mean ± SD. Significance was set P<.05. Intra-observer variability for each radiographic measurement was evaluated by calculating the CV for each variable obtained by 3 measurements performed on radiographs of 20 randomly selected dogs with patellar luxation. A 95% confidence interval (CI) for normal values was calculated for selected measurements from control dogs. Group means were compared with control using analysis of variance (PROC MIXED, SAS 9.2, Cary, NC), with stifle nested within dog because analysis was based on 1 or 2 stifles for each dog. Nonnormally distributed variables were log transformed before ANOVA was performed. The effect of stifle angle on femorotibial measurements was examined by regressing each femorotibial measurement (as well as the square of the femorotibial measurement to explore for the presence of a curvilinear relationship) against stifle angle using multivariable regression (PROC REG, SAS 9.2) with MPL and LPL as covariates. The relationship between DJD score and PLL:PL, A:PL, FCL:FW, and FCL:PL for all radiographs was explored by calculating the Spearman’s rank correlation coefficient (Spearman’s rho; PROC CORR, SAS 9.2).

RESULTS

Body weight and age did not differ significantly between the 3 groups of dogs studied (control, MPL, LPL). Mean (± SD) body weight was 28.1 ± 9.8 kg and age 3.1 ± 2.8 years (range, 5.5 months to 13.5 years).
Dogs with Clinically Normal Stifles (Controls)

Fifty-one dogs (66 stifles) met the criteria for inclusion in the control group. Thirty-six (71%) dogs were admitted for fractures, affecting the pelvis, femoral head, neck, greater trochanter, proximal femoral diaphysis (nondisplaced), or distal tibia with no evidence of stifle disease (stifle measurements were performed on the fractured limb in 18 dogs, the normal limb in 11 dogs, and both fractured and normal limbs in 7 dogs). Six dogs (12%) were clinically and radiographically normal with no evidence of orthopedic disease, and 12% also had a CCL tear on the opposite stifle with no evidence of stifle disease on the measured side. Two dogs (4%) had radiographic evidence of bilateral coxarthrosis but normal stifle joints, and 1 dog had bilateral hip dysplasia (total hip replacement had been performed on both hips).

Breeds in the control group were: 26 (51%) Labrador Retrievers; 4 (8%) Golden Retrievers; 2 (4%) each of Doberman, Australian Cattle, German Shepherd, Border Collie, and Australian Shepherd; and 1 (2%) each of Rottweiler, Great Dane, Boxer, Bull Mastiff, Saint Bernard, Great Pyrenees, and Irish Wolfhound; and 4 dogs were mixed breeds.

Dogs with Patellar Luxation (Diseased Group)

Patellar luxation was diagnosed in 55 dogs (76 stifles); 84% (46 dogs) had MPL and 16% (9 dogs) had LPL. Twelve of 65 (19%) stifles with MPL had grade I luxation, 31 (48%) had grade II, 13 (20%) had grade III and 9 (14%) had grade IV MPL. Among 11 stifles with MPL, 2 (18%) had grade I, 3 (27%) grade II, 2 (18%) grade III and 4 (36%) had grade IV MPL. Among the 46 dogs (65 stifles) with MPL, 27 (59%) were affected unilaterally and 19 (41%) had bilateral luxations. Seven of 9 (78%) LPL dogs had unilateral luxation whereas both limbs were affected in 2 (22%) dogs.

Radiographic evidence of DJD was identified in 25 of 76 (33%) stifles with patellar luxation. Degenerative changes were scored as: 1 in 8 stifles (10.5%), 2 in 12 (15.7%), and 3 in 5 (6.6%). Orthopedic conditions associated with patellar luxation included hip dysplasia (n = 16 dogs, 29%), CCL disease (n = 10, 18%), hip dysplasia and CCL tear (n = 4, 7%), healed femoral neck fracture (n = 1, 2%), slipped capital femoral physis (n = 1, 2%), 4th lumbar vertebrae mass (n = 1, 2%), and panosteitis (n = 1, 2%). Thirteen of 46 (28%) dogs with MPL had CCL disease whereas only 1 of 9 (11%) dogs with LPL had CCL disease. Patellar luxation was the only orthopedic disease in 21 (38%) dogs.

Dogs with patellar luxation included 16 mixed breeds (29%), 10 (18%) Labrador Retrievers, 3 (5%) each of Cocker spaniel and Akita, 2 (4%) each of German Shepherd, Bulldog, Husky, Cavalier King Charles Spaniel, and Newfoundland, and 1 (2%) each of Great Dane, Boston Bull Terrier, Golden Retriever, Flat Coated Retriever, Bull Mastiff, Shar Pei, Soft Coated Wheaten Terrier, Keeshond, Basset Hound, Australian Cattle dog, Bouvier des Flanders, Border Collie, and Weimaraner.

Reproducibility of Radiographic Measurements

The CV of radiographic measurements varied between 0.96% and 2.11% (Table 2). Stifle angle did not differ between groups (Table 2), varying from 43–134°. The median (range) of stifle angle was 86° (43–130°) in the control group, 93° (60–134°) in the MPL group and 94° (57–122°) in the LPL group. PLL varied with stifle angle in a curvilinear manner: PLL = 3.00 + 0.056(angle)−0.00040(angle)² (R² = 0.18, P < .0001) with a maximum value for PLL occurring at a stifle angle of ~70°. The value for PLL:PL also varied with stifle angle in a curvilinear manner: {PLL:PL} = 1.07 + 0.22(MPL) + 0.023(angle)−0.00014(angle)² (R² = 0.32, P < .0001; Fig. 7) with a maximum value for PLL:PL occurring at 90°. The PLL to PL ratio was constant over a stifle angle range of 70–110°. The indice {PLL + PL}:{PTL + FTL} was weakly associated with stifle angle in a curvilinear manner (R² = 0.072, P = .008). Indices that were curvilinearly affected by stifle angle included PLL (P < .0001) and measurements crossing the joint: J (r = −0.60, P < .0001), {PLL + PL}:{J (r = + 0.56, P < .0001). Radiographic evaluation indicated that DJD score was positively correlated with PLL:PL (r = + 0.22, P = .011) but was not correlated with A:PL (P = .11), FCL:FW (P = .46), or FCL:PL (P = .19).

Proximodistal Alignment of the Patella

The 95% CI of the modified PLL:PL was 1.97–2.06 for controls, 2.18–2.29 for dogs with MPL, and 1.77–2.02 for dogs with LPL. The value for PLL:PL was increased in dogs with MPL (P < .0001) but did not differ in dogs with LPL compared with controls (Table 2).

The 95% CI of A:PL was 1.92–2.03 for control, 2.18–2.37 in dogs with MPL, and 1.49–1.95 for dogs in the LPL group. The value for A:PL was greater in the MPL group (Fig. 8, P < .0001) and lower in dogs with LPL (Fig. 9, P = .003) compared with the control group. A:PL was evaluated from craniocaudal views in 44 of 66 (67%) normal stifles, in 8 of 11 (73%) stifles with LPL and 49 of 65 (75%) stifles with MPL.

The height of the femoral condyle (FCL:PL) was increased relative to the length of the patella in both diseased groups, compared with controls (Table 2). The length of the femoral trochlea normalized by the size of the corresponding patella (FTL:PL) was only increased...
in the MPL group. Also, in dogs with MPL the proximal tibia was approximately wider (95% CI of PTW:FCL, 1.028–1.061, \( P = .009 \)) than in dogs without patellar luxation (95% CI of PTW:FCL, 1.005–1.026). In dogs with LPL, the proximal tibia was proportionally longer (95% CI of PTW:FCL, 1.005–1.026) than in dogs with MPL. Also, in dogs with MPL the proximal tibia was proportionally shorter than the distal femoral condyle and proximal tibia, based on 2 ratios: \( \{\text{PLL} + \text{PL}\} : \{\text{PTL} + \text{FTL}\} \), \( P = .004 \); \( \{\text{PLL} + \text{PL}\} : J \), \( P = .023 \).

### DISCUSSION

Although patellar luxation remains more common in small breeds, this study focused on larger dogs because of the increasing incidence of MPL and greater risk of postoperative complications in large dogs.\(^{4,5,25}\) In addition, proximodistal malalignment of the patella (i.e. patella alta) has previously been proposed as a predisposing factor to postoperative recurrence of patellar luxation.\(^6\) The main findings of our study reported were: (1) the intraobserver variability of radiographic measurements was <2.5%; (2) measurements influenced by stifle angle included those that crossed the joint as well as PLL; (3) the normal range (95% CI) of the modified PLL:PL and A:PL were 1.97–2.06, and 1.92–2.03, respectively. Therefore, values above or below these CI ranges might be considered to represent a pathologic condition (i.e. patella alta or baja, respectively); (4) MPL was associated with patella alta, whereas LPL was associated with patella baja; (5) dogs with MPL had a relatively long patellar ligament compared with controls; and (6) dogs with LPL had a relatively longer proximal tibia than controls.

The conventional Insall’s index\(^26\) relies on observation of the patella and patellar ligament on lateral radiographs. The point of insertion of the patellar ligament has previously been associated with a small indentation on the tibial tubercle which can be used as a landmark for orthopaedic surgeons as a landmark to guide the insertion of the PCL in total knee arthroplasty.\(^8\)
measure the PLL in dogs. However, identification of this landmark as well as the patellar ligament itself is difficult in dogs with joint effusion or DJD. All dogs with patellar luxation in our study (subjectively) appeared to have a similar degree of joint effusion based on radiographs and the only dogs without joint effusion were those without stifle disease (control group). These 2 populations differ by more than 1 variable, preventing an evaluation of the effect of joint effusion on radiographic measurements. To palliate this potential issue, all measurements in our study were specifically designed to rely on bony landmarks rather than observation of soft tissue structures. For example, the modified PLL:PL and a ratio (A:PL) derived from the human literature were selected to evaluate the proximodistal alignment of the patella.

Values for PLL:PL were previously reported to be independent of stifle angle. However, our findings indicated that the value of modified PLL:PL varied in a curvilinear manner with stifle angle (Fig 7), with the maximal value occurring at an angle of $\sim 90^\circ$. The discrepancy between our findings and the previous report may reflect the larger number of observations in our study (106 versus 13 large breed dogs), which increased statistical power. The large range of flexion in our study ($43^\circ$–$134^\circ$ versus $75^\circ$–$148^\circ$ in the previous study) may also have contributed to the difference between the 2 studies, in that the value for modified PLL:PL remained constant over a stifle angle range of $70^\circ$–$110^\circ$. Although the influence of stifle flexion on the value for modified PLL:PL may affect the assessment of individual patients, the angle of flexion did not differ between our 3 groups, thereby permitting comparisons to be made between groups.

The vertical distance between the proximal extent of the patella and transcondylar axis of the distal femur divided by the length of the patella (A:PL) did not appear to be affected by stifle angle in our study; however, our ability to evaluate the influence of stifle position on the value for A:PL was limited by our inability to determine the degree of flexion of the stifle on caudocranial or craniocaudal radiographs. Another limitation is the potential effect of magnification between caudocranial and craniocaudal radiographic views of the stifle joint. Nevertheless, the index A:PL appears clinically valuable when observation of the patella and the patellar ligament is...
impairment on mediolateral radiographs because of superimposition of the luxated patella over the distal femur. In these cases, the PL can be easily determined on the caudocranial or craniocaudal view.

Values for the 2 indices used to evaluate proximodistal alignment of the patella (modified PLL:PL, A:PL) were greater in dogs with MPL than in controls. Based on the 95% CI we calculated, PLL:PL values > 2.06 are consistent with patella alta. This value is comparable to the ratio (1.97) previously proposed.6 Our findings therefore confirm the previously reported association between MPL, patella alta, and an increased length of the patellar ligament.5 The ligament may be inherently long in these dogs or may have stretched secondary to patellar luxation. The positive correlation between radiographic scores of DJD and PLL:PL supports the second mechanism. Proximal displacement of the patella in dogs with patella alta may create a patellofemoral articulation that extends proximal to the femoral trochlear groove during extension of the stifle joint.6 The potential loss of the buttressing effect of the proximal trochlear ridges may be exacerbated in dogs with MPL by the presence of a relatively wide proximal tibia that may reduce the retropatellar pressure (femoropatellar contact force). This loss of patellar pressure with the femoral condyle would facilitate medial luxation of the patella, especially in dogs with shallow trochlea, medial tibial torsion, coxa vara, or lateral torsion of the distal aspect of the femur.27,28 The only other clinically relevant difference between control and MPL groups was the presence of longer femoral condyles in dogs with MPL. This finding may be because of secondary degenerative changes affecting the proximal aspect of the femoral trochlear ridges. Our inability to establish a correlation between DJD and the length of femoral condyles may be explained by the fact that secondary changes were scored based solely based on the presence and size of patellar enthesiophytes.21

Although the scope of our study is limited by the small number of dogs with LPL, the PLL did not appear to be abnormal in this group. Although values for modified PLL:PL did not differ between controls and dogs with LPL, values for A:PL were decreased in dogs with LPL. This change is unlikely to reflect a difference in position and radiographic positioning. Indeed, the percentage of dogs radiographed in a craniocaudal position was greater in the LPL (73%) than in the control (67%) group. Under these conditions, the distance between the patella and the femoral condylar axis (A) would have been more magnified, thereby increasing A:PL in dogs with LPL. The proximal tibia in dogs with LPL was also relatively longer than that in controls, potentially contributing to the distal position of the patella in spite of a normal patellar ligament. Based on these findings, a thorough evaluation of the proximal aspect of the tibia is recommended in dogs with LPL and based on our 95% CI, dogs with PTL:DTW values > 1.65 should be considered at risk for developing patella baja. This finding explains the differences in measurements evaluating the relationship between the patellar mechanism {(PLL + PL): (PTL + FTL); {PLL + PL}: J) between control dogs and dogs with LPL. The medial ridge of the trochlear groove is normally thicker than the lateral ridge in its midportion, predisposing a low riding patella to luxate laterally rather than medially,29 especially when combined with lateral tibial torsion or coxa valga.19

Surgical treatment of patella alta with recurrent patellar luxation has been reported to restore normal patellar position in humans.30 The tibial tubercle is transposed both distally and medially to correct patella alta, and elevated anteriorly to reduce patellofemoral joint reaction forces, thereby allowing normalization of the patellar index.31–36 Our results suggest that positioning the tibial tuberosity distally during routine tibial tuberosity transposition in dogs may be indicated in order to move the tibial tuberosity distally and correct patella alta, when indicated. Cranial transposition is unlikely to help because the proximal tibia appeared relatively wider than the femoral condyle in our dogs with MPL. The caudalization previously reported after tibial transposition in dogs may, in fact, be beneficial.7,37 The optimal method for surgical correction of patella baja remains unclear. In humans, patella baja is corrected by proximal transfer of the tibial tuberosity38,39 or Z-plasty lengthening of the patellar ligament.38,40 Proximal transposition of the tibial crest in dogs is limited by the bone stock available in that region and would palliate, but not address, any underlying malformation of the proximal tibia.

Thorough evaluation of the morphology of the tibia in a larger population of dogs with LPL appears warranted to further define the treatment options for patella baja in affected dogs. We believe that the measurements we describe may better estimate the indication and extent of a proximodistal transplantation of the tibial tuberosity during surgical correction of patellar luxation in dogs. This may, in the future, reduce the frequency of recurrence after surgical treatment of this condition. Although our results support an association between proximodistal malalignment of the patella (patella alta versus baja) and the side of patellar luxation (medial versus lateral), the retrospective nature of our study precludes any conclusion about the primary versus secondary nature of these changes. Early evaluation of immature dogs with patellar luxation may help further elucidate the contribution of proximodistal malalignment of the patella as a cause of patellar luxation.

Preoperative measurement of modified PLL:PL and A:PL is recommended in dogs with patellar luxation and surgical correction should be considered in those with abnormal values. Medium to giant-breed dogs with
PLL:PL values > 2.06 or A:PL values > 2.03 are considered to have patella alta, whereas dogs with A:PL values < 1.92 are considered to have patella baja. MPL is associated with patella alta, whereas LPL is associated with patella baja. Patella alta is associated with an increased PLL, whereas patella baja is associated with an increased PTL. A thorough evaluation of the proximal tibia is recommended in dogs with LPL because dogs with PTL:DTW values > 1.65 are considered at high risk for developing patella baja.

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