Radiographic measurement for femoral varus in Pomeranian dogs with and without medial patellar luxation

C. Soparat; C. Wangdee; S. Chuthatep; M. Kalpravidh
Department of Surgery, Faculty of Veterinary Science, Chulalongkorn University, Bangkok, Thailand

Keywords
Femoral varus, Pomeranian dog, patellar luxation, dog

Summary
Objectives: To measure radiographically the inclination angle (ICA), femoral varus angle (FVA), anatomical lateral distal femoral angle (aLDFA), and mechanical lateral distal femoral angle (mLDFA) in Pomeranian dogs with and without medial patellar luxation (MPL).

Materials and methods: Stifles of 34 Pomeranian dogs were graded and allocated into three groups: normal, grades I-II MPL, and grade III MPL. Angle values were measured from craniocaudal radiographs of the hindlimbs by each of the three examiners on three separate occasions.

Results: Each of the three groups consisted of 15 stifles. Means ± SD for the ICA, FVA, aLDFA and mLDFA in the normal stifles were 136.46 ± 7.12°, 5.85 ± 3.18°, 95.21 ± 3.48° and 99.46 ± 4°, respectively. No significant differences (p >0.05) in the measured values for the ICA between groups were observed. The FVA, aLDFA and mLDFA values in grade III MPL group were significantly (p <0.05) greater than those in the other two groups. Significant differences in the three angles between the normal and grades I-II MPL groups were not observed.

Clinical significance: Significant change of distal femoral varus exists in Pomeranian dogs with grade III MPL.

Introduction
Distal femoral varus is defined as angulation of the distal femur toward the body midline, and is one of many skeletal abnormalities associated with medial patellar luxation (MPL). Excessive distal femoral varus moves the long axis of the quadriceps femoris muscles medial to the trochlea, contributing to MPL. Persistent pressure on the distal femoral physis generated by the luxated patella aggravates deformities of the femur (1). Though multiple surgical techniques for correction of MPL have been described, relaxation is reported in as many as 48% of cases (2). Recent focus on the treatment of MPL in large-breed dogs is centred on femoral malalignment secondary to excessive femoral varus, which requires corrective osteotomy (3–8). Femoral varus may be radiographically evaluated from either the femoral varus angle (FVA) or the anatomical lateral distal femoral angle (aLDFA) (9–12). Although many surgeons agree that excessive femoral varus coupled with MPL should be corrected, the criteria for corrective osteotomy are still unclear (3–8). It has been recommended that femoral varus deformities in large-breed dogs with MPL be corrected when the FVA equals or exceeds 10° or 12° or the aLDFA value is greater than 102° (3–5, 8).

The normal ranges for femoral angles in humans are used as reference values to determine the degree of angular deformity, type and degree of correction needed, and postoperative evaluation (13). Similar to humans, reference values for femoral angles in dogs may be used to determine the degree of deformity for which surgical correction is indicated. However, one limitation of this approach is that reference values for the normal femoral angles in dogs are mostly reported for the large breeds (9–11). While MPL is more prevalent in small-breed dogs, there is only one report of the femoral angles in normal femora, and one in femora with MPL (14–17). Most normal canine femora have some degree of varus shape, and there are probably breed variations in femoral angles (10, 11). Therefore, studies focusing on conformational factors predisposing dogs to patellar luxation should assess small-, medium- and large-breed patient groups separately (18). The aim of the present study was to determine radiographic values for the inclination angle (ICA), FVA, aLDFA, and mechanical lateral distal femoral angle (mLDFA) in Pomeranian dogs with and without MPL. Our hypothesis was that significant difference in distal femoral varus exists in Pomeranian dogs with MPL compared to normal Pomeranian dogs.

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**Materials and methods**

**Animal inclusion criteria**

Based on the MPL classification of Piermattei et al., stifles of 34 Pomeranian dogs were graded and allocated into three groups: normal, grades I-II MPL, and grade III MPL (7). The normal group consisted of orthopaedically normal stifles. The grades I-II MPL group included stifles with the patella staying in the trochlea but easily luxated manually at full extension of the stifle joint (grade I), or when the foot was internally rotated while the patella was pushed (grade II). The grade III MPL group consisted of stifles with the patella located out of the trochlea most of the time and deviation of the tibial crest between 30° and 60°. For bilateral MPL to be included in the study, both stifles had to have the same grade of luxation. Age, weight, sex, MPL grades and the affected stifles of the animals were recorded.

**Radiography**

Radiographs were obtained with dogs under light anaesthesia following premedication with acepromazine (0.03 mg/kg IM) and tramadol (3 mg/kg IM), induction with propofol (2–4 mg/kg IV), and maintenance with isoflurane in oxygen. Dogs were positioned in dorsal recumbency with lateral padded support, both tibias were grasped, and the hips were extended to get the femora parallel to the table and the pelvic long axis. Craniocaudal radiographic views were obtained with the beam centred at the mid-diaphysis and reviewed for proper positioning: that is the femora were parallel to the long axis of the pelvis, the patella was centred (if not luxated) within the trochlea, the fabellae were bisected by their respective femoral cortex, and the tip of the lesser trochanter was visible at the medial aspect of the femur (9, 19) (Fig. 1). For the grade III MPL group in which the patella was permanently located outside the trochlea, it was impossible to see the patella within the trochlea. However, the well-positioned radiograph had to reveal parallel lines of the vertical walls of the intercondylar notch (19).

**Radiographic measurements**

The ICA, FVA, aLDFA and mLDFA were measured on each craniocaudal radiographic view by three examiners (a radiologist and two surgeons) on three separate occasions using a computer image programme. The proximal femoral long axis (PFLA) was drawn by connecting two or three central points of the proximal femoral diaphysis 1 cm distal to the lesser trochanter and 1 cm apart distally (10). The ICA was formed between the PFLA and the line connecting the bisection points of the femoral head and neck (Fig. 2). The transcondylar axis (TCA) was drawn tangential to the distal articular surface of the femoral condyles. A line drawn perpendicular to the TCA and bisecting the intercondylar notch defined the distal femoral long axis (DFLA). The FVA was defined as the angle formed between the PFLA and DFLA. For measurement of aLDFA, a line was drawn from the proximal to the distal femur through the centres of the proximal third and midshaft of the femur; the aLDFA was the angle formed between this line and the TCA. A line was drawn from the centre of the femoral head to the centre of the inter-

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![Fig. 1](A) Cranio-caudal radiographs of stifles of Pomeranian dogs in (A) grades I-II MPL and (B) grade III MPL groups showing the femur parallel to the spinal or pelvic long axis, the fabellae bisected by the femoral cortices, parallel lines of the vertical walls of the intercondylar notch, and the patella localising within (A) or outside (B) the trochlea.
condylar fossa; the mLDFA was the angle formed between this line and the TCA.

 Statistical analysis

An analysis of variance (ANOVA) was performed and values of p < 0.05 were accepted as significant for determining the difference between groups relating to animal age, weight, and the values for the four femoral angles measured by the three examiners. Within the group, the values for each femoral angle measured by each of the three examiners were compared. Following ANOVA, the least significant difference test was used to indicate the mean value in which groups differed from another group. The 95% confidence intervals of the mean values for the four femoral angles, and correlations of animal age and weight with the measured values for each femoral angle were determined.

 Results

The number of dogs and the distribution of sexes in each group were not different between groups. Values shown following each range value below are shown as ‘mean ± standard deviation (SD); median’.

The normal group consisted of 15 normal stifles (left: n = 5; bilateral: n = 5) in ten dogs (females: n = 4; males: n = 6), with an age range from 3 – 48 months (12.60 ± 13.83; 8 months) and a body weight range of 1.60 – 2.80 kg (2.14 ± 0.41; 2.15 kg).

The grades I-II MPL group consisted of 15 stifles (right: n = 5; left: n = 6; bilateral: n = 2; grade I: n = 8; grade II: n = 7) in 13 dogs (female: n = 6; male: n = 7), with an age range from 3 – 69 months (17.69 ± 18.42; 13 months) and a body weight range of 1.70 – 6.20 kg (3.55 ± 1.51; 3.10 kg).

The grade III MPL group consisted of 15 stifles (right: n = 3; left: n = 4; bilateral: n = 4) in 11 dogs (female: n = 6; male: n = 5), with an age range from 5 – 132 months (33.73 ± 40.68; 9 months) and a body weight range of 1.65 – 3 kg (2.31 ± 0.45; 2.10 kg).

Significant differences in animal age between groups were not found. The body weight of the dogs in grades I-II MPL group was significantly greater than those in the other two groups. The correlations of the animal age (r <0.45) and body weight (r <0.2) with the measured values for the four femoral angles were not significant.

Table 1 shows ranges, medians and means (45 measurements of the three examiners) for the ICA, FVA, aL DFA and mL DFA in all three groups, and the 95% confidence intervals of the mean values for the four femoral angles. No significant differences were found between the mean values measured by the three examiners. The median value for each angle was close to the mean value. No significant differences between groups in the ICA values were observed. The mean values for FVA, aL DFA and mL DFA in grade III MPL group were significantly greater than those in the other two groups. There were no significant differences in the mean values for the latter three angles between the normal and grades I-II MPL groups.

 Discussion

The present study reports values for the femoral angles for the Pomeranian dog, which has a high prevalence of MPL at our institution. This breed, along with the Yorkshire Terrier, Chihuahua, Miniature and Toy Poodle, and Boston Terrier, has a significantly increased risk for patellar luxation (14). Reference values for distal femoral angles will probably prove to be more useful than values for proximal angles because most deformities occur in the distal femoral context.
In the present study, severity of MPL was not increased with animal age. There was no significant difference of the age of Pomeranian dogs between the groups and no significant correlation of age or body weight with any of the measured values for the four femoral angles. However, the mean weight of the dogs in grades I-II MPL group was significantly greater than that of the dogs with a more severe grade (grade III MPL group). Though our data did not provide strong evidence that femoral angles could change with growth, further longitudinal studies of Pomeranian dogs with MPL should be done to determine if the femoral angles change with growth and aging. Recently, an increase in cartilage erosion of the patella was found to accompany an increase in MPL grade, and the erosion amount did not have a correlation with age, but was significantly greater in heavier dogs and dogs with grade IV MPL (20).

Coxa vara is one of the pathologic anatomical features that may be associated with MPL (7). In contrast, another study has found that coxa valga appears to be associated with MPL in small-breed dogs (21). The present study found no significant differences in the mean values for the ICA between the normal stifles and MPL stifles to indicate the presence of either of these two pathologic features. Therefore, ICA may not have a relation with the pathophysiology of MPL in Pomeranian dogs. Although the mean values for FVA, aLDFA and mLDF are significantly different between some groups in our study, another report of pooled data from eight Poodles, five miniature pinchers, two crossbreed dogs, a Yorkshire Terrier, a Cocker Spaniel, and an Australian Cattle dog found no significant differences of the ICA and FVA among four grades of MPL (17). The latter report did not describe the positioning technique which, with breed variations, could affect the different findings. The mean ICA value of grades I-II MPL group was greater than those reported for grades I, II and III MPL, but comparable to that reported for grade IV MPL (17). The latter report did not describe the positioning technique which, with breed variations, could affect the different findings. The mean ICA value of grades I-II MPL group was greater than those reported for grades I, II and III MPL, but comparable to that reported for grade IV MPL (17). The latter report did not describe the positioning technique which, with breed variations, could affect the different findings.

### Table 1

**Ranges, medians and means (45 measurements) for the inclination angle, femoral varus angle, anatomical lateral distal femoral angle, and mechanical lateral distal femoral angle of 15 stifles each in the normal, grades I-II MPL, and grade III MPL groups from 34 Pomeranian dogs.**

<table>
<thead>
<tr>
<th>Group</th>
<th>ICA (°)</th>
<th>FVA (°)</th>
<th>aLDFA (°)</th>
<th>mLDF (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>121.72 – 151.10</td>
<td>2 – 12.68</td>
<td>90 – 103.29</td>
<td>91.70 – 109.73</td>
</tr>
<tr>
<td>Median</td>
<td>136.33</td>
<td>5</td>
<td>95.11</td>
<td>99.28</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>136.46 ± 7.12</td>
<td>5.85 ± 3.18 a</td>
<td>95.21 ± 3.48 b</td>
<td>99.46 ± 4 a</td>
</tr>
<tr>
<td>95% CV</td>
<td>134.32 – 138.60</td>
<td>4.90 – 6.81</td>
<td>94.16 – 96.25</td>
<td>98.26 – 100.66</td>
</tr>
<tr>
<td><strong>Grades I-II MPL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>125.60 – 148.31</td>
<td>3.29 – 16.00</td>
<td>90.85 – 106.31</td>
<td>94.92 – 109.39</td>
</tr>
<tr>
<td>Median</td>
<td>135.20</td>
<td>10</td>
<td>98.53</td>
<td>101.64</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>136.76 ± 6</td>
<td>9.38 ± 3.73 a</td>
<td>98.88 ± 3.87 a</td>
<td>101.65 ± 3.14 a</td>
</tr>
<tr>
<td>95% CV</td>
<td>134.96 – 138.57</td>
<td>8.26 – 10.51</td>
<td>97.72 – 100</td>
<td>100.71 – 102.60</td>
</tr>
<tr>
<td><strong>Grade III MPL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>125.35 – 158.47</td>
<td>5.31 – 36</td>
<td>95.96 – 126.34</td>
<td>96.76 – 114.49</td>
</tr>
<tr>
<td>Median</td>
<td>139</td>
<td>12.80</td>
<td>102</td>
<td>103.65</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>139 ± 9</td>
<td>13.15 ± 5.50 b</td>
<td>103.24 ± 5.92 b</td>
<td>104.48 ± 4.36 b</td>
</tr>
<tr>
<td>95% CV</td>
<td>136.34 – 141.76</td>
<td>11.49 – 14.81</td>
<td>101.46 – 105</td>
<td>103.17 – 105.79</td>
</tr>
</tbody>
</table>

Key: ICA = inclination angle; FVA = femoral varus angle; aLDFA = anatomical lateral distal femoral angle; mLDF = mechanical lateral distal femoral angle; MPL = medial patellar luxation; 95% CV = 95% confidence intervals of the mean values. Mean values in the same column that have different superscript lower case letters are significantly different (p <0.05).
A recent study found that differences in the FVA, anatomic lateral proximal femoral angle, aLDFA, mechanical lateral proximal femoral angle, and mL DFA between normal femora and femora with grade III MPL in small-breed dogs were not significant (22). According to findings of two reports, corrective osteotomy may not be required in small-breed dogs with grade III MPL (17, 22). However, the FVA and aLDFA of the stifles with grade III MPL in the present study were significantly greater than those of the normal stifles, and the values are close to those recommended for corrective osteotomy in the large-breed dogs (3–5). Therefore, our findings and the reported incidence rate up to 48% of MPL relocation after traditional surgical treatments would suggest that distal femoral osteotomy should be performed in Pomeranian dogs with excessive femoral varus (2). Moreover, torsions of the femur and tibia should be identified before a treatment plan is devised (19). Failure to correct femoral and tibial malalignments is proposed to be one cause of the relocation (3, 4).

Acknowledgements

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Conflict of interest

None declared.

References

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