The prevalence of canine patellar luxation in three centres
Clinical features and radiographic evidence of limb deviation

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Introduction
Patellar luxation (PL) is a frequently diagnosed developmental orthopaedic condition and is considered to be one of the five most important hereditary defects in dogs (1). The current view is that small breeds are more commonly affected than large dogs (2–4). Medial patellar luxation (MPL) has been identified more commonly than lateral luxation (LPL) in all breeds, although LPL has been frequently associated with larger breeds (2, 3).

There are a number of studies which speculate on the aetiology of PL in both small and large breeds (4–6). It is possible that PL in small and large breeds has a different aetiology, although there is a lack of evidence to support this in the literature. It has been suggested that the aetiology of MPL is related to a decreased angle of inclination (AOI) of the femoral neck (coxa vara) (2, 4, 7). This significantly affects the eventual conformation of the limb, leading to a genu varum; a medial bowing of the distal third of the femur, and compensatory distortion of the proximal third of the tibia (2). These defects result in stifle malformation and PL (4).

The objective of this paper was to expand upon previous knowledge regarding the prevalence, and to provide evidence of the conformational changes that drive PL. There were two parts to this study. The first hypothesis is that although the incidence of PL in dogs over 25 kg is increasing, LPL is not increasing. The purpose of this study was to evaluate the prevalence of PL in dogs treated at a first opinion practice, an orthopaedic referral centre and a university referral centre (breed, sex, age at diagnosis, medial or lateral luxation, concurrent orthopaedic problems).

The second hypothesis is that MPL in both small and large breeds is associated with coxa vara and genu varum. The AOI of the femoral neck was measured along with the degree of distal femoral and medial tibial bowing in order to give an insight into the conformational changes that predispose to the condition.

Materials and methods
Prevalence data collection
The medical records for all of the dogs with PL that were examined at a first opinion centre (Practice 1), an orthopaedic referral centre (Practice 2) and a university small animal hospital (Practice 3) in the period June 2001 to June 2005 were reviewed. Breed, weight, age at onset of clinical signs, the limb affected, whether the luxation was medial or lateral, and any concurrent hind-limb orthopaedic conditions were recorded for all of the dogs with patellar luxation with a complete set of stifle radiographs. The aetiology of the luxations was assumed to be congenital/developmental, unless there was a clear history of related trauma, in which case the dogs were excluded.

The breeds were divided up into four categories according to Kennel Club standards for weight as described in previous studies (1, 3): small breed, 9 kg and less; medium, 9.1 to 18.2 kg; large, 18.3 to 36.4 kg; and giant breed, 36.5 kg and over. Mixed breed dogs were also included in the study, and placed in the appropriate category on the basis of their weight. Puppies or adolescent...
dogs were classified according to their adult target weight.

**Measurements of femoral and tibial conformation**

Measurements were obtained from original radiographs relating to AOI and medial bowing of the distal femur and proximal tibia. Only radiographs appropriately positioned were used in the study. All of the radiographs included the stifle, on some it was included on the ventrodorsal hip radiographs, and on others it was radiographed separately. The stifle radiographs were classed as appropriately positioned if they were a true craniocaudal view where you can see the intercondylar notch and see two condyles without superimposition. As this study uses a population of dogs including a large group with PL, it would not have been possible to obtain a group of radiographs as consistently positioned as in the study by Tomlinson et al. (9).

**Angle of inclination**

In each of the cases where appropriately positioned hip radiographs were available, the AOI was calculated using the previously reported standardised method of measurement (10, 11). All of the hip radiographs fulfilled the inclusion criteria according to the paper by Montavon et al. (11). It has been established from this study (11) that the normal range of AOI measured from craniocaudal views of the femur is 140.5–156.5°. In this study, the range of AOI from dogs with PL was compared to this normal set of values. The measurement of AOI is dependent on the degree of femoral rotation, and, as this can vary considerably in a ventrodorsal radiograph of the hips and pelvis, the reliability of this measurement was tested by comparing pre- and postoperative radiographs from a group of patellar luxation cases.

**Femoral bowing**

Bowing of the distal femur was calculated by determining the angle between the axis of the femoral shaft and the condylar surface. From a craniocaudal view of the stifle, a line was drawn connecting the most distal parts of the medial and lateral femoral epicondyles (Fig. 1, Line A). Line B was drawn connecting the narrowest part of the diaphysis, perpendicular to the long axis of the femur. If the radiograph did not include the narrowest part of the femur, the line was drawn as far proximal as possible. Halfway between Lines A and B, Line C was drawn parallel to Line B. The centre of Lines B and C were connected by another Line, D. Where Line D bisects Line A, Angle \( \alpha \) was formed (Fig. 1).

**Tibial bowing**

The conformation of the tibia was assessed from the craniocaudal view of stifle. Line E was drawn connecting the most proximal parts of the medial and lateral condyles. Line F was drawn between the narrowest parts of the cortices on the tibial shaft. A large proportion of stifle radiographs did not extend to the mid shaft of the tibia, hence a different method of obtaining a line perpendicular to the long axis had to be employed. If the radiograph did not include the narrowest part of the tibia, Line F was drawn as far distal as possible. A line perpendicular to Line F was drawn (Line G). Line H was drawn perpendicular to Line G and consequently parallel to Line F at the level of the lateral condyle. Angle \( \gamma \) was formed where Line H bisects Line E. In cases where Angle \( \gamma \) was less than 0° it was assigned a negative value in the statistical analysis (Fig. 2).

Since there was not any available published data on the degree of bowing of the normal stifle, a control group of dogs was set up. A group of dogs (n=42) diagnosed with CrCL rupture at Practice 3 over a period of 3 months from April to July 2005 were reviewed. The stifles were measured using the method as described above. Dogs with concurrent PL were excluded from the study.

**Sample size**

In order to determine the number of dogs required to produce a statistically significant result, a sample size calculation was per-
formed on estimations of variation of data relating to stifle angles for both groups of dogs with PL from Practice 2 and CrCL rupture. The power required was taken to be 80% and the significance level 0.05. From an Altman’s nomogram, the sample size required to investigate angle $x$ for dogs with PL was found to be 50 and 22 for CrCL rupture. The number of dogs required in order to calculate angle $y$ was 80 in the case of dogs with PL and 12 for dogs with CrCL rupture. Since 95 dogs with PL and 42 with CrCL had this data available, these targets were met.

**Statistical analysis**

**Prevalence**

Breed categories from each practice were presented in a histogram. Due to the large number of breeds that were represented, only those with four or more animals were presented individually; the remainder were separated into breed size categories. Since the number of dogs from each practice were different, the percentage of dogs of each breed was used.

**Angle of inclination**

The reliability of measuring the AOI was assessed using the repeatability coefficient. Any postoperative hip radiographs had the AOI compared to the preoperative films using a paired t-test to test for any bias present. Since the anatomical AOI cannot be changed by stifle surgery, the repeated measurements should be identical. The British Standards Institution (BSI) repeatability coefficient was calculated for the measurements before and after surgery. Assuming a normal distribution, 95% of the differences in the population should lie within the limits of agreement (mean difference ± 2 SD). This provided information regarding whether the agreement between pairs of readings was acceptable.

The AOI of dogs with PL was compared to the normal range as reported in previous studies (140.5–156.5°) (11). Angles greater than 156.5° are associated with coxa valga, and the risk of different characteristics (breed and sex) was assessed by odds ratios (OR) comparing the number of femurs with coxa valga to those without.

The weight of each dog was compared to its AOI using a scatter plot and a Pearson’s product moment correlation coefficient (correlation coefficient) in order to assess for any positive or negative correlation.

**Femoral and tibial bowing**

The distribution of the data from the dogs with PL and the control group was assessed for normality using the Kolmogorov-Smirnov test. The group of dogs with CrCL rupture was compared to those with PL using a Mann-Whitney U Test in order to compare the medians of angles $x$ and $y$.

The weight of each dog was compared to its $x$ and $y$ angles on a scatter plot and a correlation coefficient was calculated to check for any relationship.

**Results**

**Prevalence**

One hundred fifty-five dogs were studied in total, 24 from Practice 1, 87 from Practice 2 and 44 from Practice 3 (Fig. 3, Table 1).

The greatest group of dogs were large breeds (n=62). Fifty-seven dogs were small breeds, 33 were in the medium category and three were giant breeds.

Fifty-four percent of dogs with PL were female; 40 were entire and 43 were neutered. Seventy-two male dogs were affected in total with 42 of these being castrated. The male:female ratio at Practice 1 was 12:12; at Practice 2 it was 35:52, and at Practice 3 it was 25:19.

The mean age at diagnosis was 26 months. The dogs were diagnosed earlier at Practice 2 (13 months). A diagnosis was made at 24 months at Practice 3, and at 42 months at Practice 1.

Most of the luxations were medial (n=142). Of the 14 dogs with lateral luxations, one was a small breed dog, two dogs were medium, five were large, two were giant, and two of the patients were of mixed breed.

Data relating to concurrent pelvic limb orthopaedic disorders was only fully avail-
able from Practice 2 where it was present in 15 dogs. Six cases had hip dysplasia or laxity; six had concurrent CrCL instability or rupture, and three were affected by another condition. Hip dysplasia was diagnosed on radiographs and was associated with LPL in only one dog; the other three dogs with LPL did not display any signs of hip pathology.

**Angle of inclination**

The measurement technique for AOI was assessed using the repeatability coefficient. A paired t-test showed little or no evidence against the null hypothesis (the t statistic was 1.596). The BSI repeatability coefficient was 17.98 and the limits of agreement were -12.55 and 23.41. A scatter plot comparing the difference between each pair of readings and the mean of the two values did not reveal any relationship. This suggested that the measurement technique was unreliable in an individual basis.

One hundred seventy-eight femurs had data relating to AOI. There were 69 femurs within the normal range (140.5–156.5°) (11). AOI data was only available for one dog from Practice 1; the angle was 145°. The mean AOI for dogs at Practice 2 was 159° and the range was from 130 to 182°. At Practice 3, the mean AOI was taken to be 140° with a range of 130° to 150°.

Ten femurs were below the lower limit of normal (140.5°) and 99 femurs lay above the upper limit. From this data, the risk of having an angle greater than 156.5° (i.e. coxa valga) was compared to each breed category (Table 2). Most risk was associated with small breeds and giant breeds had the least risk. The risk of being female and having coxa valga was 1.285 (Confidence Intervals [CI] 0.69, 2.39), which suggests a sex association.

Since Labradors were the breed most commonly affected by PL, an OR was implemented in order to assess the risk of this particular breed with coxa valga. A value of 0.429 (CI 0.206, 0.895) was obtained, which indicates that Labradors are not associated with an increased AOI.

The correlation of weight to AOI was assessed using a scatter plot for Labradors only. A mild positive correlation was achieved when the correlation coefficient was calculated (0.07). This was not significant at the 0.05 level.

**Femoral bowing**

A scatter plot and correlation coefficient relating to weight and angle x for Labradors revealed a mild positive relationship (0.097), which was not significant at the 0.05 level.

A set of ‘normal’ angles was established using the dogs with CrCL rupture. The range was 62 to 90° for angle x with an average of 84°. The data from the dogs with PL had a range of 42 to 119° and a median of 78°. A Kolmogorov-Smirnov test indicated that the results violated the assumption of normality, hence a Mann-Whitney U Test was used. The two sets of measurements were significantly different (P<0.001).

**Tibial bowing**

A scatter plot and correlation coefficient relating to weight and angle y data suggested a mild positive correlation producing a value of 0.14. However, this was not significant at the 0.05% level (2 tailed).

The tibial (angle y) range in the dogs with CrCL rupture was from -4 to 10° with an average of 3°. The median of angle y in dogs with PL was 5° and the range extended from ~20 to 28°. A Kolmogorov-Smirnov test revealed that the results were not normally distributed. A Mann-Whitney U Test using the CrCL data found the two sets of data to be significantly different (P<0.001).

**Discussion**

In this study, Labradors, and large breeds in general, were overrepresented as in other studies (8). Moreover, the distribution of breeds is similar from primary to referral centres. Despite the high numbers of large breed dogs, MPL dominated the clinical picture. Coxa valga appears to be associated with PL in small dogs, but did not appear to be a problem in the largest group of large dogs (Labradors).

Owing to the retrospective nature of this study, and having to rely on medical records, there were limitations and consequently potential areas for improvement. The clinical rational for the femoral radiographs was to assess the position of the patella and to rule out any significant orthopaedic problems. As a result, the radiographic views may not have been those required for AOI measurement technique (11) or for measuring genu valgus. Although the dogs were anaesthetised for both pre- and postoperative measurements, it is possible that differing degrees of tone and muscle relaxation could have contributed to the variability between angles. On some radiographs, it was not possible to visualise the entire femur nor to assess its contribution to valgus or varus deformity. Despite variability, which may have been produced by using clinical radiographs, and which may not always have been perfectly reproducible, there was still a significant difference in valgus deformity. The agreement of AOI measurements from pre- and postoperative radiographs was unreliable. During surgery, it is unlikely that the alignment of the limb could have been altered. However, when the postoperative films were taken, the radiographic positioning may have been altered slightly, thus leading to differences in AOI measurements. The clinical significance is that it would not be possible to reliably measure the AOI and relate that to the probability of a dog developing PL. Although the technique was unreliable on an individual basis, the trend showed that a high proportion of small dogs with PL also had coxa valga.

Radiographic positioning will influence both AOI and those angles of deviation of the femur and tibia. Mild differences in radiographic technique between the practices have the potential to have a slight impact on the data. The collection of data from the same establishment could limit these differences although it would reduce the

<table>
<thead>
<tr>
<th>Breed</th>
<th>OR</th>
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<tr>
<td>Small</td>
<td>2.355</td>
<td>1.21, 4.59</td>
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<tr>
<td>Medium</td>
<td>0.331</td>
<td>0.12, 0.93</td>
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<tr>
<td>Large</td>
<td>0.479</td>
<td>0.25, 0.91</td>
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<tr>
<td>Giant</td>
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<td>Invalid</td>
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<tr>
<td>Mixed</td>
<td>1.065</td>
<td>0.41, 2.7</td>
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prevalence information. In addition, there were certain cases with PL where the ventrodorsal view of the pelvis included the stifle and there were not any additional cranio-caudal stifle views. Since the view of the pelvis would have the primary beam centered on the hips, there may be implications on the femoral and tibial angles, however, the majority of cases had separate cranio-caudal views of the stifle.

The ‘normal’ group of dogs, from which a set of femoral and tibial measurements were taken, were CrCL patients; therefore they may not be totally distinct from PL dogs. There have been links drawn between CrCL rupture and PL in the literature due to the conformational changes associated with the condition (2, 5, 12). Although it is possible that CrCL rupture is related to the onset of PL, it seems unlikely that the same confirmation drives both conditions. In this study, the conformation of the distal femur and proximal tibia in the PL dogs were significantly different to those with CrCL rupture, thus indicating that there is a genuine difference in conformation. Dogs without any hindlimb orthopaedic pathology would provide a superior control group and could be investigated further.

From a prevalence point of view, a control population would be useful. A case-control study would allow odds ratios to be calculated for sex, breed, and age at diagnosis comparing the dogs with PL to a normal population. This would allow risk factors to be identified for both medial and lateral PL. These results could be compared more scientifically to previous case-control surveys, such as that performed by Hayes et al. (3).

The most important finding in terms of prevalence was the high number of Labradors with PL. This contrasts with a number of previous studies which have shown that large breeds are at less risk (1, 6, 13–16), and conflicts with a 1972 survey which discovered that Labrador Retrievers are at low risk (1), however, it is in agreement with the 2006 study (8). One possible explanation could be that the popularity of this breed has increased. The Kennel Club reported that the most popular dog breed registered in 2005 were Labradors (17). Although the risk of disease may be low in this breed, more Labradors in the population may result in a higher number being diagnosed with PL. In addition, certain breeds may be more common in certain areas, e.g. Staffordshire Bull Terriers in urban areas, therefore the prevalence of PL may be altered by geographical location.

The first opinion centre saw a higher proportion of small breed dogs than the referral centres (Fig. 3). It is possible that referral centre case loads may not be an accurate representation of the overall population. Many first opinion practices may diagnose and treat PL without the need for referral and it may be that such practices see more small breeds. However, even in the first opinion practice the largest single group was the Labrador.

Females appear to be at a greater risk of developing PL than males, which concurs with previous studies (1). In contrast, a recent study of large breed dogs (8) reported a male: female ratio of 1.8:1 and suggested that PL may be more common in male large breed dogs and female small breed dogs. One explanation could be that females are overrepresented in the study population, a fact that could have been eliminated if there had been a control group. However, hormonal factors or genetic links could influence the development of the condition (1,14).

This study found that less than 8% of dogs had LPL and supports the hypothesis that although PL in large breeds is increasing, LPL is not. Studies conducted over 10 years ago (3) show that 11% of dogs had lateral luxation. In this study, MPL was common in all breeds. Previously, MPL was considered to be a small dog problem and LPL was associated with larger breeds (2–4). PL in large breeds was thought to be associated with coxa valga (2, 16) and in small dogs there was a lack of real evidence explaining the cause of the condition. In this study, the majority of dogs had normal hip conformation or coxa valga yet they were largely affected by MPL. This contradicts previous theories that coxa valga is related to LPL and that coxa varus is related to MPL. Additionally, the results showed that the lower the weight of the dog, the greater the degree of coxa valga. This conflicts with previous authors who have linked MPL with deformities, such as coxa varus and genu varum (2, 16) Therefore, it is a possibility that the anatomical deformities that cause MPL are a stifle problem only.

There was a significant difference in stifle conformation between dogs with PL and a control population. The range of angles measured was greater for both angle $x$ and $y$ in dogs with PL. In particular, the median of angle $x$ was much smaller in dogs with PL, which suggests that medial bowing of the femur is a feature of the condition. Angle $y$ in the control dogs had a narrower range and a lower median than dogs with PL. If there were not any conformational deviations, the mean should be close to zero and so an association can be drawn between dogs with PL and tibial bowing. It is difficult to ascertain whether the PL is a cause or a consequence of the stifle deviation.

To conclude, the incidence of PL in large breed dogs is increasing and luxation is most commonly medial. This supports the first hypothesis and demonstrates that the prevalence of the condition is changing, and is probably related to the increasing proportion of Labradors within the breed population. Clinicians should consider PL as a common differential for stifle conditions in large dogs, particularly in Labradors. There have been many papers in the past that have speculated on the prevalence of PL, including a recent account by Gibbons et al. (8). However, this paper used dogs from one centre only and has no data regarding the aetiology of the condition. This paper contains information from three different centres which offers a large and diverse population of dogs. By identifying risk factors in larger breed dogs, the diagnosis and treatment of the condition can be enhanced.

This study indicated that coxa valga is a risk factor in all breeds which is statistically significant in small breeds. This disproves the second hypothesis of the aetiology of MPL in relation to coxa vara. There was a significant difference in the conformation of the stifles of dogs with PL compared to control dogs, which confirms the hypothesis relating to genu varum. It appears that coxa valga and genu varum are associated with the aetiology of MPL and there is no evidence for coxa valga being particularly as-

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sociated with LPL in large dogs. By identifying radiographic features, dogs may be identified as being ‘at risk’ before any clinical signs are evident, hence there is the possibility that a screening program could be implemented. This would prevent any animals with a conformation significantly predisposing them to PL from breeding, therefore limiting the hereditary component of the condition.

References


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