Vertical position of the patella in the stifle joint of clinically normal large-breed dogs

Allen L. Johnson, DVM; Curtis W. Probst, DVM; Charles E. DeCamp, DVM, MS; Diana S. Rosenstein, DVM; Joe G. Hauptman, DVM, MS; Tari L. Kern, DVM

Objective—To define the vertical position of the patella in clinically normal large-breed dogs.

Sample Population—Cadavers of 13 clinically normal large-breed dogs.

Procedure—Both hind limbs were harvested with intact stifle joints and mounted on a positioning device that allowed full range of motion of the stifle joint. Lateral radiographic views were obtained with the stifle joints positioned at each of 5 angles (148°, 130°, 113°, 96°, and 75°). Vertical position of the patella through a range of motion was depicted on a graph of mean stifle angle versus corresponding mean proximal patellar position (PPP) and distal patellar position (DPP) relative to the femoral trochlea for each dog. Ratio of length of the patellar ligament to length of the patella (L:P) was determined for each dog. Overall mean, SD, and 95% confidence intervals for L:P were calculated for all dogs.

Results—Evaluation of vertical position of the patella through a range of motion revealed a nearly linear relationship between joint angle and PPP and joint angle and DPP. Evaluation of L:P results did not reveal significant differences between limbs (left or right) or among joint angles. Overall mean ± SD L:P for all dogs was 1.68 ± 0.18 (95% confidence interval, 1.33 to 2.03).

Conclusions and Clinical Relevance—The L:P proved to be a repeatable measurement of vertical patellar position, which is independent of stifle angles from 75° to 148°. This measurement could be used as a quantitative method for diagnosing patella alta and patella baja in large-breed dogs. (Am J Vet Res 2002;63:42–46)

Abnormalities of the patellofemoral articulation are frequently observed in humans. Patella alta (proximal displacement of the patella within the femoral trochlear groove) has been associated with recurrent patellar dislocation, subluxation, chondromalacia, and pain in the anterior aspect of the knee. Many techniques have been used to describe the typical vertical position of the patella and to aid in the diagnosis of patella alta in humans. A widely used technique (Insall-Salvati technique) allows clinicians to assess patellar position on the basis of the ratio for the length of the patellar ligament to length of the patella. The patellar ligament is nonelastic throughout a passive range of motion; therefore, its length determines the position of the patella, assuming the tibial insertion is constant and that the patellar ligament is taut. The Insall-Salvati technique is reliable, simple to perform, and can be calculated with a single lateral radiographic view of the knee independent of knee flexion, size, or radiographic magnification.

To the authors’ knowledge, there has not been a description of typical vertical position of the patella in the stifle joint of dogs; therefore, patella alta in dogs has not been defined quantitatively. It is speculated that patella alta may play a role in patellar luxation in dogs. When the patellofemoral articulation is proximal to the femoral trochlear groove, the buttressing effects of the troclear ridges will be lost, resulting in an increased risk of luxation as the patella begins to move distally during flexion. When patella alta is suspected of being involved in patellar luxation, it has been recommended that the tibial tubercle be transposed distally as well as medially or laterally when performing a tibial tubercle transposition. Without a precise method of determining the characteristics that constitute patella alta, the diagnosis has been made solely on the basis of subjective clinical impressions.

The objective of the study reported here was to quantitatively define the vertical position of the patella within the femoral troclear groove throughout a physiologic range of motion in clinically normal large-breed dogs and develop an accurate simple measurement for vertical patellar position. Our hypothesis was that a technique similar to the Insall-Salvati technique could be used in dogs to determine the typical vertical position of the patella independent of stifle joint angle.

Materials and Methods

Sample population—Twenty-six stifle joints were obtained from the cadavers of 13 clinically normal large-breed dogs. The 13 dogs represented various breeds (3 Golden Retrievers, 2 Rottweilers, 2 Labrador Retrievers, 2 Dalmatians, and 4 mixed-breed dogs) and had a mean weight of 31.9 kg (range, 25.0 to 38.6 kg). The dogs were euthanized for reasons unrelated to the study. It was determined that the dogs did not have evidence of disease of the stifle joints on the basis of results of orthopedic examination and examination of radiographs of the stifle joints. Specimens consisting of femur, tibia, and intact stifle joints were harvested from the hind limbs of each cadaver. Soft tissues were dissected from the specimens, leaving only the joint capsule and ligaments of the stifle joint intact. The tendon of insertion of the quadriceps muscle was transected 1.5 cm proximal to the patella. Specimens were wrapped in a cloth moistened with isotonic saline (0.9% NaCl) solution and frozen at −7°C until time of testing.

Procedure—Paired specimens of the hind limbs from each cadaver were removed from the freezer and thawed at room temperature (20°C) for 12 hours prior to test-
ing. Paired specimens were mounted on 2 identical positioning devices designed by the investigators (Fig 1). Each positioning device consisted of 4 vertical 4.2-mm stainless-steel rods permanently fixed to an acrylic mounting plate. The mounting plate was bolted to an acrylic platform, which elevated the specimen to allow full range of motion of the stifle joint and intact tibia. The femur of each specimen was attached to the vertical rods of the positioning device in identical orientation, using two 3.2-mm transfixation pins and medium Kirschner-Ehmer single-connecting clamps (KE clamps). The transfixation pin in the distal portion of the femur was placed in a lateral-to-medial direction at a point 8 cm proximal to the center of the stifle joint; it then was attached to the 2 cranially positioned vertical rods of the positioning device, using KE clamps. The femur was positioned so that the angle between the femur and mounting plate was maintained at 32°, and the center of the stifle joint was positioned 12 cm above the base of the platform. The transfixation pin in the proximal portion of the femur was placed through the KE clamps and femur at the level of the 2 caudally positioned vertical rods of the positioning device to maintain the aforementioned femoral angle and joint position. Monofilament nylon suture (fishing line with a minimal tensile strength of 11.4 kg) was attached to the tendon of insertion of the quadriceps muscle, using a locking loop pattern. The opposite end of the nylon suture was placed through an eyebolt at the level of the proximal portion of the femur, and a standard weight (525 g) was attached to the suture in a manner that would prevent the weight from touching the positioning device as the stifle joint was placed through a full range of motion. This weight was used to simulate the force of the quadriceps muscle and to cause extension of the stifle joint. In a preliminary study, 525 g was determined to be the weight necessary to cause full extension of the stifle joint for our model. A 3.2-mm intramedullary pin was inserted in a lateral-to-medial direction across the distal portion of the tibia; the pin extended 2.0 cm beyond both cortices. A 4.8-mm wooden dowel and KE clamps were used to connect the pin in the distal portion of the tibia to the positioning device. This allowed the stifle joint to be positioned and maintained at various angles. During all phases of mounting and testing, stifle joints were sprayed with isotonic saline solution as needed to prevent drying of tissues.

Each stifle joint was positioned in each of 5 angles (148°, 130°, 113°, 96°, and 75°), and radiographs were obtained (Fig 2). Angles of the stifle joint were measured on each specimen by use of a goniometer and were determined by the angle formed from 3 points (center of the femoral greater trochanter, center of the lateral collateral ligament of the stifle, and center of the lateral malleolus of the tibia). A lateral radiographic view was obtained of each stifle joint at each angle, using a horizontal beam and appropriate radiographic settings (54 kilovolts peak, 3.2 MAS, and focal-film distance of 40 cm). Each radiograph was centered at the stifle joint and included the entire femur and tibia.

The various angles of the stifle joint were selected to allow evaluation of patellar position throughout a physiologic range of motion, as determined on the basis of kinematic data reported elsewhere.\(^18,19\) Angles of 148° and 113° are the typical maximal extension and flexion, respectively, of the stifle joint during walking in large-breed dogs,\(^18\) whereas angles of 150° and 96° are the typical maximal extension and flexion, respectively, of the stifle joint during trotting in large-breed dogs.\(^19\) The various angles of the stifle joint were selected to allow evaluation of patellar position throughout a physiologic range of motion, as determined on the basis of kinematic data reported elsewhere.\(^18,19\) Angles of 148° and 113° are the typical maximal extension and flexion, respectively, of the stifle joint during walking in large-breed dogs,\(^18\) whereas angles of 150° and 96° are the typical maximal extension and flexion, respectively, of the stifle joint during trotting in large-breed dogs.\(^19\)

---

**Figure 1**—Photograph of a dissected specimen of the stifle joint obtained from the cadaver of a clinically normal large-breed dog and mounted on a positioning device. A = Vertical rods. B = Acrylic mounting plate. C = Acrylic mounting platform. D = Standard weight of 525 g. E = Wooden dowel.

---

**Figure 2**—Lateral radiographic views of a representative stifle joint positioned at each of 5 angles. Notice the vertical position of the patella at stifle angles that are typical of dogs during walking and trotting.

---

**Figure 3**—Lateral radiographic view of a representative stifle joint positioned at an angle of 130° indicating the technique used for measurement of patellar position. TA = Trochlear axis. X = Distance from the proximal extent of the trochlear ridges to the proximal extent of the patella. Y = Distance from the proximal extent of the trochlear ridges to the distal extent of the patella. TL = Trochlear length. PPP = Proximal patellar position, calculated as X/TL. DPP = Distal patellar position, calculated as Y/TL. 0 = Proximal extent of the femoral trochlear ridges. 1 = Origin of the tendinous portion of the long digital extensor muscle.
Measurements of patellar position throughout a range of motion (patellar excursion)—For each radiograph, the patellar position along the femoral trochlea was determined (Fig 3). The actual angle of the stifle joint on each radiograph was measured, using a goniometer and the previously described anatomic points. A line (trochlear axis) was drawn through the proximal extent of the femoral trochlear ridges and origin of the tendinous portion of the long digital extensor muscle. Lines perpendicular to the trochlear axis were drawn at the proximal extent of the femoral trochlear ridges, proximal extent of the patella, distal extent of the patella, and origin of the tendinous portion of the long digital extensor muscle. Distance measured on the trochlear axis from the proximal extent of the femoral trochlear ridges to the origin of the tendinous portion of the long digital extensor muscle was defined as trochlear length (TL) of the femur. One value (X) was defined as the distance on the trochlear axis from the proximal extent of the femoral trochlear ridges to the proximal extent of the patella. This measurement was given a positive value when the proximal extent of the patella was proximal to the proximal extent of the trochlear ridges and a negative value when the proximal extent of the patella was proximal to the proximal extent of the trochlear ridges. Another value (Y) was defined as the distance on the trochlear axis from the proximal extent of the femoral trochlear ridges to the distal extent of the patella. Proximal patellar position (PPP) and distal patellar position (DPP) were defined by the ratio of the distance from the proximal extent of the femoral trochlear ridges to the proximal or distal extent of the patella, respectively, relative to TL. Therefore, PPP was equal to X/TL, and DPP was equal to Y/TL. On the basis of the aforementioned criteria, the point on the trochlear axis at the proximal extent of the trochlear length had a value of 0 (0/TL), whereas the point on the trochlear axis at the origin of the tendinous portion of the long digital extensor muscle had a value of 1.0 (TL/TL). All measurements were obtained in millimeters, using a digital caliper.

Measurement of the length of the patellar ligament and length of the patella—For each radiograph, the ratio of the length of the patellar ligament to length of the patella (L:P) was determined (Fig 4). Length of the patellar ligament was measured on the caudal aspect of the patellar ligament from the origin on the distal portion of the patella to the insertion on the tibial tubercle. Length of the patella was determined, using the measurement for the longest dimension of the patella. The L:P then was calculated for each specimen at all angles of the stifle joint. Again, measurements were obtained in millimeters, using the digital caliper.

Data analysis—Each value obtained from the radiographs was measured 3 times with the digital caliper. To evaluate data for the patellar excursion, mean angle of the stifle joint was plotted against corresponding mean PPP and DPP for each of the specimens at all 5 angles (ie, mean of right and left hind limb for each dog). The best-fit linear pattern and R² values were determined for PPP and DPP data, using a data analysis software program. The L:P data were analyzed, using a 3-factor ANOVA with fixed factors of limb (right or left) and angle of the stifle joint and the random factor of dog. Significance was set at a value of P ≤ 0.05. Mean L:P for each dog was determined by averaging the ratios of all angles for the stifle joints from both hind limbs. Overall mean ± SD L:P for all 13 dogs was calculated, and the 95% confidence interval (CI) was calculated as follows: 95% CI = mean L:P ± (1.96 × SD). Variances attributable to each factor were determined by setting the calculated mean square equal to the estimated mean square from the ANOVA table. Repeatability was determined by intra-class correlation.

Results

Patellar excursion—Mean value for angle of the stifle joint, PPP, and DPP was determined for each dog at all 5 angles of the stifle joint. Mean angle of the stifle joint was plotted on the x-axis, and corresponding mean PPP and DPP were plotted on the y-axis (Fig 5). Lines were nearly linear, with R² values of 0.96 and 0.94 for the PPP and DPP data, respectively. At typical
maximal extension of the stifle joint during walking and trotting (148°), the proximal aspect of the patella was found to be slightly proximal to the proximal extent of the trochlear ridges (mean PPP, –0.08). The proximal aspect of the patella moves distally approximately one-third the length of the femoral trochlea (mean PPP, 0.35) at typical maximal flexion (113°) during walking. The proximal aspect of the patella moves distally approximately one-half the length of the femoral trochlea (mean PPP, 0.52) at typical maximal flexion (96°) during trotting (Fig 2).

Analysis of L:P—Analysis of the data by use of the 3-factor ANOVA did not reveal significant differences in L:P between right or left limbs (mean value for both, 1.68) or among any of the 5 joint angles (range, 1.68 to 1.69). Because there was not a significant difference between limbs or joint angles, mean L:P for each of the 13 dogs was calculated by averaging the L:P of all joint angles in both hind limbs. Overall mean ± SD L:P for all dogs was 1.68 ± 0.18 (range, 1.37 to 1.92; 95% CI, 1.33 to 2.03). Variance attributable to dog was 0.032, whereas variance attributable to repetition was 0.00012. Repeatability of measurements was > 99%.

Discussion

Kinematic gait analysis of large-breed dogs during walking reveals that the typical angle of the stifle joint ranges from 113° to 148°, whereas analysis of large-breed dogs during trotting reveals that the typical angle of the stifle joint ranges from 96° to 150°. In the study reported here, radiographic views of the stifle joints were selected to simulate the position of the patella at maximal typical flexion and extension of the stifle joint of dogs during walking and trotting. An angle of 148° for the stifle joint was used to evaluate the patella at typical maximal extension during walking and trotting. It was believed that evaluation at 148° was sufficiently close to the reported value of 150° for typical maximal extension during trotting such that it did not warrant radiographic evaluation at both of these angles.

It would be technically difficult to use the patellar excursion data to evaluate the vertical position of the patella in a clinically affected dog. Measuring the patellar position within the femoral trochlear groove is rather involved and time consuming (Fig 3). Additionally, clinicians would have to extrapolate data from plotted lines (Fig 5) or obtain a lateral radiographic view of the stifle joint positioned in a predetermined angle (eg, 148°). Obtaining a radiograph of a dog’s stifle joint positioned at a predetermined angle often necessitates multiple exposures. If a lateral radiographic view was obtained of the stifle joint at an angle of 148° then the proximal aspect of the patella should be slightly proximal to the proximal extent of the femoral trochlear ridges. Developing a simple measurement that is independent of angle of the stifle joint would substantially simplify the process of defining a normal vertical patellar position, patella alta, and patella baja (distal displacement of the patella) in affected dogs. Therefore, the L:P was evaluated as a measurement of vertical patellar position.

Value of L:P did not differ significantly among the 5 joint angles ranging from 75° to 148°, proving that the patellar ligament is nonelastic, and its length did not change at the applied load used in our model. This is consistent with results reported for humans, which has indicated that the patellar ligament is nonelastic throughout a passive range of motion. Thus, it is reasonable to assume the length of the patellar ligament in dogs and, therefore, the L:P will not change throughout a passive range of motion in a clinically affected dog (ie, a lateral radiographic view of the stifle joint in a dog positioned in lateral recumbency).

The low variance attributable to repetition (0.00012) indicates that measurement of L:P was extremely repeatable (< 1% of the variation was attributable to measurement repetition). Because the ratio is used, measurement of the L:P becomes independent of size of the dog and radiographic magnification. The L:P is easily obtained on any lateral radiographic view of the stifle joint by obtaining 2 linear measurements, which makes evaluation of vertical position of the patella in a clinical situation a relatively simple procedure. In our model that used limbs from cadavers of 13 clinically normal large-breed dogs, overall mean L:P was 1.68 with a 95% CI of 1.33 to 2.03. This would indicate that a L:P > 2.0 (ie, a patellar ligament more than twice the length of the patella) would result in a diagnosis of patella alta, and a L:P < 1.3 would indicate patella baja. Results of this study provide evidence that the L:P is repeatable and independent of angle of the stifle joint (from 75° to 148°), but readers are cautioned that the mean L:P value only represents data for 13 clinically normal large-breed dogs. To more accurately identify the normal L:P a larger population of clinically normal dogs would need to be evaluated.

We used a model for the stifle joint in large-breed dogs for 2 major reasons. It is our clinical impression that large-breed dogs with medial patellar luxation often appear, subjectively, to have a patella that is proximally positioned within the trochlear groove (possible patella alta), and medial patellar luxation appears to be increasing in large-breed dogs. In a study in which investigators evaluated the incidence of patellar luxation for the period from 1964 to 1969, only 48 of 542 (8.9%) dogs with patellar luxation were considered large-breed dogs (> 18.2 kg). In contrast, a similar study conducted for the period from 1982 to 1992 revealed that 48 of 124 (38.7%) dogs with patellar luxation were considered large-breed dogs. Use of the L:P measurement in small-breed dogs was not evaluated in the study reported here; therefore, use of the L:P to diagnose patella alta or baja in small-breed dogs may be inaccurate.

The model used in this study allowed accurate and repeatable positioning of stifle joints at various angles. The amount of weight placed on the tendon of insertion of the quadriceps muscle was determined by the weight necessary to cause full extension of the stifle joint (ie, 525 g in our model). This weight was standardized for every specimen and allowed the patellar ligament to be placed under tension. Calculating the L:P in clinically affected dogs should be accomplished with the stifle joint slightly flexed to provide tension.
on the patellar ligament. Calculating the L:P in a hyperextended stifle (> 148°) may be inaccurate because of the laxity induced within the quadriceps mechanism and patellar ligament. This may falsely decrease the value for length of the patellar ligament, decreasing the L:P and possibly resulting in an incorrect diagnosis of a normal vertical patellar position when, in fact, the dog has patella alta.

Having the ability to definitively diagnose patella alta in dogs may aid in the diagnosis of related conditions (eg, chondromalacia) and help clinicians select appropriate treatment options. As mentioned previously, patella alta in humans has been associated with conditions such as recurrent dislocation, subluxation, chondromalacia, and pain in the anterior aspect of the knee.23 Chondromalacia causes substantial pain in the anterior aspect of the knee of affected people and can result from patellofemoral incongruity. In patella alta, the patella is proximal to the normal contact area in the femoral trochlear groove, resulting in patellofemoral incongruity and, ultimately, chondromalacia.23 This condition also may exist in dogs with patella alta but, to our knowledge, has not yet been reported. In cases of patella alta and patellar luxation, it may be advisable to distally transpose the tibial tubercle as well as to make any necessary medial or lateral corrections to place the patella in a normal vertical position within the femoral trochlear groove. This would increase the buttressing effect of the femoral trochlear ridges and help prevent recurrent luxation as well as, theoretically, increase the congruence of the patellofemoral joint.

References