Evaluation of the Effect of Distal Femoral Elevation on Radiographic Measurement of the Anatomic Lateral Distal Femoral Angle

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Objective: To determine the effect of elevation of the distal femur on radiographic determination of the anatomic lateral distal femoral angle (aLDFA) in an *in vitro* canine model.
Study Design: *In vitro* study.
Sample Population: Cadaveric canine femora (n = 7 pairs).
Methods: Dissected femora were positioned in a custom-mounting frame. The distal end of the frame was elevated in 5° increments from 0° to 45°, with craniocaudal (CrCd) radiographs obtained at each position. The aLDFA was measured from the radiograph of each femur at each elevation. Statistical comparison of measured values was performed and radiographs were evaluated for radiographic indicators of positioning.
Results: There was significant increase in measured aLDFA at all elevations >5° when compared to 0° elevation. The mean value for aLDFA increased from 92.3° at 0° elevation to 95.0° at 45° elevation. The femoral trochlear ridges and walls of the intercondylar fossa were identified as the most useful radiographic landmarks. The fabellae, though extrafemoral and inconsistently retained in the current study, may also be beneficial. The lesser trochanter and nutrient foramen were less useful landmarks because of anatomic variability.
Conclusion: Elevation of the distal femur had a significant effect on measured aLDFA at all elevations greater than 5°.

Medial patellar luxation (MPL) is a common orthopedic abnormality in the dog.[1–3] Anatomic malalignment of the extensor mechanism (consisting of the quadriceps musculature, patellar tendon, patella, trochlear groove, patellar ligament, and tibial tuberosity) contributes to patellar luxation.[1] This malalignment can occur with genu varum, external rotation of the hip, relative femoral head retroversion, coxa vara, external distal femoral torsion, medial displacement of the tibial tuberosity, and tibial valgus among others.[4–6] Distal femoral varus (medial angulation of the distal femur) has also been reported as a contributing factor to MPL.[5,7] Distal femoral varus shifts the long axis of the extensor mechanism medially, rather than directly overlying the femoral trochlea. This induces significant medial tension on the patella during muscular contraction and can lead to subsequent medial luxation.

In the veterinary literature, there are limited reports of assessment of distal femoral varus in surgical planning for correction of MPL.[8,9] Distal femoral varus can be evaluated by measurement of the anatomic lateral distal femoral angle (aLDFA; Fig 1). Whereas excessive distal femoral varus may necessitate surgical correction, the degree at which this should be performed has not been definitively determined, though recommendations for correction of femoral varus greater than 10° above normal have been reported.[5]

Distal femoral varus is typically measured from a craniocaudal (CrCd) radiograph of the femur. This projection allows observation of the frontal plane of the femur. Normal aLDFA values from this projection have been reported for 4 breeds of dogs.[10] To obtain a true CrCd projection, the femur must not be internally or externally rotated.[5,6] The long axis of the femur must be parallel to the radiographic cassette.[5,6] The radiographic beam must be perpendicular to the long axis of the femur and thus, the radiographic cassette.[5,6] This position will direct the radiographic beam in a true CrCd direction. Radiographic positioning for this projection can be difficult and may be affected by conformation, concurrent orthopedic disease, patient tolerance, or the level of sedation. Concurrent orthopedic pathology of the hip or stifle typically limits the ability to obtain full extension of those joints[5] and may be common in dogs with increased distal femoral varus.[7,8] Inability to obtain full extension of these joints can lead to elevation of the distal femur off of the radiographic table and limit the ability to obtain a true CrCd projection of the femur. To counteract reluctance or inability to fully extend the hip and stifle,

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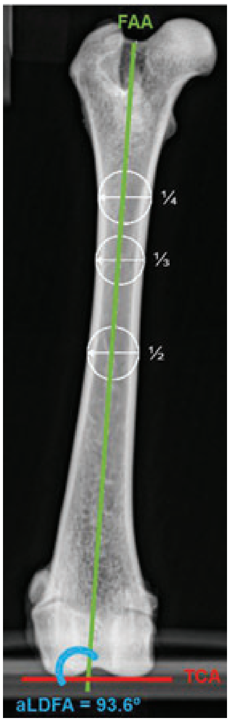

Figure 1 The femoral anatomic axis (FAA, green) was determined in the frontal plane by marking points along the femoral length at $\frac{1}{4}$, $\frac{1}{3}$, and $\frac{1}{2}$ distances. The width of the femur was measured at each of these points (white circles). The FAA was the best-fit line connecting the center of the femoral width at these points. The transcondylar axis (TCA, red) was drawn as a line tangential to the most distal aspects of both femoral condyles. The anatomic lateral distal femoral angle (aLDFA, blue) was measured. The angle was formed between the FAA and the TCA.

numerous alternatives have been reported. These include the use of sedation or anesthesia, horizontal beam radiology, angled-beam projections, fluoroscopic verification of positioning, a "torso elevated position," or a caudocranial projection, though the ability for these techniques to capture a true CrCd projection have not been directly assessed.[5,6,9,11]

Radiographic landmarks to aid in the evaluation of femoral positioning have been described.[5,6,9–12] These include the patella, the fabellae, the lesser trochanter, the walls of the intercondylar fossa, the nutrient foramen, and the femoral trochlea. Evaluation of reliability of these landmarks is limited in the veterinary literature.[10–12] Incorrect positioning of a patient for radiographs may have an effect on measurements, and thus on treatment recommendations and surgical planning. We hypothesized that elevation of the distal femur, as is typical with incorrect positioning, would lead to an increased measurement of aLDFA.

Our objective was to assess the effect of increasing distal femoral elevation on the radiographic measurement of distal femoral varus, as measured by the aLDFA. Additionally, we evaluated reliability of reported radiographic landmarks for correct positioning of a true CrCd radiographic projection of the femur.

MATERIALS AND METHODS

Seven pairs of cadaveric canine femora were studied. The femora were obtained from medium to large breed dogs euthanatized for reasons unrelated to this study. These dogs had no history of lameness and were determined to have no degenerative changes or gross pathology involving the distal aspect of the femur. The femora were disarticulated from the coxofemoral and stifle joints and dissected free of soft tissue. An attempt was made to preserve the fabellae. Preservation of the fabellae was successful both medially and laterally in 5/14 femora and only laterally in 5/14 femora. The remaining fabellae were determined to be loose or to have shifted position after soft tissue dissection, and were thus not evaluated. The patella was not preserved in any specimen.

Femoral Positioning

After dissection, each femur was mounted in a customized orthogonal frame to ensure consistent CrCd positioning (Fig 2A). The distal and caudal portions of the femoral condyles were positioned flush against the orthogonal portion of one end of the frame (Fig 2B). The proximal aspect of the femur was elevated using a radiolucent position screw until the lesser trochanter and lateral supracondylar tuberosity were of equal heights above the frame (Fig 2C). Positioning was similar to a previous report.[12] Once positioned appropriately, the femur was not altered or adjusted. The distal frame and femur were elevated in 5° increments from 0° to 45° and a CrCd digital radiograph (TruDR™, Sound Technologies Medical Systems Inc., Carlsbad, CA) was obtained at each increment. At each 5° increment, foam wedges were used to maintain position and a goniometer was used to verify the angle of elevation (Fig 3). The radiographic beam was centered over a point marked on the distal third of the femoral diaphysis to maintain consistency. The process was repeated for all femora individually.

aLDFA Measurement

The aLDFA was calculated from each radiographic projection, using a digital measurement program (VetPacs™ 2006 TruPacs©, Sound Technologies) for all lines, angles, and measurement. All measurements were made a single time, by a single observer (GMJ).

The femoral anatomic axis (FAA) was created on all femora. This axis was created by first measuring the length of the femur from the junction of the femoral neck and the intertrochanteric fossa proximally to the center of the intercondylar fossa distally. Points were marked along this measurement at $\frac{1}{4}$ and $\frac{1}{3}$ (proximally) and $\frac{1}{2}$ of the length

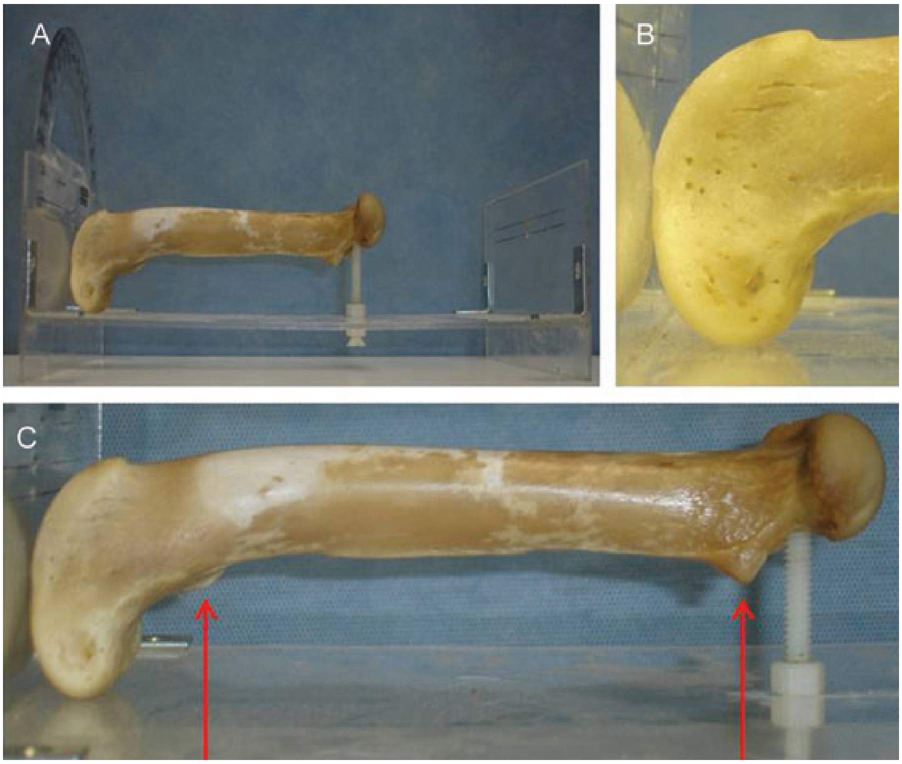

Figure 2 (A) Position of a cadaveric femur in the custom frame; (B) the distal and caudal aspects of the femoral condyles were placed flush against the frame; and (C) the proximal femur was elevated using a radiolucent screw until the lesser trochanter and the lateral supracondylar tuberosity were equal heights above the frame (red arrows).

Figure 3 Positioning of the femur and custom frame with 20° distal femoral elevation. Foam wedges were used to maintain elevation and a goniometer was used to verify degree of elevation. Inset: Close up of goniometric verification of 20° elevation.

of the femur. All 3 marks were located between the lesser trochanter and the mid-femoral diaphysis. Femoral width, from the outer lateral cortex to the outer medial cortex, was measured at each of these points using a circular measuring tool, and the center of the femoral width was marked. The FAA was the best-fit line connecting the 3 mid-width points and was extended proximally and distally beyond the femur. The distal femoral joint line or transcondylar axis (TCA) was determined on each projection by creating a line tangential to the distal aspect of both femoral condyles. The aLDFA was measured as the proximolateral angle of intersection between the FAA and the TCA (Fig 1). The aLDFA was recorded for each femur, at each elevation point. The mean aLDFA value ± standard deviation (SD) at each elevation was calculated for all femora.

Radiographic Landmark Evaluation

Radiographic femoral landmarks, including the lesser trochanter, nutrient foramen, fabellae, the walls of the intercondylar fossa, and the proximal and distal portions of the trochlear ridges were evaluated for consistent positioning at each level of femoral elevation. Specifically each landmark was evaluated for changes in proximodistal and sagittal position during increasing elevation.

Statistical Analysis

Descriptive statistics were generated to summarize outcome measures. Specifically, outcome measures were summarized in means ± SD of measured aLDFA for each elevation

Table 1 Summary Statistics for Overall aLDFA (Average Between Left and Right Femora) for Each Elevation. There are Significant Increases From 0° Elevation to 10°, 15°, 20°, 25°, 30°, 35°, 40°, and 45° Elevation

Elevation	Mean aLDFA	SD	*P* value*
0°	92.32	2.46	
5°	92.88	2.93	0.0525
10°	93.11	2.90	0.0220†
15°	93.34	2.48	0.0202†
20°	93.56	2.38	0.0065†
25°	93.91	2.49	0.0022†
30°	93.99	2.61	0.0020†
35°	94.22	2.80	0.0013†
40°	94.47	3.13	0.0021†
45°	95.04	3.35	0.0026†

**P* value for comparison to elevation 0°.
†$P < .05$.

increment. A paired t-test was used to compare joint angle degrees between elevation degrees (0° versus 5°, 10°, . . . , 45^0). Linear regression analysis was performed to evaluate the association between increasing degree of elevation and measured aLDFA across all femora.

All *P* values were two-sided, with $P < .05$ indicating significant statistical differences. Data analysis was performed using software (SAS® version 9.2 software, SAS Corp., Cary, NC).

RESULTS

When comparing all femora together (mean aLDFA), there was a significant increase for aLDFA at all elevations greater than 5° (Table 1). Linear regression analysis revealed a positive association between increasing elevation and increasing aLDFA measurement (Fig 4). Calculated R^2 was 0.07, the slope parameter was 0.06, and $P = .03$. The mean value for aLDFA increased from 92.3° at 0° elevation to 95.0° at 45° elevation.

Radiographic landmarks to aid in the assessment of distal femoral elevation and femoral rotation were identified. The femoral trochlear ridges and walls of the intercondylar fossa appeared most useful. The fabellae, though inconsistently retained in the current study, may be beneficial, when present, in assessing femoral rotation. The lesser trochanter and nutrient foramen were less useful because of the variability in radiographic position.

DISCUSSION

We confirmed our hypothesis that distal elevation of the femur significantly altered radiographic measurement of aLDFA. A significant difference was noted between mean aLDFA value of femora at 0° elevation and all elevations greater than 5°. Mean aLDFA increased from 92.3 ± 2.5° at 0° elevation to 95 ± 3.4° at 45° elevation.

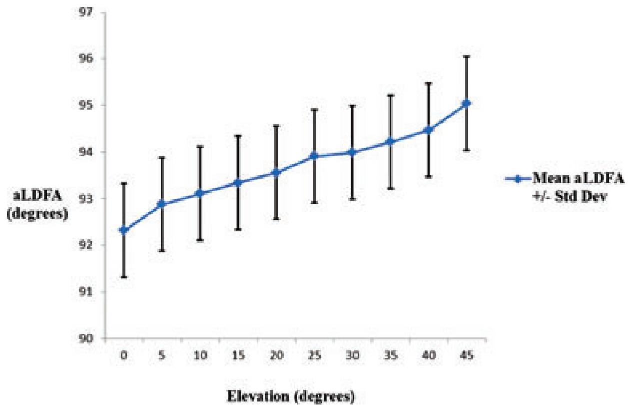

Figure 4 Association between femoral elevation and measured aLDFA. Linear regression analysis was performed to evaluate whether there was a linear trend. The R^2 was 0.07 with a significant slope parameter of 0.06 ($P = .03$), ie, there was a evidence for a positive association between increasing elevation and increasing measured aLDFA.

The clinical impact of these results is unknown. Distal femoral elevation of up to 45° only resulted in increases in mean aLDFA measurements of 3°. Increased measurement of 3° of aLDFA is not suspected to lead to unnecessary surgical therapy in a dog and in the current study none of the dogs would have been candidates for corrective surgery. However, because this study only evaluated normal femora, it is not known what effect excessive femoral varus, in addition to malposition would have on measurement of aLDFA. Clinically, it is important to try and obtain as accurate a measurement of distal femoral angulation as possible. With the association between increased femoral elevation and increased measured aLDFA reported here, there is potential to recommend surgical therapy based on a falsely elevated aLDFA measurement. Additionally, repeatability is important, as inconsistent position during postoperative or follow-up radiographs could affect the precision of measurements. We recommend close evaluation of radiographic position, in addition to clinical evaluation, in dogs with increased measurements of aLDFA, to avoid unnecessary surgical procedures. Additionally, follow-up evaluation should be performed with consistent radiographic positioning and technique to reduce variation.

In this study, a single observer (GMJ) made all measurements and measurements were only obtained once. Based on consistent positioning of defined landmarks, we felt a single measurement was adequate. Similar measurement methods have been reported.[10,11] Repeatability and reproducibility of measurements of distal femoral varus have also been assessed, with acceptable results.[12] As such, we feel it is unlikely that repeated measurements or multiple measurers would have significantly affected the results of the current study.

We measured aLDFA in this report to maintain consistency with previous reports, in both human and veterinary literature, for the angulation of the distal femur.[10,13,14]

This system was developed to allow ease in naming specific joint angles, based on their location and has become the recognized nomenclature within the human field of limb deformity correction.[13]

Normal aLDFA has been reported for 4 dog breeds.[10] In these breeds, the mean aLDFA was greater than 90° which may indicate that the typical conformation of the canine distal femur has a slight degree of varus. This is in contrast to the human femur that typically has distal valgus.[15,16] The mean aLDFA values in the current study were below the previously reported canine means, but the values reported here fell within the 95% confidence interval for individual values in the previous report. In that report, projections from a radiographic database were evaluated. Acceptable positioning required full femoral extension, though distal femoral elevation was not objectively assessed. This may explain the difference in measurement of the aLDFA between the studies. If distal femoral elevation was present in the radiographic positioning, increased measurements of aLDFA could have been induced. Additionally, differences in calculated aLDFA may be because of smaller numbers in the present study, breed differences, possible outliers from the normal population, or differences in position of the radiographic beam.

Early veterinary reports measured the femoral varus angle (FVA) rather than the aLDFA to assess distal femoral varus.[5–8,11,12] The FVA is the angle between the FAA and the distal FAA, a line perpendicular to the TCA through the center of the intercondylar fossa (Fig 5). Using standard geometry, the aLDFA and FVA measurements can be related. The aLDFA equals 90° + FVA (Fig 5).

All long bones have an anatomic and mechanical axis. The anatomic axis is defined as a mid-diaphyseal line through the long axis of the bone.[13] The mechanical axis is defined as a straight line connecting the centers points of the proximal and distal joints of a bone.[13] Additionally, in all joints, orientation lines can be determined based on anatomic points along the articular surface. The intersection of the joint orientation line and either the anatomic or mechanical axis is used to determine the angles of a particular joint.

We chose FAA as the reference axis, rather than the femoral mechanical axis. Clinically, the FAA is typically used for evaluation of candidacy for surgical correction.[7,8] The canine femur is relatively straight in the frontal plane; therefore, the anatomic axis is a straight line in this plane. In the sagittal plane, the canine femur has some degree of procurvatum. Therefore, in the sagittal plane, the FAA follows a curved mid-diaphyseal line rather than a straight line.[13] The amount of femoral procurvatum varies between individuals. Because of this we chose to standardize sagittal positioning in this study using anatomic landmarks, bringing the proximal and distal portions of the femoral diaphysis to same level of elevation off of the radiographic plate. Similar positioning has been reported in the evaluation of distal femoral varus.[12]

The FAA was determined using 3 points in the proximal half of the diaphysis similar to previous reports.[11,12]

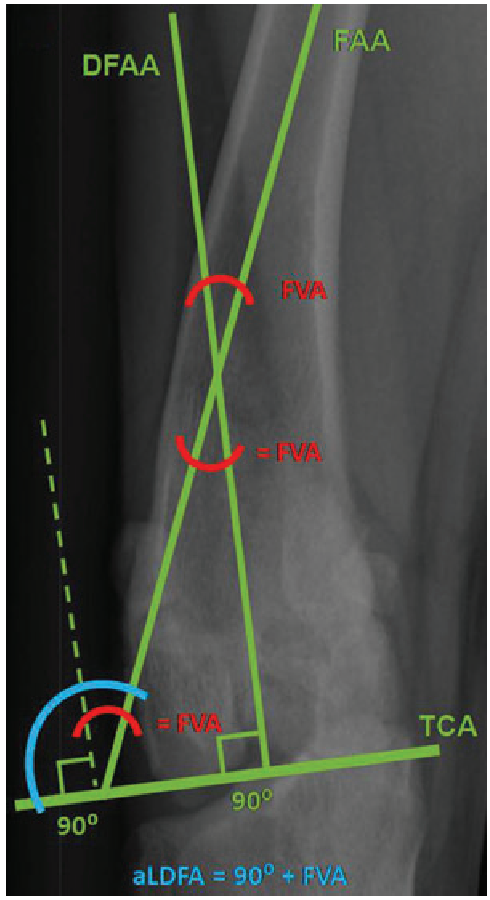

Figure 5 Relationship between anatomic lateral distal femoral angle (aLDFA, blue) and femoral varus angle (FVA, red) measured on a femoral radiograph. Using standard geometry aLDFA equals 90° + FVA. The femoral anatomic axis (FAA), distal femoral anatomic axis (DFAA), and transcondylar axis (TCA) are identified, all in green. A parallel line to DFAA is identified by the dashed line.

Varying numbers and locations of axis points have been used to determine the FAA[10–13]; however, the overall method for determination of the FAA was similar. Location of these points, rather than the number of points used, is likely the most important aspect and it is recommended that all points are between the lesser trochanter and the mid-diaphysis of the femur, as most angular deformities occur in the distal 1/3 of the diaphysis.[10] Location of the points may need to be adjusted if there is obvious anatomic abnormality of the femur.

Centering the radiographic beam at or near the level of the joint of focus has been recommended in people.[17] We centered the radiographic beam over the distal third of the femur. In our experience, radiographic evaluation of the femur in dogs is typically performed with the beam centered at the mid-diaphysis of the femur. Radiographic evaluation with the beam centered over the joint of interest may be limited by the size of available radiographic cassettes in veterinary facilities. Smaller cassettes may limit the ability to center the beam over the stifle and still capture a projection of the entire femur. We chose to center the beam over distal third of the femoral diaphysis as we felt this was a clinically applicable situation, allowing both centering of the beam closer to the joint of interest, and ensuring the entire femur was projected onto the cassette. Position of the radiographic beam in this area may reduce radiographic parallax artifact of the distal femur. We are not aware of any current veterinary reports that have assessed the effect of varied position of the radiographic beam on the calculation of joint angles; however, this should be investigated as variation that may lead to inaccurate or inconsistent measurements. Additionally, position of the radiographic beam at various locations may project different radiographic landmarks that may be useful as indicators of position.

Rotation of the femur, either because of positioning or anatomic torsion, is suspected to alter the measurement of femoral joint angles. The effect of rotation on calculation of the aLDFA was not assessed in this study, but rotation is suspected to additionally contribute to inaccurate calculations. External rotation has been reported to increase measured femoral varus,[11] but the extent to which this occurs has not been objectively assessed. Clinically, we find that rotation can significantly alter the radiographic assessment of distal femoral angulations, though this is only a subjective observation at this time. The combined effects of elevation and rotation may also be more significant than malpositioning in a single plane.

In our study, rotation was eliminated by placement of the distal and caudal aspects of the femoral condyles flush on planar surfaces in the custom frame, rather than by the use of femoral landmarks. Similar technique has been reported,[12] though it is limited to cadaveric rather than clinical specimens. As such alternate methods of evaluation of positioning in a clinical setting, including radiographic landmarks, would be beneficial. Such landmarks have been reported,[5,6,9–12] but their reliability has not been previously assessed.

The patella has been reported as a positional landmark,[10–12] but was not evaluated in the current report. The patella has the potential for variability, as it is a freely moving, extra-femoral structure and may luxate in patients with increased femoral varus. Based on this, we did not evaluate the patella as a positional landmark.

The use of the fabellae as reference points has been reported, with correct position showing transection of the fabellae by the femoral cortices.[5,6,10–12] In our study, 15/28 fabellae were evaluated. The remaining fabellae shifted position or had variable amounts of movement after initial soft tissue dissection. Ten of the 15 retained fabellae were lateral fabellae. The reason for this is unknown, but could indicate that the lateral fabella has reduced positional variability, making it a better landmark. Throughout the range of elevation in the current study, the retained fabellae were consistently transected by the femoral cortices (Fig 6A–D). This supports the previously reported use of the fabellae as landmarks for assessing rotation, but limits their ability to be used as landmarks to assess distal elevation. However, the fabellae are still extra-femoral landmarks. Variable position and absence have also been reported[18] and noted clinically by the authors, and could limit their use as landmarks.

Use of landmarks confined to the femur would be ideal to aid in consistency and reproducibility of radiographic positioning. The corticocancellous tip of the lesser trochanter has been reported to be only partially visible medially when the femur is not rotated.[5,6,10–12] In this report, radiographic projection of the lesser trochanter was variable. Minimal or no portion of the lesser trochanter was visible radiographically in 4 pairs of femora, despite positioning in the custom frame without rotation. This normal anatomic variation may limit its usefulness in assessing rotation of the femur. Additionally, because the lesser trochanter is a proximal structure, distal femoral torsion may affect its radiographic observation. External torsion of the distal femur can contribute to MPL[6] and would cause the lesser trochanter to be less visible during appropriate positioning without rotation. In our study, when the lesser trochanter was visible, the amount protruding was consistent throughout the range of elevation. Based on our results, the lesser trochanter was determined to be a limited radiographic landmark in determining rotational position or distal femoral elevation.

The nutrient foramen should be centered between the medial and lateral cortices.[11] In our study, only 6/14 were centered. The remainders were either at the lateral (7/14) or medial (1/14) extent of the middle $\frac{1}{3}$ of the femoral width. In individual femora, positioning was again consistent at all elevations. We felt the nutrient foramen was less useful as a rotational landmark, and was a poor landmark for evaluation of distal femoral elevation.

The walls of the intercondylar fossa should be parallel to each other and centered in an unrotated femur.[5,6,10] In our study, this positioning was noted and consistent throughout the range of distal femoral elevation (Fig 6A–D). This supports them as a landmark for assessment of rotation of the femur, rather than distal femoral elevation.

In a previous study, the trochlear ridges were noted to be centered between the femoral condyles on appropriately positioned radiographs.[9] In our study, this position was confirmed, supporting use of the trochlea as a landmark for assessment of rotation. The trochlear ridges were also identified as potential landmarks assessing distal femoral elevation. On the true CrCd projection (0° distal femoral elevation), the trochlear ridges were observed extending beyond the distal aspect of the femoral condyles (Fig 6A and B). This protrusion was typically noted until approximately 15° of distal femoral elevation. To our knowledge, evaluation of the femoral trochlear ridges in this way has not been previously reported. In our clinical experience, this landmark is not identified on typical hip extended CrCd femoral projections, potentially because of variable amounts of distal femoral elevation with this projection. In this *in vitro* study, radiographic observation of the distal aspect of the trochlear ridges beyond the femoral condyles may have been because of either level positioning of the femora or due to centering the radiographic beam closer to the joint than

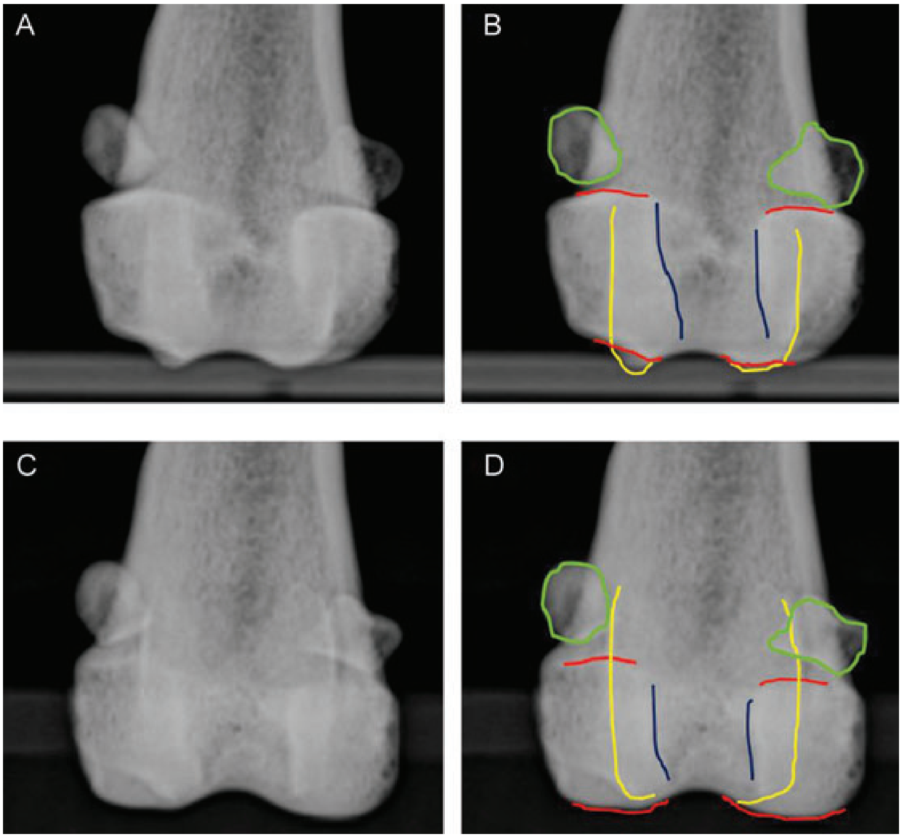

Figure 6 (A) Distal portion of the radiograph of the right femur from specimen 2 at 0° elevation illustrating the trochlear ridges, walls of the intercondylar fossa, and fabellae. (B) Identical image to (A), with the trochlear ridges (yellow), walls of the intercondylar fossa (blue), and fabellae (green) identified in comparison to the femoral condyles (red). Note that observation of the trochlear ridges beyond the femoral condyles distally. The proximal extent of the trochlear ridges overlaps the condyles. The fabellae are transected by the femoral cortices and the walls of the intercondylar fossa are parallel and centered within the femoral condyles. (C) Distal portion of the radiograph of the right femur from specimen 2 at 25° elevation. (D) Identical image to (C) with structures marked as in (B). Note that approximately 30% overlap of the trochlear ridges and femoral condyles. The trochlear ridges are not visualized beyond the condyles distally. The position of the walls of the intercondylar fossa and the fabellae are essentially unchanged.

is typically performed in a clinical situation. Centering the beam closer to the stifle projects a more tangential view of the distal femur than when the beam is centered at the mid-diaphysis. It should be noted that care must be taken in assuring consistent use of the distal most portion of the condyles as the anatomic location for the TCA, rather than the trochlear ridges. In this *in vitro* study, lack of observation of the trochlear ridges distal to the femoral condyles indicated femoral elevation of more than 15°. The potential for clinical use of this radiographic landmark has not been evaluated.

Additionally, the proximal aspects of the trochlear ridges were noted within the confines of the femoral condyles in femora without distal elevation. With increasing elevation, the proximal aspects of the trochlear ridges were observed proximal to the femoral condyles (Fig 6C and D). Approximately 30% overlap was noted at approximately 25° of distal femoral elevation. This may also be useful in determining positioning to radiographically assess the weight-bearing portion of the stifle, which is located tangent to the radiographic beam at approximately 25° of distal femoral elevation. Observation of the proximal portion of the trochlear ridges was difficult in some of the cadaveric specimens in this report, and the presence of additional overlying soft tissues may make evaluation of this structure difficult in some clinical cases. When visible, use of the percentage of the proximal aspect of the trochlear ridges overriding the femoral condyles may allow assessment of distal femoral elevation.

Clinically, radiographic positioning for a true CrCd femoral projection may be affected by multiple factors including patient tolerance, temperament, pain, conformation, or concurrent orthopedic disease. Heavy sedation or anesthesia is recommended and may be necessary to obtain appropriate positioning. However, conformational differences, including thigh muscle mass, may prohibit full extension of the femur, despite sedation or anesthesia. In a clinical report of dogs with elevated distal femoral varus in association with MPL, 80% had a grade III or IV MPL.[9] Pathology associated with these higher grade MPLs include periarticular fibrosis and muscle contracture[1,19] and may limit stifle extension in these patients. Inability to obtain appropriate radiographs for perioperative measurements in a dog with grade IV MPL has also been reported.[20] Additionally, concurrent pathology in the hip or stifle can limit appropriate positioning, either because of pain or decreased range of motion secondary to osteoarthritis. Concurrent hip dysplasia was noted in up to 41% and concurrent cranial cruciate ligament rupture in 46% of dogs with increased distal femoral varus,[7,8] indicating a high prevalence of concurrent joint pathology in clinical populations in which assessment of femoral varus is needed.

As our results demonstrate, distal femoral elevation leads to a statistically significant elevation in measured radiographic aLDFA. The literature has indicated a high prevalence of factors that may limit appropriate and repeatable radiographic positioning of patients with excessive femoral varus. Therefore, description and evaluation of alternative methods to obtain appropriately positioned radiographs, or the use of advanced imaging modalities, such as computed tomography, are crucial to standardized assessment of distal femoral varus.

Based on our results and clinical experience, we recommend thorough evaluation of radiographic positioning of the femur for measurement of distal femoral varus. Verification of parallel position of the femoral long axis and the radiographic cassette is necessary to obtain a true CrCd projection. Additionally, the available radiographic landmarks should be assessed to confirm appropriate and repeatable radiographic position. Future focus should include evaluation of the normal aLDFA across a wider variety of breeds, larger scale evaluation of dogs with increased femoral varus, further assessment of the accuracy and precision of various radiographic techniques or imaging modalities for measurement of aLDFA, and the evaluation of the effect of femoral rotation on aLDFA.

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