

# Influence of Limb Positioning and Measurement Method on the Magnitude of the Tibial Plateau Angle

ULLRICH REIF, DVM, Diplomate ACVS & ECVS, LOIC M. DEJARDIN, DVM, MS, Diplomate ACVS, CURTIS W. PROBST, DVM, Diplomate ACVS, CHARLIE E. DECAMP, DVM, MS, Diplomate ACVS, GRETCHEN L. FLO, DVM, MS, and ALLEN L. JOHNSON, DVM, Diplomate ACVS

**Objective**—To evaluate the effect of limb positioning and measurement technique on the magnitude of the radiographically determined tibial plateau angle (R-TPA).

**Study Design**—In vitro study, R-TPA was determined by 6 blinded observers and image measurement software.

**Animals**—Five canine cadaver hind limbs.

**Methods**—The legs were positioned on a custom-made positioning device simulating a radiographic tabletop technique in lateral recumbency. True lateral positioning was defined by superimposition of femoral and tibial condyles on the radiographic projection. Radiographs were taken while the specimens were relocated in a proximal, distal, caudal, and cranial direction with respect to the radiographic beam. For each specimen, 25 different radiographic views were obtained and 6 blinded observers determined the radiographic TPA using 2 different methods. The conventional method used precise anatomic landmarks to determine the tibial plateau. To simulate osteoarthritic changes complicating identification of these landmarks, the tangential method estimated the tibial plateau as the tangent to the central portion of the tibial plateau. After periarticular soft tissue dissection the anatomic tibial plateau angle (A-TPA) was determined. The A-TPA and the R-TPA were compared.

**Results**—The R-TPA significantly decreased as limb position with respect to the X-ray beam changed from cranial proximal to caudal distal. The maximal mean radiographic R-TPA difference was 3.6° with the first and 5.7° with the second method. Regardless of the method used there was no significant difference between A-TPA and R-TPA in the true lateral position. In the peripheral positions, however, significant differences between anatomic and radiographic TPA were seen.

**Conclusions**—Limb positioning influenced the radiographic appearance of the tibial plateau and the magnitude of the measured TPA. Cranial and proximal positioning of the limb relative to the X-ray beam leads to overestimation whereas caudal and distal positioning leads to underestimation of the TPA.

**Clinical Relevance**—True lateral positioning of the tibia defined by superimposition of the femoral and tibial condyles should be used for accurate TPA determination before tibial plateau leveling osteotomy.

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**Key words:** dogs, canine, tibial plateau angle, limb position, radiography.

## INTRODUCTION

**D**ETERMINATION OF the tibial plateau angle (TPA) is an important component of tibial plateau

leveling osteotomy (TPLO).<sup>1</sup> TPLO aims to provide functional stability during the stance phase of the gait cycle by decreasing cranial tibial thrust, a cranially directed force generated by tibial compression and respon-

From the Department for Small Animal Clinical Sciences, College of Veterinary Medicine-Michigan State University, East Lansing, MI.

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Address correspondence to Dr. Ullrich Reif, Fachtierarzt für Kleintiere, Tierklinik Dr Reif, Schönhardterstr. 36, 73560 Böbingen, Germany. E-mail: ulli@tierklinik-reif.de.

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sible for cranial drawer motion in the cranial cruciate ligament (CrCL) deficient stifle.<sup>2,3</sup> Preceding TPLO surgery the TPA is measured on lateral radiographs and the amount of tibial plateau rotation necessary for the procedure is inferred from the magnitude of the measured TPA.<sup>4</sup> Individual TPA determination before TPLO is necessary, because the magnitude of the normal canine TPA varies between individuals and breeds.<sup>5,6</sup>

Canine cadaver studies investigating tibial plateau leveling showed a close relation between the magnitude of the TPA and the amount of cranial tibial thrust generated during axial tibial loading.<sup>7,8</sup> At a TPA of 6.5° cranial tibial thrust was converted into caudal tibial thrust.<sup>7</sup> Further rotation past this minimal tibial plateau rotation angle was associated with increased caudal tibial thrust and increased caudal cruciate ligament strain. Over-rotation of the tibial plateau may adversely affect the outcome of surgery and has been associated with post-operative caudal cruciate ligament rupture.<sup>3</sup> By contrast, insufficient rotation during TPLO may not provide the dog with a functionally stable stifle joint because of insufficient reduction of cranial tibial thrust. Accurate TPA measurement is thus necessary in clinical patients before TPLO to avoid over-rotation or insufficient rotation of the tibial plateau. It also allows evaluation of the clinical importance of TPA magnitude after TPLO.

Physeal injuries resulting in abnormally high TPAs have been associated with CrCL rupture.<sup>9</sup> The authors hypothesized that the increased TPA generated increased strain in the CrCL ultimately leading to CrCL rupture. Also, it has been suggested that the cause of CrCL disease is an abnormally increased TPA.<sup>5</sup> Several studies investigated the relationship between the magnitude of TPA and the incidence of CrCL rupture in dogs with controversial results.<sup>5,10,11</sup> Accurate TPA determination not only allows for meaningful comparison of clinical patients but is essential in prospective and retrospective studies evaluating normal dogs and dogs at risk for CrCL rupture.

Positioning of the tibia during radiography, however, may influence the appearance of anatomic landmarks used for TPA determination and therefore induce measurement variability. In previous reports evaluating TPA, the actual methods used to obtain TPA from radiographs were not fully described. In particular, information regarding limb positioning, centering of the limb with respect to the central X-ray beam and means of radiographic evaluation of tibial positioning were not reported. In Slocum's original report lateral radiographs of the entire hind limb were taken for TPA measurement;<sup>2</sup> later reports used lateral radiographic views of the tibia that were centered on the tibial diaphysis;<sup>5,12</sup> and others centered the central X-ray beam on the stifle joint and included the tarsus on the projection.<sup>6-8</sup> In humans,

individual measurement of TPA is an integral component of high tibial osteotomy and total knee arthroplasty for treatment of severe degenerative joint disease (DJD) of the stifle joint and several measurement methods have been described.<sup>13-15</sup>

Measurement variability may also be induced by osteoarthritis.<sup>12</sup> Osteophyte formation around the tibial condyles hinders identification of the anatomic landmarks used for tibial plateau determination (ill-defined cranial and caudal margins of the medial tibial plateau and intercondylar eminences). Severe DJD will force the observer to disregard the cranial and caudal margin of the tibial plateau and lead to TPA determination using the central region of the tibial condyles. TPA determination by a tangent to the medial tibial plateau has been described.<sup>15</sup> In addition to the conventional TPA determination method<sup>12</sup> a tangential method was used to simulate the effect of DJD on TPA measurement variability.

To alleviate variations inherent in the lack of standardization of a radiographic method for TPA measurement and potential limitations inherent to DJD, a precise method for limb positioning, relative position of the central X-ray beam with respect to the stifle joint, and identification of the tibial slope is necessary. Therefore, our purpose was to evaluate radiographic positioning for TPA measurement and to compare 2 radiographic measurement methods that would account for the absence or presence of DJD. Our hypotheses were that (1) true lateral radiographic positioning of the tibia for TPA determination (i.e., tibial condyles superimposed on radiographs) will reflect the actual anatomic TPA; (2) limb position with respect to the X-ray central beam will alter the radiographic appearance of the tibial plateau and therefore the magnitude of the measured TPA; and (3) TPA measurement using the central portion of the tibial plateau (caused by ill-defined cranial and caudal margins of the medial tibial plateau because of DJD) will increase interobserver variability.

## MATERIALS AND METHODS

### *Study Design*

Five cadaver hind legs from 5 large breed dogs (35–50 kg) euthanized for reasons unrelated to this investigation and free of orthopedic disorders were studied. The legs were harvested by femoral disarticulation and placed on a custom-made positioning device, which allowed displacement of the entire specimen across the radiology table while maintaining the specimen's spatial orientation. Multiple mediolateral radiographs of each specimen were obtained in a sequential manner resulting in 25 different radiographic views.

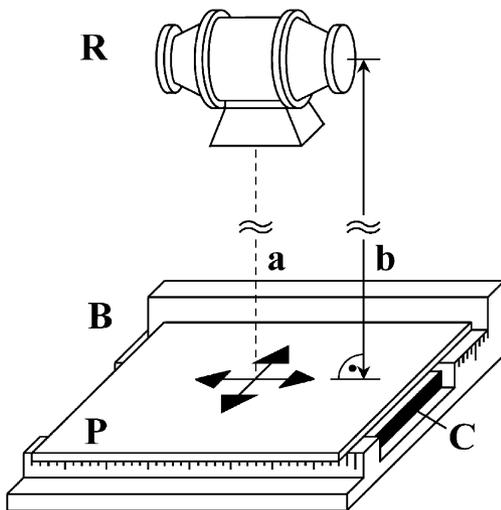
Six orthopedic surgeons, unaware of specimen positioning, traced the tibial functional axis and the tibial plateau on each radiograph using 2 different methods for tibial plateau deter-

mination. These lines were then scanned and the corresponding radiographic TPA (R-TPA) was determined using image analysis software by the lead author. After dissection of all the soft tissue structures surrounding the tibia, the anatomic tibial plateau angle (A-TPA) was determined. The A-TPA and the R-TPA in the true lateral position were compared and the effect of specimen positioning and determination method on the R-TPA was evaluated.

#### *Limb Positioning and Radiographic Method*

To obtain mediolateral radiographic views of the tibia, each specimen was placed on a custom-made positioning device (Fig 1) that consisted of a wooden base rigidly fixed to the radiology table and a glass plate on which the specimens were placed in lateral recumbency. The radiographic cassette was placed directly below the glass plate supporting the specimen and could be easily changed without a change in the position of the specimen. Motion of the glass plate was restricted to linear displacement in 2 orthogonal directions (cranial–caudal and proximal–distal) and rulers fixed to the base allowed for precise spatial positioning of the plate. The focal distance between the rotating anode and the glass plate was set at 100 cm.

The lateral aspect of the toes, tarsus, and stifle were in direct contact with the plate. Because the proximal femur had been freed of surrounding musculature, a spacer was placed below the greater trochanter (Fig 2). Initially the stifle joint was positioned below the central radiographic beam; however, radiographs of the specimen were repeated and the specimen relocated until precise superimposition of the femoral and tibial condyles was achieved on the radiographic projection. This radiographic position was defined as the true lateral po-



**Fig 1.** Schematic drawing of the positioning device. The specimen is placed on a glass plate (P) resting on a wooden base (B). The latter was fixed to the radiology table below the radiographic tube (R) emitting the radiographic beam (a). The focal distance (b) was set at 100 cm. The glass plate (P) can be relocated in a plane parallel to the radiology table.



**Fig 2.** Side view of the positioning device. The specimen is placed on the glass plate (P). The dissected thigh muscles and the proximal femur are wrapped in cloth. Note the spacer (S) between the glass plate and the trochanter replacing the dissected muscles. The radiographic cassette (C) is resting on the wooden base (B) below the glass plate (P).

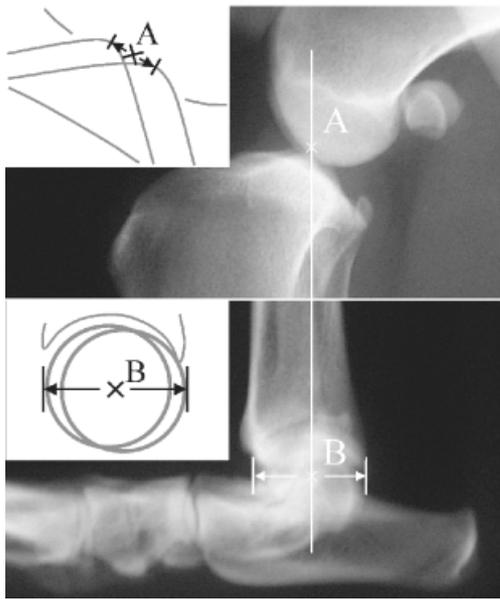
sition. Once true lateral positioning was verified on the radiographs, the specimen was moved along 2 orthogonal directions in 5 cm increments to 24 positions surrounding the true lateral position. Radiographs of the tibia including the stifle and hock joint were taken at each of these positions resulting in 25 different radiographic views of each specimen with the true lateral position being at the center.

#### *Radiographic Tibial Plateau Angle (R-TPA) Determination*

Six blinded observers (LD, CP, CD, GF, AJ, and UR) identified the tibial plateau and the long axis of the tibia on the radiographs using 2 methods. In both methods, the long axis of the tibia was determined by a line connecting the midpoint between the 2 apices of the tibial intercondylar eminences and the center of the talar body (Fig 3). For the conventional method (CM) the medial tibial plateau was determined by its most cranial and most caudal margin (Fig 4). For the tangential method (TM) the observers had to estimate the medial tibial plateau by drawing a line tangential to the tibial plateau at the point of intersection between the long axis of the tibia and the tibial plateau (Fig 4). The TM was used to simulate osteoarthritic changes leading to poor definition of the cranial and caudal margins of the tibial plateau. The R-TPA was defined as the angle between the medial tibial plateau and a line perpendicular to the functional axis of the tibia. The resulting lines were digitally scanned and the R-TPA determined using image measurement software (SigmaScan, Jandel Scientific, San Rafael, CA). After the radiographic study, the specimens were dissected to measure the A-TPA.

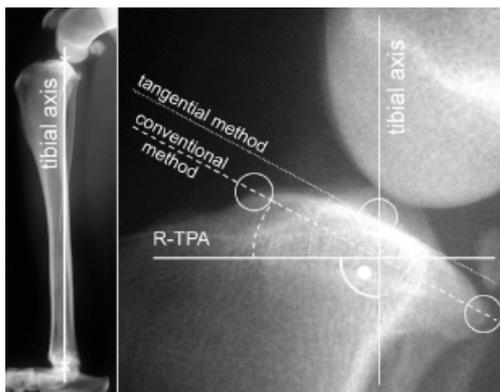
#### *Anatomical Tibial Plateau Angle Determination*

All soft tissue structures were removed from the tibia. To define the cranial and caudal extent of the medial tibial

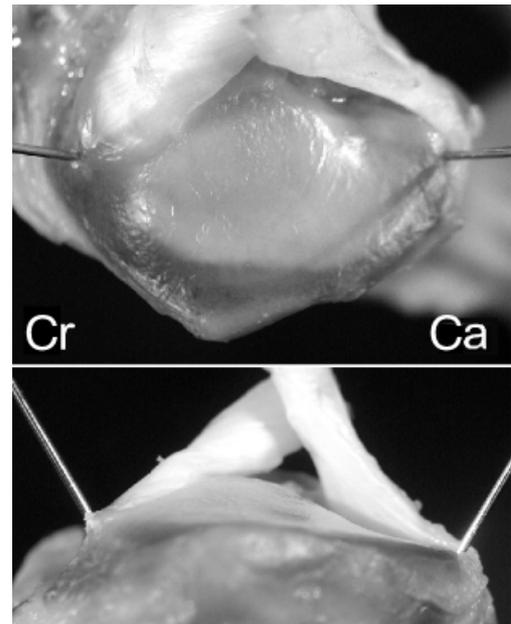


**Fig 3.** Determination of the tibial axis by the midpoint between the 2 apices of the tibial intercondylar eminences (A) and the center of the talus (B).

plateau, 2 0.035-Kirschner wires were inserted into the subchondral bone. The K-wires were placed at the level of the cranial intercondylar area (immediately cranial and medial to the insertion of the CrCL) and into the caudal edge of the tibial condyle immediately medial to the caudal cruciate ligament (Fig 5).<sup>7</sup> The functional axis of the tibia was defined by the midpoint between the intercondylar eminences and the center of the talo-crural joint. To measure the A-TPA a rigid



**Fig 4.** Determination of the tibial plateau angle. The conventional method (dashed line) determined the medial tibial plateau by its most cranial and most caudal margin (circles on dashed line). For the tangential method (dotted line) a line tangential to the tibial plateau drawn at the point of interception between the long axis of the tibia and the tibial plateau (circle on dotted line). The radiographic tibial plateau angle (R-TPA) was then determined between the tibial plateau and a line perpendicular to the tibial axis.



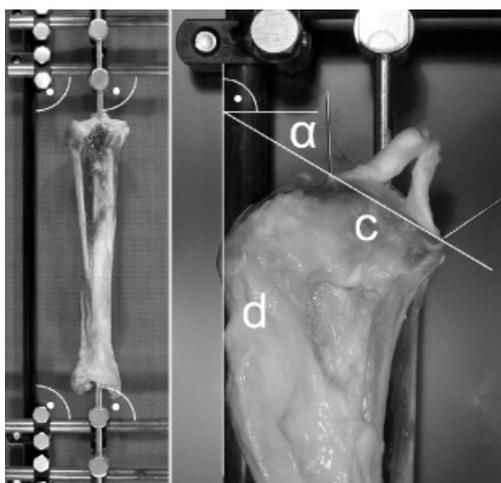
**Fig 5.** Dorsal and medial view of the medial tibial condyle. Two K-wires were inserted into the caudal (Ca) and cranial (Cr) extent of the tibial plateau for evaluation of the anatomical tibial plateau angle.

rectangular external fixator frame (SK-system, Imex Veterinary Inc, Longview, TX) was constructed. One side consisted of a smooth 4.75 mm Steinman pin mounted parallel to the connecting bar (Fig 6). The Steinman pin was then substituted by 2 half-pins between which the specimen was secured. The proximal pin was affixed to the midpoint between the intercondylar eminences and the distal one to the midpoint of the intermediate ridge separating the cochlea tibiae, thus ensuring that the functional axis of the tibia was parallel to the connecting bar of the frame. The K-wires defining the tibial plateau and the connecting bar representing the tibial functional axis were aligned in a plane parallel to the table.

A digital camera (Digilux, Leica Camera AG, Solms, Germany) was centered above the intercondylar eminences and the specimen was photographed. To avoid distortion of the specimen, the focal distance was set at 100 cm. The A-TPA ( $\alpha$ ) was defined on the photograph by a line joining the insertion points of the K-wires (c) and a line perpendicular to the connecting bar (d; Fig 6). The angle  $\alpha$  was determined using image measurement software (SigmaScan, Jandel Scientific, San Rafael, CA).

#### *Statistical Analysis*

Repeated measures analysis of variance (ANOVA) was used to calculate the variation in R-TPA related to limb positioning, determination method, and observer. The R-TPA measurements of the 25 radiographic positions were reported after subtraction of the R-TPA measured at the true lateral position of each dog and each observer. Therefore, the results show increase or decrease of the R-TPA in relation to the true



**Fig 6.** Cranio-caudal and proximal medio-lateral view of the specimen mounted in the external fixator. The connecting bars and the pins securing the tibia were mounted at exactly  $90^\circ$ . The anatomical tibial plateau angle ( $\alpha$ ) is determined between a line (c) connecting the points of insertion of the 2 K-wires and a line perpendicular to the connecting bar of the fixator (d).

lateral position independent from the magnitude of the individual TPA of the dogs. The increase or decrease in R-TPA measurements in the 25 different radiographic positions was compared with the R-TPA in the true lateral position using a Student's *t*-test. The single A-TPA and the mean ( $\pm$  SD) R-TPA were reported for the 5 specimens. The difference between R-TPA measurements in the true lateral position and A-TPA was modeled using linear regression with non-normal errors. Interobserver variability was determined using the method of residuals previously described by Bland and Altman.<sup>16</sup> The 95% confidence interval for interobserver variability was calculated for each measurement method. Statistical significance was set at a  $P < .05$ .

## RESULTS

### *Anatomic and Radiographic TPA*

The A-TPA and the R-TPA in the true lateral position determined with CM and TM are shown in Table 1. Regardless of measurement method used, the R-TPA in the true lateral position was not significantly different from the A-TPA.

### *Limb Positioning and Radiographic TPA*

The mean R-TPA of the 25 radiographic positions for the 2 methods are shown in Table 2. Radiographic positions in which R-TPA measurements were significantly different from R-TPA measurements in the true lateral position were specified. The maximal difference of the mean R-TPA because of positioning was  $3.6^\circ$  for CM and  $5.7^\circ$  for TM. The R-TPA significantly decreased in both

Table 1. Results of the Anatomical and Radiographic Tibial Plateau Angle in the True Lateral Position of the Different Specimens in Degrees

Specimen	Anatomic Tibial Plateau Angle	Anatomic Tibial Plateau Angle*	
		Conventional Method	Tangential Method
1	22.0	22.1 ( $\pm$ 2.4)	22.5 ( $\pm$ 1.7)
2	26.2	26.9 ( $\pm$ 3.1)	26.1 ( $\pm$ 2.6)
3	23.8	23.5 ( $\pm$ 2.7)	22.3 ( $\pm$ 1.7)
4	26.0	26.7 ( $\pm$ 1.4)	26.1 ( $\pm$ 2.4)
5	26.8	25.4 ( $\pm$ 2.8)	26.3 ( $\pm$ 2.4)
		Mean: 24.9 ( $\pm$ 3.0)	Mean: 24.6 ( $\pm$ 2.7)

\*Mean value ( $\pm$  SD) of 6 observers evaluating the true position.

methods as the limb was positioned from cranial to caudal with respect to the X-ray beam. In addition, there was a significant decrease in R-TPA when the limb was positioned from proximal to distal with respect to the radiographic beam when measured with TM. Although this decrease was also observed with CM, the trend was not significant.

### *Determination Method*

The mean ( $\pm$  SD) R-TPA differences between each position and the true lateral position are reported in Table 2. The mean ( $\pm$  SD) R-TPA was  $24.9^\circ$  ( $\pm$  3.0) and  $24.6^\circ$  ( $\pm$  2.7) for CM and TM, respectively. These values were not statistically different. In both methods, the magnitude of the difference between R-TPAs increased as the specimens were moved to extreme positions with respect to the true lateral position. In addition, the magnitude of this difference was significantly greater in TM compared to CM.

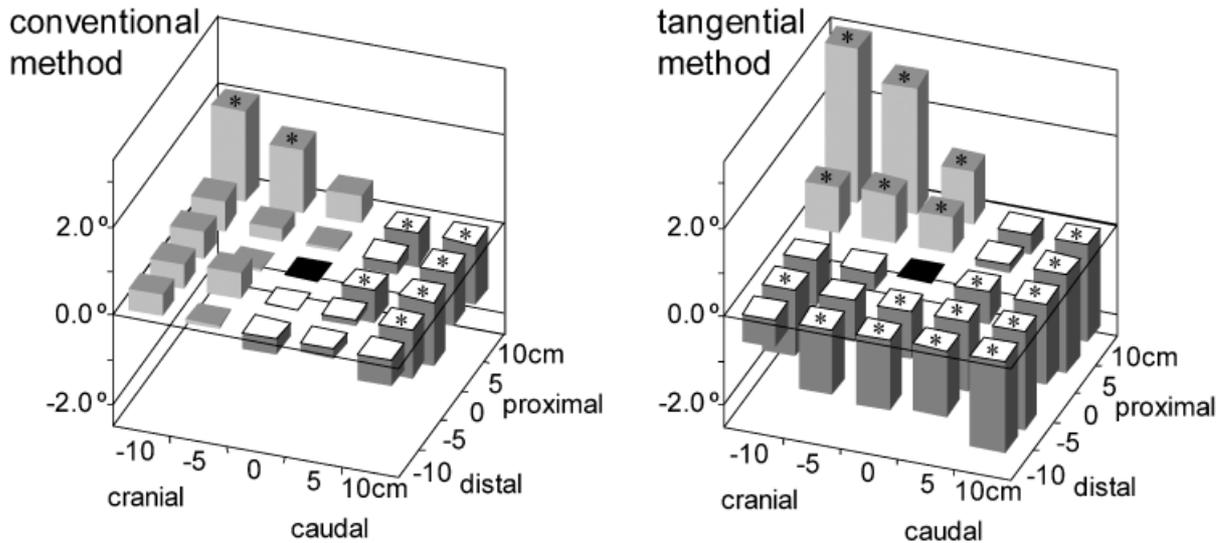
### *Intraobserver and Interobserver Variance*

The 95% confidence interval for interobserver variability was  $\pm 3.8^\circ$  for CM and  $\pm 4.5^\circ$  for TM.

## DISCUSSION

In previous studies TPA determination was performed on radiographs of the entire hind limb,<sup>2</sup> lateral tibial views centered on the tibial diaphysis,<sup>5,12</sup> and radiographs centered on the stifle joint.<sup>6-8</sup> Our purpose was to evaluate the effect of limb positioning on TPA measurement. A reproducible central position had to be chosen from which the change in location and the concomitant change in R-TPA could be evaluated. Accurate lateral positioning of the tibia for TPA determination appears to be a logical aspect as it places the observer perpendicular to the cranio-caudally inclined tibial plateau. True lateral positioning of the tibia was defined by superimposition of

Table 2. Results of the Mean ( $\pm$  SD) Difference of the Radiographic Tibial Plateau Angle (R-TPA) in the 24 Peripheral Positions Relative to the True Lateral Position (TL)



The conventional and tangential R-TPA determination methods are reported. Cranial and proximal relocation of the specimen resulted in a higher R-TPA while caudal and distal relocation resulted in a lower R-TPA. The tangential method resulted in a larger amount of R-TPA variation than the conventional method.

\*Indicates significant difference from the true lateral position (black square).

the femoral and tibial condyles. The large condyles were easily identified and patient positioning as well as positioning of the spacer below the trochanter were adjusted until superimposition was achieved. Only intact specimens from normal individuals were used and superimposition of femoral condyles coincided with superimposition of tibial condyles.

True lateral positioning of the distal femur, however, does not assure true lateral positioning of the tibia in clinical patients. Rupture of the CrCL allows for increased internal tibial rotation, torn and dislocated menisci can lock the stifle in internal or external rotation, and the degree of flexion of the stifle may influence tibial positioning as physiologic internal rotation of the tibia occurs during flexion of the stifle.<sup>17</sup> In view of total knee arthroplasty, human studies have evaluated tibial varus and valgus alignment during flexion of the knee on radiographic projections, finding that positioning does significantly alter alignment measurements.<sup>18</sup> Tibial positioning should therefore be evaluated for superimposition of the tibial condyles, regardless of femoral positioning. When comparing the R-TPA in this true lateral position with the A-TPA determined on the dissected specimen no difference was detected.

Malpositioning of the specimen influenced the radiographic appearance of the tibial plateau and the measured R-TPA. While cranial and proximal positioning

with respect to the central beam resulted in increased R-TPA measurement, a decrease in R-TPA was seen with caudal and distal positioning of the specimen. The change in position caused a maximal mean R-TPA difference of 3.6° and 5.7° when measured with the conventional and the tangential method, respectively. The influence of limb positioning on the TPA can partly be explained by the transformation of a 3-dimensional object into a 2-dimensional image. Repositioning of the specimen will alter the inciting angle of the radiographic beam projecting the complex 3-dimensional proximal tibia. This will change the spatial orientation of the tibia with respect to the radiographic beam and modify the resulting radiographic image. The medial and lateral tibial plateau will drift apart, the appearance of the curvilinear medial tibial plateau is changed, and different parts of the subchondral bone will compose the cranial and caudal limit of the tibial plateau. The perceived cranial and caudal margin of the tibial plateau may not correspond to the anatomic cranial and caudal margin. The same is true for the landmarks used for determination of the tibial functional axis. These landmarks, however, are at a greater distance than the ones used for identification of the tibial plateau. A small imprecision during tibial plateau identification will therefore have greater influence on TPA measurement than an imprecision during identification of the tibial axis.

Interestingly, the direction of malpositioning was closely related to the change in R-TPA. Cranial and proximal positioning with respect to the central beam resulted in increased R-TPA measurements and caudal and distal positioning resulted in decreased R-TPA measurements. These changes seemed to occur when the specimen was moved along the slope of the tibial plateau (cranio-proximal to caudo-distal). As the incident angle of the radiographic beam is altered, different areas of the peripheral border of the tibial plateau are projected as the cranial and caudal margin; the cranial and flatter or caudal and steeper part of the tibial plateau is projected as the central region. In addition, relocation of the limb results in unequal magnification and distortion of the tibial plateau. The resulting change in appearance will alter R-TPA measurement. Our hypothesis that limb position during radiography has an influence on the measured R-TPA was verified.

To simulate osteoarthritis and osteophyte formation around the tibial condyles hindering identification of the anatomic landmarks of the tibial plateau (ill-defined cranial and caudal margins of the medial tibial plateau and intercondylar eminences), the observers ignored these landmarks and determined the TPA using the tangential method. Identification of the tibial plateau by a tangent to the medial tibial plateau has been described and used for TPA determination.<sup>15</sup> For the tangential method, a specific and reproducible point in the central region of the tibial plateau had to be chosen. The tangent was determined at the point of intersection of the tibial axis with the tibial plateau. Although the direction, namely over- or under-estimation relative to the true lateral position, was identical in both methods, the magnitude of R-TPA variation was greater with the tangential method. Specimen relocation caused a maximal mean R-TPA difference of 3.6° and 5.7° when measured with the conventional and the tangential method, respectively.

In addition to the previously described factors leading to change in the tibial plateau appearance, the spatial relationship between the intercondylar eminences and the tibial plateau is altered. As the tibia is moved cranial and proximal, the medial plateau being closest to the origin of the radiographic beam is projected cranial and proximal with respect to the intercondylar eminences and the lateral plateau. Since the eminences are relocated to the caudal and steeper part of the medial plateau, R-TPA measurement increases. Caudal and distal positioning of the specimen moves the eminences in the cranial and flatter part of the plateau decreasing R-TPA measurement. In the true lateral position no difference between measurement methods was found. In this position the intercondylar eminences are located in the central part of the plateau and therefore tangential TPA determination is performed in the central region. Thus true lateral po-

sitioning is particularly important when the landmarks of the tibial plateau are poorly defined and the observer is forced to evaluate the central portion of the tibial plateau for TPA determination.

Overall the interobserver variability was  $\pm 3.8^\circ$  for CM and  $\pm 4.5^\circ$  for TM, indicating that variability because of different observers was greater for TM. This is most likely because estimation of a convex surface by a tangent is less reliable than determination of the starting and end point of the surface. As mentioned previously, the amount of error introduced by the observer decreases as the distance between the 2 landmarks used for determination is increased. These values are smaller than the previously reported interobserver variability for TPA determination of  $\pm 4.8^\circ$ .<sup>12</sup> That study evaluated clinical patients seen for CrCL rupture and DJD was present in those stifle joints. TPA determination in our study was performed on joints having no signs of DJD.

Measurement of the TPA after TPLO may be problematic because of rotation of the osteotomized segment affecting not only orientation of the tibial plateau, but also the location of the intercondylar eminences with respect to the long axis of the tibia.<sup>19</sup> These changes, however, are minimal as the intercondylar eminences are close to the center of rotation of the osteotomized segment and the landmarks used for tibial axis determination are at a greater distance. In humans, several measurement methods have been described for tibial plateau slope determination.<sup>14,15</sup> One study found a strong correlation and reliability of measurements comparing the tibial plateau slope to the tibial shaft anatomical axis, the tibial proximal anatomical axis, and the posterior tibial cortex.<sup>15</sup> Although these findings have not been verified in dogs, TPA measurement error induced by TPLO-related intercondylar eminence shift may be circumvented by comparing pre- and post-operative TPA measurements using the tibial proximal anatomical axis or the tibial anterior cortex instead of the functional tibial axis.

Standardization of the radiographic technique for TPA determination and accurate measurement of the TPA are necessary to calculate the amount of tibial plateau adjustment required during TPLO and to evaluate the actual amount of rotation on post-operative radiographs. Most importantly, it allows for meaningful interpretation of clinical and experimental research investigating TPA in the face of CrCL injury or post-operative TPA in the face of clinical outcome after TPLO.

True lateral positioning of the tibia defined by radiographic superimposition of the femoral and tibial condyles should be used for TPA determination to avoid over- and underestimation of the TPA. This is particularly important when identification of the cranial and caudal margin of the medial tibial plateau is hindered by

osteoarthritis. When possible the tibial plateau should be determined by its cranial and caudal margin.

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