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A modified technique for radiographic measurement of the tibial plateau angle in dogs

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ABSTRACT: This prospective study was aimed at testing a modified method for the measurement of the tibial plateau angle on radiographs of the stifle joint and the proximal part of the tibia. Forty-four stifle joints of 32 client-owned dogs were included in this study. Dogs were presented for hindlimb lameness and suspected cranial cruciate ligament rupture. The diagnostic procedures included radiographic examination. The mediolateral projection of the stifle joint including the tibia and the tarsal joint was used in this study. We tested the most widely used gold standard method as well as three additional methods for tibial plateau angle measurement on each joint. The tibial plateau angle, the positioning of the stifle joint and the presence of osteoarthrosis were recorded. Only 29 (66%) joints had correct position on the radiograph and were used for further study. Repeated-measures ANOVA identified significant differences in mean tibial plateau angle between the different measuring methods. Dunnett's post-hoc test identified a significant difference between the TA-2 and TA-2i methods and TA-0. No significant differences in tibial plateau angle were identified between joints with and without osteoarthrosis. The positioning of the limb significantly influenced the tibial plateau angle. One of the modified methods was found to not differ significantly from the gold standard method; thus, it can be recommended for further testing.

Keywords: proximal tibial axis; stifle joint; cruciate ligament disease; musculoskeletal imaging; radiology

Rupture of the cranial cruciate ligament leads to translational and rotational instability of the stifle joint (Arnoczky and Marshall 1977; De Rooster and Van Bree 1999; Kowaleski et al. 2005). Many different surgical methods have been described to stabilise the stifle joint in dogs with rupture of the cranial cruciate ligament (Slocum and Slocum 1993; Montavon et al. 2002; Kim et al. 2008; Boudrieau 2009). One of the most popular methods is tibial plateau leveling osteotomy (Aragon and Budsberg 2005; Fitzpatrick and Solano 2010; Nicoll et al. 2014). For a successful application of this surgical procedure, the tibial plateau angle (TPA) measurement is crucial. The TPA is measured on a mediolateral radiographic projection of the stifle joint. The widely used method to define the longitudinal tibial axis requires a radiograph depicting the entire tibia including the stifle and tarsal joints (Caylor et al. 2001; Abel et al. 2003; Baroni et al. 2003). Measurement of the TPA based on a radiograph of the stifle joint without visualisation of the entire tibia has been previously described, but the method was considered inferior to the widely used method (Abel et al. 2003).

The aim of this study was to find an accurate method for measuring the TPA on mediolateral stifle radiographs using only the proximal tibial axis. We also tested if the positioning of the stifle

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joint and the presence of osteoarthritic changes on the tibial plateau result in any changes in the TPA.

MATERIAL AND METHODS

Animals and radiographic technique. We carried out a prospective study of client-owned dogs referred for radiographic examination because of suspected cranial cruciate ligament rupture. Owner consent was obtained prior to the radiographic study. A radiograph of the stifle joint in mediolateral projection including stifle and tarsal joints (whole-tibia radiograph) was available for each dog. Dogs were sedated or anaesthetised during radiographic examination. For sedation, medetomidine (10–20 μg/kg *i.v.* Domitor, Pfizer) and butorphanol (0.2 mg/kg *i.v.* Butomidor, Richter Pharma AG) were used. For general anaesthesia, the same combination of drugs was used and propofol (1–2 mg/kg *i.v.* Propofol, Abbott) was added. Each radiograph was taken using a "table-top" technique without any grid. The beam was centred over the mid-diaphysis of the tibia. All radiographs were taken with settings of 50 kVp and 8.0 to 15.8 mAs depending on the size of the stifle joint. The imaging plates were processed with a computed radiography system (Capsula XL, Fuji, Japan).

Measurements. All measurements were taken as a single measurement by the first author using DICOM viewer software (JiveX 4.3.5, VISUS Technology Transfer GmbH, Germany). Four different methods for TPA measurement were tested in this study. For each method, a line representing the tibial plateau was drawn between the cranial edge of the tibial articular surface and the caudal edge of the medial tibial condyle; also, a characteristic tibial axis was created. For the widely used method (TA-0), a longitudinal tibial axis was created as previously described (Caylor et al. 2001; Baroni et al. 2003; Reif et al. 2004) (Figure 1). The tibial axis for the TA-2 method was constructed as previously described (Abel et al. 2003) and based on that report, we decided to use only the longest proximal tibial axis (2 × the width of the proximal tibia). The remaining two methods (TA-2o, TA-2i) were defined as modifications of the TA-2 method. The purpose of these modifications was to create a proximal tibial axis that is parallel to the tibial axis created in the TA-0 method. The first point for the definition of the proximal tibial axis in TA-2o and TA-2i methods was the most proximal point of the intercondylar eminence or the point of intersection of both eminences. To create the second point, a circle of a radius of 2 × the width of the proximal tibia and centred at the intercondylar eminence was created. The proximal tibial width was measured between the most cranial point on the tibial tuberosity and the caudal edge of the tibial plateau. The intersection of the circle with the periosteal (TA-2o) and the endosteal (TA-2i) surfaces of the

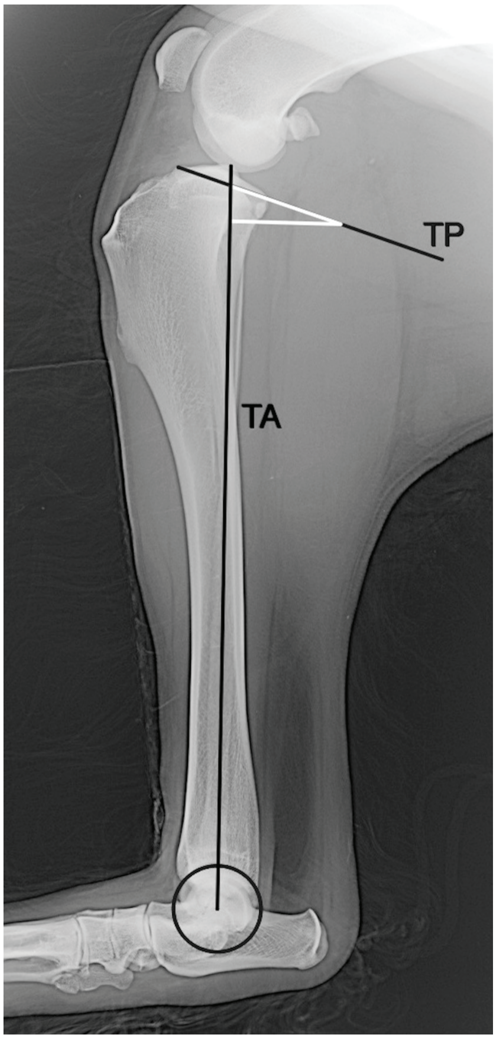

Figure 1. Mediolateral radiograph of the stifle joint including the tarsal joint. Tibial axis (TA) of the widely used method is shown between the centre point of the talus and the intercondylar eminence. The tibial plateau (TP) is shown as a black line between the cranial edge of the tibial articular surface and the caudal edge of the medial tibial condyle. The tibial plateau angle (white lines) was measured between the tibial plateau line and the line perpendicular to the tibial axis

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caudal tibial cortex, respectively, was set as the second point for the proximal tibial axis (Figure 2). In all methods, the TPA was measured as the distance between the tibial plateau line and a line perpendicular to the various tibial axes.

The positioning and presence of osteoarthritic changes were recorded for each joint during the angle measurement. There were two categories for both variables. The position was scored as correct if the femoral and tibial condyles were superimposed. Deviation from the superimposition of less than 3 mm was considered acceptable. Otherwise, the position was scored as incorrect and these joints were excluded from the study. Osteoarthritic changes on the tibial plateau were scored qualitatively (yes/no). Only the TA-0 method was used for these two analyses.

Statistics. Data were analysed using a commercial statistical software (Minitab 16, Minitab Inc., Coventry, UK). Differences between the various measuring methods were tested using repeated-measures ANOVA. Simultaneous confidence intervals were created in the Dunnett test using the TA-0 method as a control. The Dunnett test (comparison with a control) generates smaller confidence intervals and is more powerful compared to the all-pairs tests. Differences between TPA caused by the positioning of the stifle joint or by the presence of osteoarthritic changes on the tibial plateau were tested with two-sample *t*-test. The level of significance for all statistical analyses was set at $P < 0.05$.

RESULTS

Forty-four stifle joints from 32 dogs were included in this study. The mean age of the dogs was 45.4 months (SD 29.0 months; median 38.5 months). Mean body weight was 44.5 kg (SD 13.6 kg; median 44.0 kg). There were eight (25%) intact females, 22 (69%) intact males, one (3%) spayed female and one (3%) neutered male. The dogs were of the following breeds: Labrador retriever (3), German shepherd (3), Dogo Argentino (2), Dogue de Bordeaux (2), Belgian shepherd (2), Boxer (2), Cane corso (2), Doberman pincher (2), Caucasian shepherd dog (2),

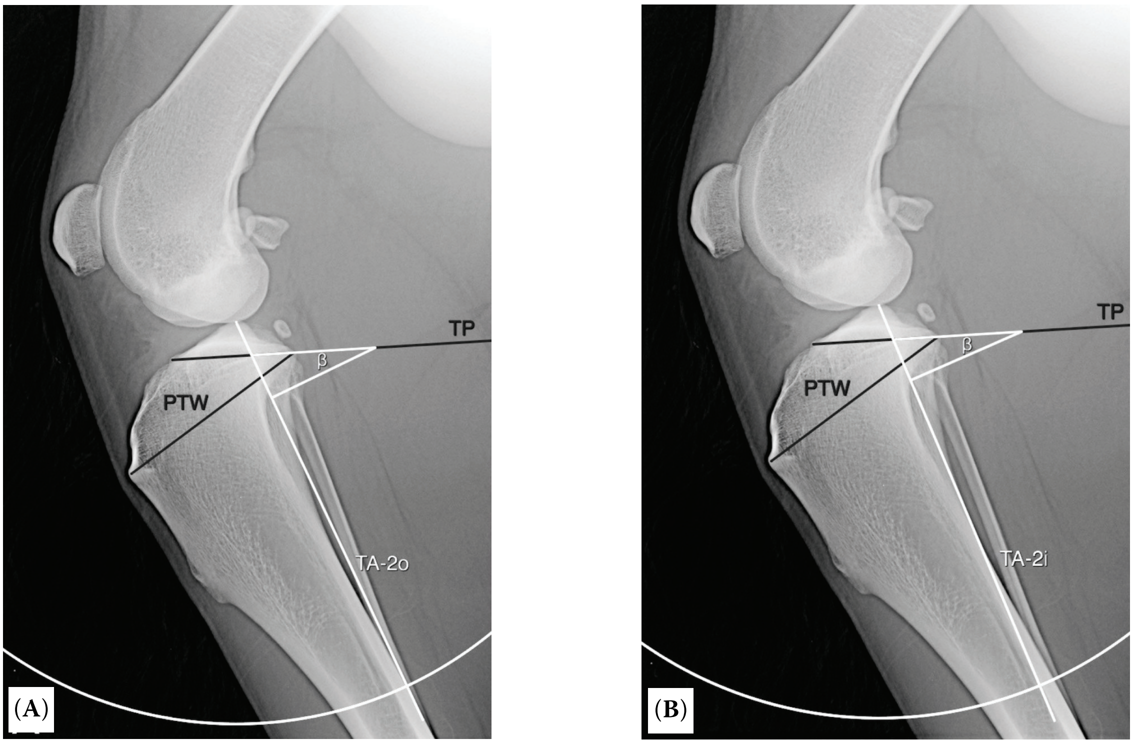

Figure 2. Mediolateral radiograph of the stifle joint showing only the proximal part of the tibia. The intersection of the circle (white curved line at the bottom of the figure) with the caudal tibial cortex was used as a second point for the tibial axis. Tibial axes were set between the intercondylar eminence and the intersection point on the periosteal (**A**) or endosteal (**B**) surface of the caudal tibial cortex

ß = tibial plateau angle, PTW = proximal tibial width, TP = tibial plateau

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Table 1. Descriptive statistics of the measurements made using the methods described in this study. All the values in the table are in degrees

Method	TA-0	TA-2	TA-2i	TA-2o
Mean	25.09	28.80	23.59	26.12
SE Mean	0.72	0.51	0.62	0.63
SD	3.87	2.74	3.32	3.37
Median	25.81	28.48	23.81	25.93

American bulldog, American staffordshire terrier, Irish wolfhound, Vizsla, Newfoundland, Pitbull terrier, Russian terrier, Rottweiler, Saint Bernard dog, Tosa-Inu, Tibetan mastiff and crossbreed (one each).

Fifteen (34%) joints had incorrect positioning on the radiograph, i.e., femoral or tibial condyles were not superimposed; these were excluded from the study. Only 29 (66%) joints were used for further analysis regarding different measuring methods. However, we compared the mean TPA in the group of correctly positioned joints with the group of incorrectly positioned joints. The difference between the mean TPA values in these two groups was significant ($P = 0.0137$). The mean TPA in the incorrectly positioned group was 28.53° (SE mean 1.23°; SD 4.77°) and for the correctly positioned group it was 25.09° (SE mean 0.72°; SD 3.87°). Mean, SE of the mean, standard deviation and median values for the correctly positioned joint group are listed in Table 1.

Repeated-measures ANOVA identified a significant difference in the mean TPA values between the methods. Dunnett's post-hoc test identified a significant difference between TA-2 and TA-2i methods and TA-0. The TA-2o method was not significantly different from TA-0.

Osteoarthritic changes on the tibial plateau were seen in five (17.24%) joints and the mean TPA value was 23.14° (SE mean 1.32°; SD 2.94°). Twenty-four (82.76%) joints were without any osteoarthritic changes and the mean TPA value was 25.50° (SE mean 0.81°; SD 3.97°). There was no significant difference between the TPA in stifle joints with osteoarthritic changes and joints without osteoarthritic changes ($P = 0.2212$).

DISCUSSION

A mediolateral radiograph including the stifle and the tarsal joint is necessary for measuring the TPA according to the most widely used method in the field (Caylor et al. 2001; Abel et al. 2003; Baroni et al. 2003). The first image routinely taken when examining the stifle joint is an mediolateral projection with the X-ray beam centred on the femoral condyles depicting only the proximal tibia. To the authors' knowledge, there is only one publication describing a method for TPA measurement using the proximal tibial axis (Abel et al. 2003). The tibial axes used in that publication were not parallel to the tibial axis of the widely used method. Our assumption was that a proximal tibial axis that is parallel to the tibial axis of the widely used method would allows us to obtain the same TPA values. All the tibial axes used in this study are shown in Figure 3. Although the axes in the modified methods are not exactly parallel to the axis in the TA-0 method there was no statistically significant difference in the TPA values measured using the TA-2o and TA-0 methods. All

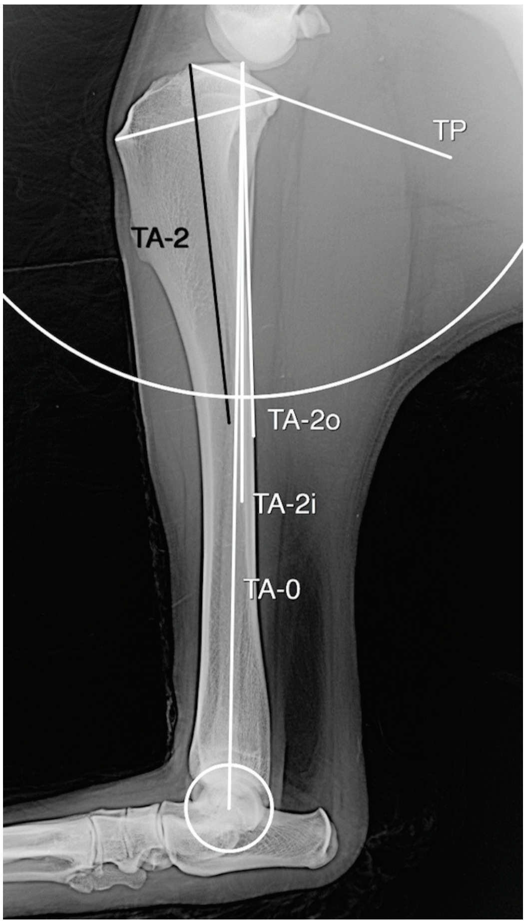

Figure 3. Mediolateral radiograph of the tibia and tarsal joint showing all tibial axes used in this study and their relation. The abbreviation used for the axes are the same as those used for the measuring methods

TP = tibial plateau

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the measured TPA values are within the range of published values (Fettig et al. 2003).

The critical step in all methods for TPA measurement is the definition of the caudal reference point on the medial tibial condyle. To identify this point is even more difficult if osteoarthritic changes are present on the tibial plateau (Fettig et al. 2003). TPA angles may differ significantly if the caudal end of the tibial plateau is not defined consistently (Baroni et al. 2003; Ocal and Sabanci 2013). Our assumption that the presence of osteophytes on the tibial plateau leads to different TPA values due to an inability to precisely locate the caudal point, was not confirmed. Although only a few of the stifle joints in our study showed osteophytes on the tibial plateau, no significant difference in TPA was identified between joints with and without osteoarthritic changes. This is in agreement with previous reports in dogs (Fujita et al. 2006; Ritter et al. 2007) and cats (Schnabl et al. 2009).

In this study, the TPA had a higher value in the incorrectly positioned stifle joint group than in the group in which it was correctly positioned. In an earlier study, the relationship between the position of the central X-ray beam and the TPA was examined. An X-ray beam centred caudo-distally to the stifle joint resulted in a higher TPA measurement compared to a beam centred exactly over the stifle joint (Reif et al. 2004). Based on this information, we could speculate that the TPA values for the incorrectly positioned stifle joints were influenced by this effect. All the radiographs in this study were centred in the same way, over the mid-diaphysis of the tibia. A slight rotation of the tibia around the long axis or X-ray beam centred caudally to the exact centre of the tibial diaphysis could be the source of the difference in TPA values. A thorough discussion of this issue is outside of the scope of this article but has been published previously (Reif et al. 2004).

There are a few limitations to this study. As this was a prospective study performed over a limited timeframe, only a small number of radiographs were included. Inadequate superimposition of the femoral condyles was observed in one-third of radiographs and only a small sample size was used for comparison of different measuring methods. We speculate that an incorrect position of the femoral condyles does not automatically suggest an incorrect position of the tibia (Reif et al. 2004). Ruptured cranial cruciate ligament results in an internal rotation of the tibia (Arnoczky and Marshall 1977). This could be interpreted also in the opposite way and during the radiographic positioning could lead to an outward rotation of the femoral condyles, but a normal position of the tibia. Therefore, it is necessary to assess the position of femoral and tibial condyles individually.

In conclusion, our experiments show that the modified TA-2o method does not significantly differ from the commonly used method (TA-0), and can thus be recommended for further testing. A new study on a larger group of dogs is warranted to validate our results.

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