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# Rock back phenomenon in 32 dogs that underwent tibial plateau levelling osteotomy

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**Abstract:** The aim of this study was to evaluate the postoperative temporal changes in the tibial plateau angle (TPA) after a tibial plateau levelling osteotomy (TPLO) in dogs. The TPA of thirty-two dogs were measured before surgery ($TPA_1$), immediately after the TPLO ($TPA_2$), and later at the healing of the osteotomy site ($TPA_3$). Three observers carried out three TPA measurements for each patient at the time of the evaluation. TPA changes were observed over the bone healing (2.05 ± 3.05°); however, no statistical significance was noted when comparing $TPA_3$ and $TPA_1$. There were no statistical differences in the inter-observer measurements among $TPA_1$, $TPA_2$, and $TPA_3$ ($P > 0.05$). The comparison between the preoperative $TPA_1$ and the rock back showed a low positive correlation ($S$ = 4 735.9, $P$ = 0.471 5, $r$ = 0.131 976 9). There was also a low positive correlation between the body weight (kg) and the change in the TPA during the bone healing ($S$ = 4 581.8, $P$ = 0.381, $r$ = 0.160 234 7). Although changes in the TPA have been observed over the time of the bone healing, they were not influenced by the preoperative and postoperative TPA, or by the body weight. The magnitude of the variation in the TPA is not determined by the previous inclination or by the degree of rotation in the plateau.

**Keywords:** cranial cruciate ligament; postoperative complication; orthopaedic surgery; TPLO; TPA

Cranial cruciate ligament disease (CCLD) is one of the most common causes of pelvic limb lameness and is responsible for most surgical procedures performed on the stifle joint in dogs (Clark et al. 2020; Won et al. 2020).

A tibial plateau levelling osteotomy (TPLO) represents the best way to treat CCLD, despite more than 5 decades since the first surgical treatment described for this condition (Barnes et al. 2019; Nanda and Hans 2019; Clark et al. 2020; Vezzoni et al. 2020). The magnitude of the cranial tibial impulse is dependent on the tilt angle of the tibial plateau; therefore, in this procedure, a proximal tibial circular osteotomy is performed, after which the tibiofemoral shear force is neutralised during the gait, establishing an angle of the tibial plateau (TPA) suitable for the dynamic joint stabilisation (Stine et al. 2018; Nanda and Hans 2019).

The angle considered ideal for neutralising tibial translation in relation to the femur is between 5° and 6.5°; however, good clinical results have also been reported in patients with wider margins

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(0° to 14°) (Warzee et al. 2001; Reif et al. 2002; Nanda and Hans 2019).

The postoperative TPA value is considered fundamental for the success of the procedure, and there should not be any excess rotation or an insufficient rotation (Nanda and Hans 2019). It is also known that the TPA achieved in the immediate postoperative period can undergo changes until the osteotomy of the TPLO consolidates. This phenomenon has been called the "rock back" phenomenon (Bergh et al. 2008; Taylor et al. 2011; Nanda and Hans 2019). This alteration is defined as the movement of the segment of the tibial plateau that occurs along the osteotomy line, causing an increase in the TPA of ≥5°, between the immediate postoperative period and the subsequent control radiographs (Duerr et al. 2008; Moeller et al. 2010). It is suggested that this is a mechanical process, determined by the secondary loss of reduction. However, the cause of the change in the TPA during the bone healing is not fully understood (Bergh et al. 2008; Moeller et al. 2010; Taylor et al. 2011).

The aim of the present study was to evaluate the presence and size of the TPA alteration during the bone healing in dogs subjected to TPLO and to determine its correlation with the preoperative TPA, immediate postoperative TPA, and patient body weight.

## MATERIAL AND METHODS

All the procedures described were in compliance with the Animal Use Ethics Commission (CEUA).

Thirty-two patients presented at the University Veterinary Hospital – UNESP – Jaboticabal (Brazil) and diagnosed with cranial cruciate ligament disease were included in the study.

The inclusion criteria were the body mass (range 20–46 kg, mean 30.38 kg), age (range 18 months to 119 months, mean 63 months old), and complete radiographic follow-up and images appropriate for the TPA measurement.

All the patients were assessed for the TPA in the pre-surgical period ($TPA_1$), immediate post-surgical period ($TPA_2$), and after consolidation of the TPLO osteotomy ($TPA_3$). The patients were clinically evaluated in the preoperative and postoperative periods. A subjective gait analysis and a tibial compression test were used. To assess the consolidation of the osteotomy, radiographs in cranio-caudal and latero-lateral views were analysed and were considered consolidated when the cortical bones were visually united, as is normally performed in the clinical routine. The influence of the body weight of each patient was correlated to the changes in the TPA during the bone healing.

The angles of the tibial plateau were measured using medio-lateral radiographs, with the affected limbs positioned with the stifle and tarsus maintained at 90° of flexion and the tibia was maintained parallel to the radiographic cassette, without any femoral or tibial rotation, in order to facilitate the overlapping of the femoral, tibial condyles, and joint alignment, following the guidelines previously described by Slocum and Slocum (1993) and Dismukes et al. (2008). To determine the TPA, two lines were drawn: a) the line which connects the cranial and caudal extensions of the medial tibial condyle and determines the axis of the tibial plateau and b) the line that connects the point which divides the tibial intercondylar tubercles (centre of the tibial intercondylar eminence) and the centre of rotation of the talus and determines the mechanical axis of the tibia in the sagittal plane (Figure 1A). The TPA is measured at the intersection of the line of the tibial plateau with the line of the mechanical axis of the tibia (Figure 1B) (Dismukes et al. 2008).

To minimise errors due to the variability in the subjective evaluation, three observers with experience, both with the measurement and the procedure, evaluated the radiographs and performed the measurements for each patient at each time of the evaluation.

Each observer performed 3 measurements for each image, with a minimum time interval of 3 days between the assessments, thus avoiding a suggestive memory when selecting the anatomical reference points. The observers randomly evaluated the images, and were blinded to the clinical details of the cases. In addition, all the measurements were made on digital radiographs, using computer programs to facilitate and standardise the measurement of the TPAs (RadiAnt DICOM Viewer 64bit, Poznań, Poland).

For comparisons between the values obtained for the TPAs between the three observers, the data was submitted to a Shapiro-Wilk test to ascertain whether the data was normally distributed, and to a Bartlett test to ascertain whether they had equal variances. For the inter-observer comparison

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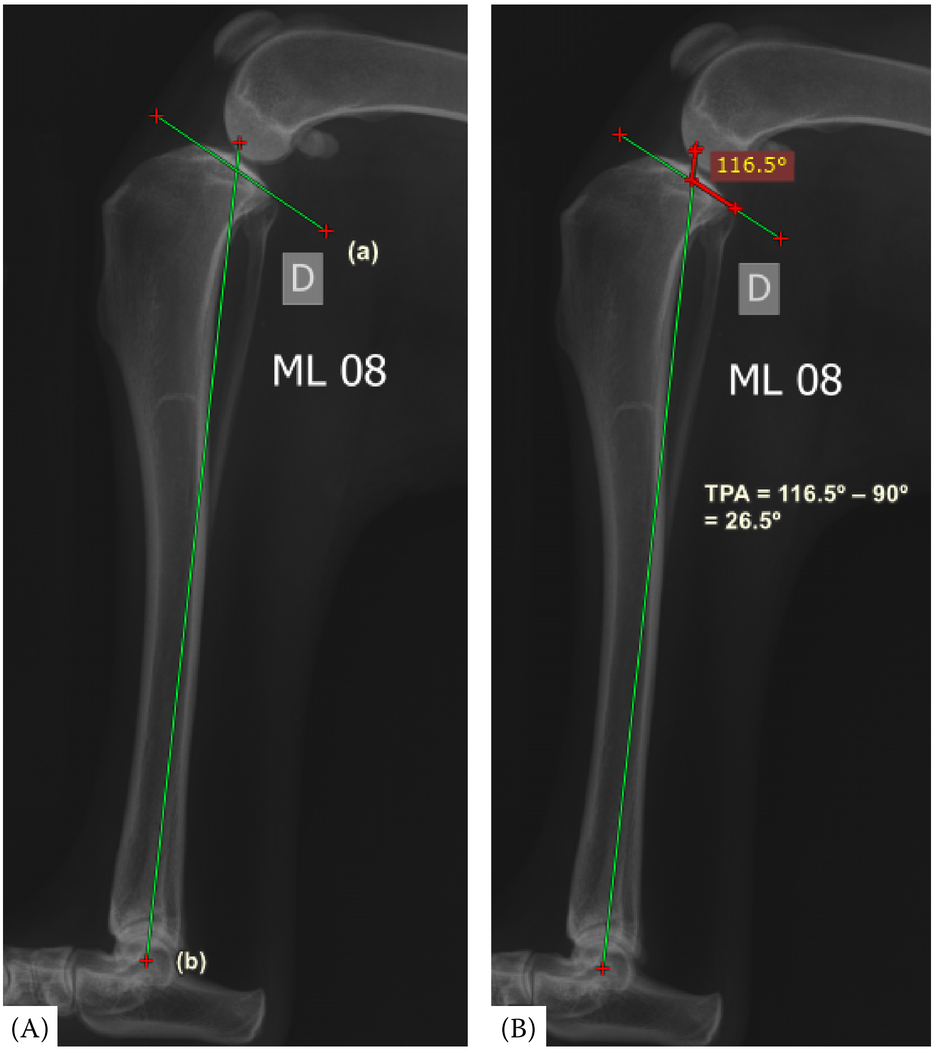


Figure 1. Determination of the TPA in the preoperative planning of the TPLO (A) Demarcation of the line of the tibial plateau (a) and the mechanical axis of the tibia (b). (B) Measurement of the tilt angle of thetibial plateau

of the data referring to the $TPA_3$ measurements, an analysis of variance test (ANOVA) was used for the measurement, followed by Tukey's post hoc analysis. To verify the inter-observer difference in the data referring to $TPA_1$, $TPA_2$, and the alteration of the TPA during the bone healing ("rock back" phenomenon), a Kruskal-Wallis test was used, followed by Dunn's post hoc test. The Shapiro-Wilk test was applied on the arithmetic mean calculated from the data obtained from each observer for $TPA_2$ and $TPA_3$ to determine whether they were normally distributed. Student's *t*-test was used to compare the data obtained for $TPA_2$ and $TPA_3$.

Pearson's correlation was used to assess the possible correlation between the TPA changes during the bone healing and $TPA_1$, whereas Spearman's correlation was used to assess the possible correlation between the TPA changes during the bone healing and $TPA_2$ and the TPA changes during the bone healing and the patient body weight.

## RESULTS

The distribution of the breeds for these thirty-two dogs was as follows: mixed breed (9), English Bulldog (5), Rottweiler (3), Golden Retriever (3), Akita (1), American Staffordshire Terrier (2), German Shepherd (1), Malinois Shepherd (1), Staffordshire Bull Terrier (1), American Pitbull (1), Boxer (1), Fila Brasileiro (1), Border Collie (1), and American Bully (1). The average age of the animals was 5 years and 3 months (range, 1 year and 6 months to 9 years and 11 months). The average body weight was 30.38 kg (range, 20–45.4 kg). Females comprised 68% (26) of the total subjects and the right joint was involved in 53.12% (17) of the cases. The means of the intra- and inter-observer measurements of the $TPA_1$, $TPA_2$, and $TPA_3$ for each patient are shown in Table 1.

The general and per-observer results of the general mean of the TPAs, the respective standard

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Table 1. Overall average of the TPAs of each animal, at the time of each assessment ($TPA_1$, $TPA_2$, $TPA_3$)

| Animal | Image | TPA (°) | Animal | Image | TPA (°) | Animal | Image | TPA (°) |
|---|---|---|---|---|---|---|---|---|
| | $TPA_1$ | 25.07 | | $TPA_1$ | 28.76 | | $TPA_1$ | 28.04 |
| 1 | $TPA_2$ | 12.92 | 12 | $TPA_2$ | 8.04 | 23 | $TPA_2$ | 12.73 |
| | $TPA_3$ | 16.07 | | $TPA_3$ | 9.02 | | $TPA_3$ | 18.05 |
| | $TPA_1$ | 29.40 | | $TPA_1$ | 31.47 | | $TPA_1$ | 23.97 |
| 2 | $TPA_2$ | 11.23 | 13 | $TPA_2$ | 12.13 | 24 | $TPA_2$ | 10.09 |
| | $TPA_3$ | 11.27 | | $TPA_3$ | 14.34 | | $TPA_3$ | 11.41 |
| | $TPA_1$ | 29.16 | | $TPA_1$ | 28.04 | | $TPA_1$ | 27.61 |
| 3 | $TPA_2$ | 7.74 | 14 | $TPA_2$ | 7.58 | 25 | $TPA_2$ | 8.02 |
| | $TPA_3$ | 10.74 | | $TPA_3$ | 13.19 | | $TPA_3$ | 7.13 |
| | $TPA_1$ | 27.53 | | $TPA_1$ | 24.97 | | $TPA_1$ | 23.35 |
| 4 | $TPA_2$ | 5.51 | 15 | $TPA_2$ | 10.86 | 26 | $TPA_2$ | 7.79 |
| | $TPA_3$ | 6.59 | | $TPA_3$ | 10.79 | | $TPA_3$ | 11.92 |
| | $TPA_1$ | 31.70 | | $TPA_1$ | 24.38 | | $TPA_1$ | 22.26 |
| 5 | $TPA_2$ | 13.54 | 16 | $TPA_2$ | 8.28 | 27 | $TPA_2$ | 8.10 |
| | $TPA_3$ | 16.48 | | $TPA_3$ | 13.88 | | $TPA_3$ | 9.56 |
| | $TPA_1$ | 29.59 | | $TPA_1$ | 28.72 | | $TPA_1$ | 26.04 |
| 6 | $TPA_2$ | 11.70 | 17 | $TPA_2$ | 10.81 | 28 | $TPA_2$ | 4.88 |
| | $TPA_3$ | 16.69 | | $TPA_3$ | 11.51 | | $TPA_3$ | 6.33 |
| | $TPA_1$ | 17.56 | | $TPA_1$ | 21.06 | | $TPA_1$ | 15.88 |
| 7 | $TPA_2$ | 4.13 | 18 | $TPA_2$ | 5.60 | 29 | $TPA_2$ | 3.30 |
| | $TPA_3$ | 8.42 | | $TPA_3$ | 6.96 | | $TPA_3$ | 3.36 |
| | $TPA_1$ | 22.77 | | $TPA_1$ | 20.01 | | $TPA_1$ | 23.24 |
| 8 | $TPA_2$ | 4.67 | 19 | $TPA_2$ | 6.13 | 30 | $TPA_2$ | 0.4 |
| | $TPA_3$ | 5.80 | | $TPA_3$ | 6.50 | | $TPA_3$ | –0.66 |
| | $TPA_1$ | 26.29 | | $TPA_1$ | 27.23 | | $TPA_1$ | 25.86 |
| 9 | $TPA_2$ | 0.92 | 20 | $TPA_2$ | 9.52 | 31 | $TPA_2$ | –0.49 |
| | $TPA_3$ | 1.93 | | $TPA_3$ | 8.87 | | $TPA_3$ | 5.77 |
| | $TPA_1$ | 22.77 | | $TPA_1$ | 28.56 | | $TPA_1$ | 24.51 |
| 10 | $TPA_2$ | 8.90 | 21 | $TPA_2$ | 8.62 | 32 | $TPA_2$ | 9.34 |
| | $TPA_3$ | 9.92 | | $TPA_3$ | 13.29 | | $TPA_3$ | 10.93 |
| | $TPA_1$ | 28.07 | | $TPA_1$ | 29.23 | | | |
| 11 | $TPA_2$ | 9.08 | 22 | $TPA_2$ | 10.74 | | | |
| | $TPA_3$ | 10.62 | | $TPA_3$ | 11.64 | | | |

TPA = angle of the tibial plateau; $TPA_1$ = preoperative; $TPA_2$ = immediate postoperative; $TPA_3$ = after the osteotomy consolidation

deviations, and the change in the TPA during the bone healing are shown in Table 2.

There were no significant differences in the inter-observer measurements in relation to $TPA_1$ ($P$ = 0.76), $TPA_2$ ($P$ = 0.839 4), and $TPA_3$ ($P$ = 0.331). The change in the TPA during the bone healing process was not found to be statistically significant ($P$ = 0.161 4). The results of Student's $t$-test

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Table 2. Overall and per-observer average of the $TPA_1$, $TPA_2$, $TPA_3$ and the change in the TPA during the bone healing

| Observer | $TPA_1$ | $TPA_2$ | $TPA_3$ | Alteration of TPA during bone healing |
|---|---|---|---|---|
| 1 | 26.21 ± 4.18 | 8.13 ± 4.81 | 10.70 ± 5.42 | 2.57 ± 3.85 |
| 2 | 25.24 ± 4.26 | 7.72 ± 4.74 | 8.90 ± 5.36 | 1.17 ± 3.13 |
| 3 | 25.70 ± 3.85 | 7.83 ± 3.13 | 10.23 ± 4.06 | 2.40 ± 2.18 |
| Overall average | 25.72 ± 4.10 | 7.89 ± 4.23 | 9.94 ± 4.95 | 2.05 ± 3.05 |

TPA = angle of the tibial plateau; $TPA_1$ = preoperative; $TPA_2$ = immediate postoperative; $TPA_3$ = after the osteotomy consolidation

for the comparison between the data obtained for $TPA_2$ (7.896 174 ± 3.631 199) and $TPA_3$ (9.947 049 ± 4.310 051) showed that there was no statistically significant difference between the final TPA after the osteotomy consolidation of the TPLO, and the TPA reached in the immediate postoperative period ($P$ = 0.438 7). There was a low positive correlation between the $TPA_1$ values and the "rock back" phenomenon ($S$ = 4 735.9, $P$ = 0.471 5, $r$ = 0.131 976 9), along with a low positive correlation between the values of the body weight and the change in the TPA during the bone healing ($S$ = 4 581.8, $P$ = 0.381, $r$ = 0.160 234 7).

## DISCUSSION

This research sought to identify the frequency and intensity of the secondary loss of the fragment rotation and the potential factors affecting it; and the consequent alteration of the postoperative TPA. An even better understanding of this complication, which is probably under-diagnosed and has effects that are not yet fully understood, was sought (Bergh et al. 2008; Taylor et al. 2011).

TPLO reduces the magnitude of the cranial tibial impulse as the angle of the tibial plateau is reduced with the rotation of the osteotomised fragment, dynamically stabilising the stifle joint (Slocum and Slocum 1993). It is already known that a certain variation in the postoperative TPA is acceptable, and capable of providing satisfactory results, contrary to the initial guidelines that the final angle should be between 5° and 6.5° (Slocum and Slocum 1993; Warzee et al. 2001). Of the thirty-two cases evaluated in our study, only three (9.3%) cases reached a TPA between 5° and 6.5° after the TPLO ($TPA_2$), with the average of the immediate postoperative TPAs being 7.9°, with a variation of –0.49° to 13.54°. Even with a wide variation in inclination degrees of the tibial plateau, there was sufficient cancellation of the cranial tibial displacement, stabilisation of the joint, and a good functional return of the limb in all the cases.

Such findings are consistent with previous studies and support the idea that the "ideal" TPA has not yet been determined (Warzee et al. 2001) or at least a wider or different variation may be acceptable as well. It has been previously shown in another study that there is no statistically significant difference between postoperative TPAs ranging from 0° to 14° when subjected to soil reaction forces (Robinson et al. 2006). It was observed that thirty-one (96.87%) of the cases in this study were within the range of 0–14 degrees.

In the same way that the excessive rotation of the tibial plateau increases the caudal tibial displacement and the tension on the caudal cruciate ligament, an insufficient rotation may not eliminate the cranial tibial displacement and does not solve the clinical dysfunction (Warzee et al. 2001; Reif et al. 2002). In addition, the TPA reached in the immediate postoperative period may undergo changes until the consolidation of the TPLO osteotomy, a phenomenon called the "rock back" of the tibial plateau (Bergh et al. 2008; Taylor et al. 2011). In our study, the change in the TPA during the bone healing was present with a variation of 2.05° ± 3.05°; however, it was not statistically significant when compared to the TPA reached in the immediate postoperative period. The average time for the radiographic verification was 128 days (range, 60–455 days). According to a study by Moeller et al. (2006) the mean change in the TPA from the immediate postoperative period up to 46 days (6.5 weeks) after the TPLO was 1.5°. However, the actual change in the TPA may be higher, as only 73.2% of the patients evaluated in their study had a bone consolidation of the osteotomy at the time of evaluation. In the study by Conkling et al. (2010), the mean change in the TPA was 1.9° which is similar to the results found in our study and those found by Moeller et al. (2006). However,

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the average time for the radiographic verification was 60.5 days (8.6 weeks), with no further changes likely.

The low positive correlation between the change in the TPA during the bone healing and the $TPA_2$ observed in this study shows that even with a variation of –0.49° to 13.54° in $TPA_2$, the change in the TPA during the bone healing was not proportional to the degree of rotation of the tibial plateau by the TPLO. A similar low positive correlation between the pre-surgical inclination of the TPA and the change in the TPA during the bone healing means that preoperative TPAs from 15.88° to 31.70° did not interfere or cause greater regression of the TPA until the bone consolidation. Further studies are needed to determine whether higher preoperative TPAs have a determinant correlation with the change in the TPA during the bone healing.

Another factor that can potentially interfere with the alteration of the rotation of the tibial plateau after the TPLO is the load exerted by the patient's weight on the stifle joint during the gait support phase, in the period of the bone consolidation. The low positive correlation between the change in the TPA during the bone healing and the patient's weight led us to conclude that the patient's body weight, after a rigid stabilisation, did not compromise the rotation of the tibial plateau and the joint stabiliser.

The cause of this complication remains to be investigated, and studies report that a change in the TPA after surgery is likely to occur due to the secondary loss of reduction or an incorrect implant fixation (Conkling et al. 2010). Several models of dedicated plates have been developed in recent years, most of them with locking systems at a fixed angle between the screws and the plate, which should reduce the factors affecting the results related to the implant (Leitner et al. 2008; Conkling et al. 2010; Kowaleski et al. 2013). On the other hand, the inadequate positioning of the osteotomy or an incompatibility between the rigid implant and a relatively soft bone (metaphyseal bone) may be associated with the alteration of the TPA (Bergh et al. 2008; Taylor et al. 2011).

Changes in the positioning, laxity, osteolysis, or implant failure were not observed in any of the cases in this study when the radiographs of the immediate postoperative period were compared with those after consolidation of the osteotomy. In all the cases, the bone healing occurred without any major complications. In this study, all the used implants had a lock between the plate and screws. It is believed that this may have helped to minimise any possible complications (Conkling et al. 2010). Thus, an intriguing inference emerges from these facts, that although underdiagnosed, the loss of angulation may not be clinically relevant in patients who are well managed surgically, since there seems to be a wider safety range for the final TPA. The satisfactory results of TPLOs with insufficient or excessive rotation, indistinguishable from the result of dogs with acceptable postoperative TPAs, may indicate that the complete elimination of the cranial tibial impulse *in vivo* can be achieved in a wide range of angles (Moeller et al. 2006; Robinson et al. 2006).

The lack of significant variability in the inter-observer measurements in this study shows that the observers' experience did not interfere with the values obtained. A study by Fettig et al. (2003) did not identify a significant difference in the TPA measurements between three groups of observers, when separated by the observer's experience, but assumed a difference in the ability to select the points for the measurements in the normal patients and dogs clinically affected by the rupture of the CCLD, as they have varying degrees of degenerative joint disease (DAD) (Fettig et al. 2003). On the other hand, Caylor et al. (2001) assessed the variability of intra- and inter-observer measurements of the TPA measurements on the lateral radiographs of dogs, and observed an intra-observer variability of ± 3.4° and inter-observer variability of ± 4.8°, with significant differences between the two experienced observers and the inexperienced observer.

The inclination of the pre-surgical tibial plateau of the animals with a CCLD disease evaluated varied from 15.88° to 31.70°, with a general average of 25.72°. Our results are similar to those found previously by Cabrera et al. (2008) and Fettig et al. (2003). In the study by Fettig et al. (2003) the measurement of the TPA was not affected by the age or body weight of the animal, but the presence of the DAD, especially at the caudal point of the tibial plateau, had a significant correlation with the variability of the TPA measurements between and within the observer.

Although all the evaluated cases had a complete bone consolidation, one of the limitations of this study was the relatively short evaluation time of an average of 128 days. A longer follow-up period would be of great value in determining the impor-

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tance of the complete assessment of these angles and in investigating the possible causes of the TPA alteration over a longer term.

The change in the TPA during the bone healing, although present, was not significantly determined by the preoperative and immediate postoperative TPAs, nor by the patient's body weight. Although it was a short follow-up, it is concluded that the intensity of the change in the TPA during the bone healing is not determined by the previous tilt of the tibial plateau, by a greater or lesser rotation of the tibial plateau by the TPLO and that the load exerted by the patient's weight on the stifle, after the rigid stabilisation by the TPLO, does not determine the compromise of the tibial plateau rotation and joint stability.

## Conflict of interest

The authors declare no conflict of interest.

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