Abstract

Cranial cruciate ligament (CrCL) disease is a leading cause of hindlimb lameness in dogs. Stifle radiographs are often taken as part of the routine workup of CrCL cases, but most general practitioners do not measure the tibial plateau angle. This article describes how to perform this measurement and its usefulness in determining suitability of certain CrCL treatments.

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ORTHOPEDICS

Cruciate Disease: How and Why to Measure Tibial Plateau Angle

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Cranial cruciate ligament (CrCL) disease continues to be a leading cause of hindlimb lameness in dogs. Multiple biomechanical and biological factors are thought to contribute to CrCL injury.[1-4]

Stifle radiographs are often taken as part of the routine workup of CrCL cases, but most general practitioners do not measure the tibial plateau angle (TPA). This additional step can be performed with only slight modification of the radiographic procedure. Many conservative and surgical treatment options exist for CrCL disease, and knowledge of a patient's TPA can help determine the most suitable treatment and aid clients in making the best decision for their pet.

ROLE OF THE TPA IN THE PATHOGENESIS OF CrCL DISEASE

While a direct association between the TPA as an isolated risk factor in CrCL injury is not established,[5,6] studies have shown higher mean TPAs in dogs with CrCL disease compared with healthy dogs[7,8] and an increased risk of contralateral CrCL injury.[9] Mechanically, cranial tibial thrust during loading of the stifle joint increases in magnitude with increasing TPA and can result in repetitive CrCL microtrauma.[10-15] Associated inflammatory changes lead to progressive CrCL injury, pain, and osteoarthritis in affected joints.[1,2] Overall, an increased TPA is considered a contributing predisposing factor in CrCL disease, along with other conformational

Take-Home Points

- A well-positioned lateral stifle radiograph is essential for accurate diagnostic interpretation and tibial plateau angle (TPA) measurement.
- The x-ray beam should be centered over the stifle joint with collimation to include the entire tibia.
- Correct tibial alignment is most important for TPA measurement. The tibia can easily be rotated with CrCL injury even when the femur appears straight.
- The average TPA in most dogs is 23° to 29°. Some small breeds can have a higher-than-average TPA.
- Knowledge of an individual patient's TPA can help guide treatment decision making.
- Dogs with a TPA greater than 30° may be poor candidates for conservative management, extracapsular suture stabilization, or tibial tuberosity advancement surgery.

FIGURE 1. Lateral stifle patient positioning. Limb positioners or tape and sandbags can be used to stabilize the limbs. The opposite limb should be pulled cranially rather than caudally to avoid rotation of the limb of interest.

abnormalities such as straight stifle angle and narrowed intercondylar notch.[1,2]

STIFLE RADIOGRAPHS

The lateral stifle projection is most useful in diagnosing CrCL injury, although caudocranial radiographs should also be performed for assessment of osteoarthritis and other abnormalities. For the lateral projection, the patient is positioned in lateral recumbency with the contralateral limb pulled forward (**BOX 1**). Conventionally, the stifle and tarsus are positioned at 90° of flexion, although this angle has been found to be less important than achieving a straight, well-centered view.[16] A true lateral position is achieved when the femoral and tibial condyles are superimposed (**FIGURES 2 AND 3**).[17] Straight positioning of the tibia is particularly important for proximal tibial landmark

BOX 1 Patient Positioning Tips for Tibial Plateau Angle (TPA) Measurement

- Position the patient in lateral recumbency with the contralateral limb pulled forward and the stifle and tarsus at 90° of flexion (**FIGURE 1**).
- Limb positioners or tape can eliminate the need for a handler (**FIGURE 1**).
- A foam wedge under the stifle, hip, or tarsus may help get the femur and tibia at the same height and parallel to the table.
- Take care to center the x-ray beam over the stifle joint with collimation to include the entire tibia (**FIGURES 2 AND 3**). This avoids image distortion that may affect TPA landmark assessment.[15]
- Include an object of known size at the same height and close to the stifle joint for image calibration (**FIGURES 4 AND 5**).

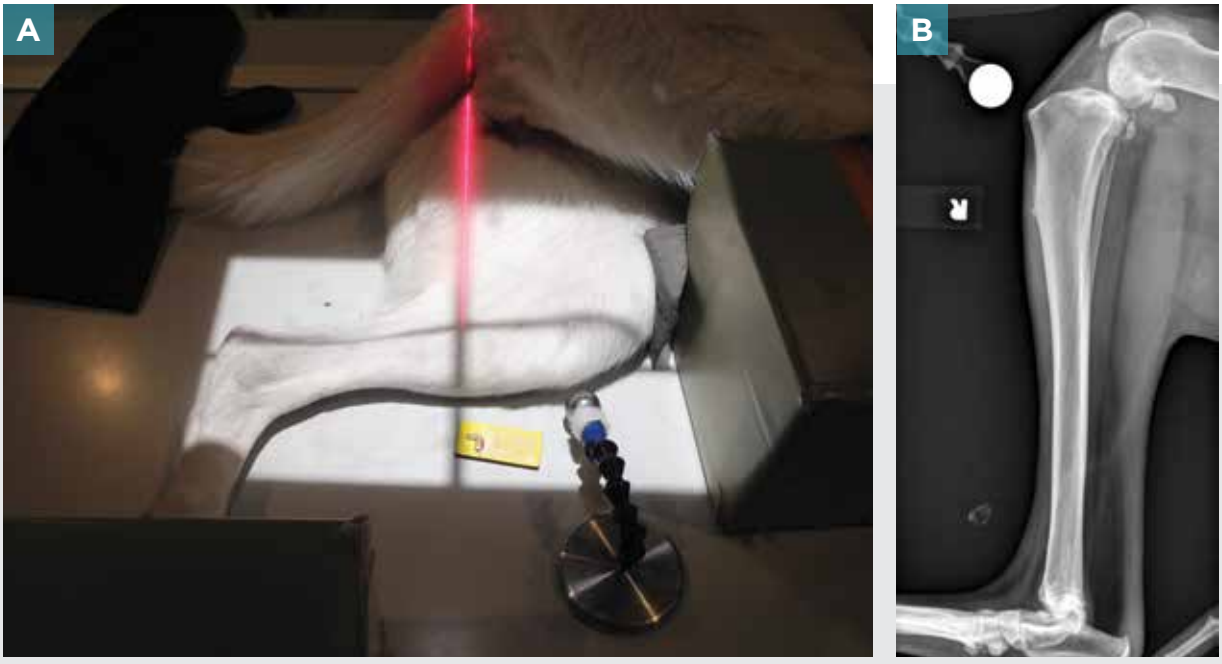

FIGURE 2. (A) X-ray beam centered incorrectly mid-tibia. **(B)** Note the poor superimposition of femoral and tibial condyles. Tibial plateau angle (TPA) landmarks are difficult to identify and can lead to overestimation of the TPA.

FIGURE 3. Radiograph of the dog in **FIGURE 1**, depicting the x-ray beam centered correctly at the stifle without repositioning the patient. Note improved clarity of the stifle anatomy and the tibial plateau angle landmarks.

identification, as CrCL instability can allow rotation across the stifle joint so that the tibia is rotated while the femur is straight (**FIGURE 4**). Care should be taken to center the x-ray beam over the stifle joint with collimation to include the entire tibia (**FIGURE 3**). This avoids image distortion that may affect TPA landmark assessment (**FIGURE 2**).[18] Centering the x-ray beam too low can lead to overestimation, and too high can lead to underestimation, of the TPA.[17]

Although image calibration (**FIGURE 5**) does not change the TPA measurement, as the angle will remain the same regardless of image size, it allows the radiographs to be used for potential surgical planning rather than only diagnostic purposes.

Other radiographic findings such as stifle effusion, osteophyte formation, and cranial tibial subluxation can be considered consistent with CrCL disease or injury (**FIGURE 6**). Severe stifle osteoarthritis with osteophyte formation around tibial condyles can make TPA landmark identification challenging (**FIGURE 7**).[19] Radiographs of the contralateral "normal" stifle may be useful in such cases, as the TPA should be very similar on both sides. Many dogs have early partial CrCL disease with minimal clinical signs on their "normal" side, so this can also be a useful screening tool of prognostic value.

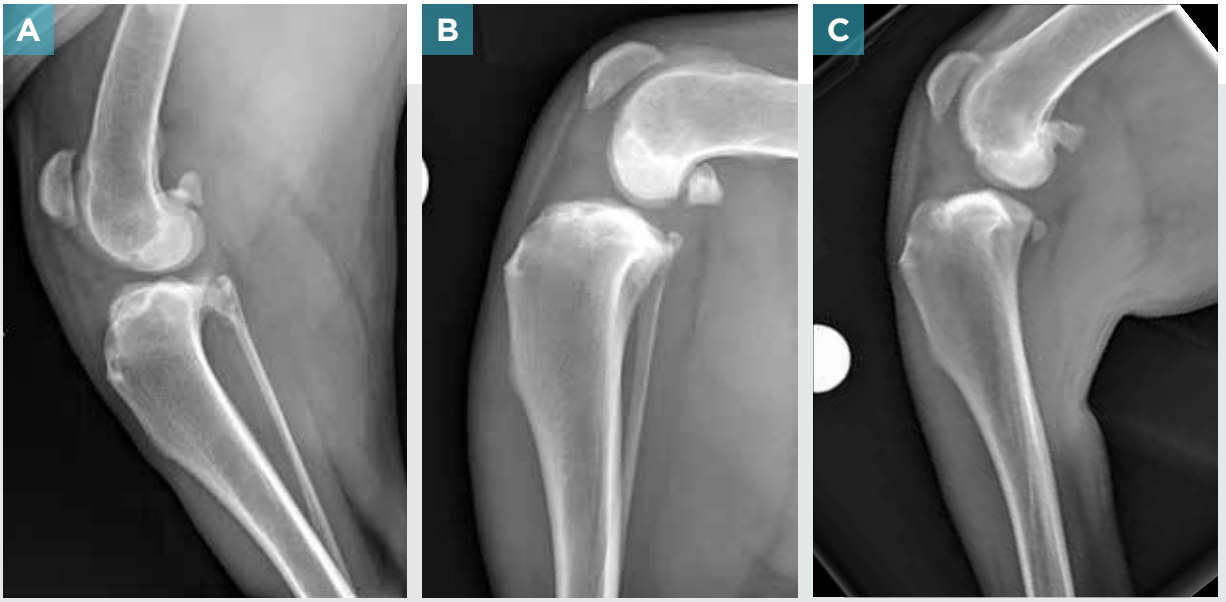

FIGURE 4. Three radiographs of the same patient with cranial cruciate ligament injury demonstrating rotational malposition of the tibia despite a straight femur. **(A)** The tibia is externally rotated. Note that more of the fibula can be seen and landmarks for tibial plateau angle measurement are difficult to identify. **(B)** The femur and tibia are positioned well. Note that a small amount of the fibula can be seen caudal to the tibia. **(C)** The tibia is internally rotated. Note that the fibula is hidden behind the tibia and the tibial condyles are not superimposed.

TPA MEASUREMENT

The tibial plateau is the proximal weight-bearing surface of the tibia. The TPA is defined as the angle between the slope of the medial tibial condyle and the line perpendicular to the mechanical axis of the tibia. The mechanical or functional axis of the tibia joins the center of the weight-bearing surfaces and is identified by the midpoint between the medial and lateral

FIGURE 5. Calibrating radiographs. An object of known size should be placed close to and at the same height as the targeted joint or bone. A 25-mm calibration ball is ideal for this purpose. If using a coin or other metallic object, be sure to specify the exact dimensions of the object on the radiograph. **(A)** Radiographic markers, left to right: a coin with material (e.g., Play-Doh) that can be shaped to achieve the necessary height and 25-mm calibration ball. **(B)** Correct positioning of the coin close to and at the height of the stifle. **(C AND D)** Correct positioning of the calibration marker.

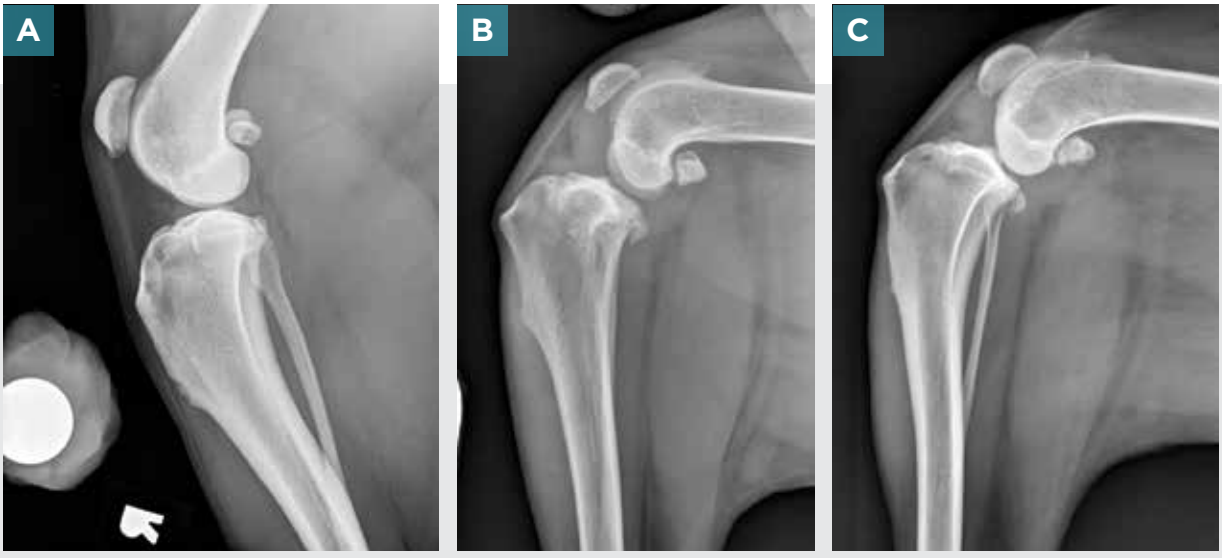

FIGURE 6. Stifle radiographs. **(A)** Normal stifle. **(B AND C)** Deficient cranial cruciate ligament with increased effusion, osteophytes, and cranial tibial subluxation.

intercondylar tubercles (also called intercondylar eminence) and center of the talocrural joint.[13]

Although different TPA measurement techniques and use of computed tomography and magnetic resonance imaging in evaluation have been described, the most commonly used radiographic method, outlined here, was originally established by Slocum and Devine.[13]

FIGURE 7. Stifle osteoarthritis making tibial pleateau angle (TPA) landmarks difficult to identify. This may significantly affect accuracy of TPA determination if the caudal reference point on the medial tibial condyle is obscured by osteophytes.

1. Draw the mechanical tibial axis (MTA) between the intercondylar eminence proximally (**FIGURE 8**) and center of the talocrural joint distally (**FIGURE 9**).
2. Draw a second line across the slope of the medial tibial condyle (**FIGURES 10 AND 11**). This is the tibial plateau line. The cranial and caudal points of this line should be equally distant from the intercondylar eminence.
3. Draw a line perpendicular to the MTA. The TPA is the angle between this line and the tibial plateau (**FIGURE 12**).

Generally, agreement on radiographic interpretation of CrCL disease is high[20]; however, inter- and intraobserver variability exists in TPA measurement.[19,21] As mentioned, poor stifle positioning, failure to center the beam on the stifle, and severe osteoarthritis can hinder accurate TPA measurement.[18,19] Variability in selection of the caudal reference point on the medial tibial condyle, particularly in the vertical direction, can result in significantly different TPA measurements.[19,22]

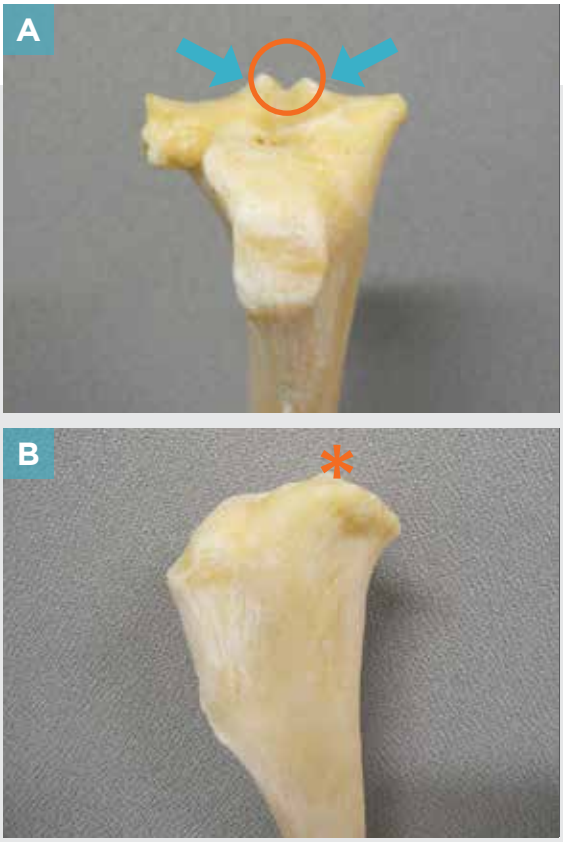

FIGURE 8. (A AND B) The intercondylar eminence **(orange circle/asterisk)** is the proximal landmark for the tibial mechanical axis. **(A)** Lateral and medial intercondylar tubercles **(blue arrows)**.

Nonetheless, for general practitioners, even a close estimate of the TPA can be of great value in guiding clinical decision making for an individual patient.

FIGURES 13, 14, AND 15 are examples of well-positioned stifle radiographs of dogs with CrCL injury and their TPA measurements. In each, the proximal tibia has been enlarged to highlight TPA landmarks.

THERAPEUTIC DECISION MAKING

The most common choices for CrCL treatment are conservative therapy; extracapsular suture stabilization (ExCap); tibial osteotomy procedures, including tibial plateau leveling osteotomy (TPLO) and center of rotation of angulation (CORA)–based leveling osteotomy (CBLO); and tibial tuberosity advancement (TTA). When guiding clients on the best treatment choice for their pet, the author considers TPA among other factors such as owner goals, pet athleticism, stifle instability, and financial constraints.

Various case series have documented TPAs between 23.5° and 29° in dogs with CrCL disease.[5,23-26] However, in a significant number of dogs the TPA exceeds 30°; in some cases, it can exceed 35°. These cases are referred to as high TPA and excessive TPA, respectively.[27,28]

It is the author's opinion that dogs with higher-than-average TPAs are poor candidates for conservative therapy and ExCap surgery. Mechanically, a higher TPA puts more stress on the stifle's natural passive and active stabilizers and makes the ExCap suture more likely to prematurely loosen or fail.[29] Recent studies have found that dogs of smaller breeds (e.g., West Highland white terrier) with CrCL disease have higher TPAs than their larger-breed counterparts.[8,28,30] This may explain why some small dogs deemed suitable for conservative management or ExCap surgery based on other considerations have failed to achieve a successful outcome with these choices.

When considering TTA surgery, the higher the TPA, the larger the TTA must be to achieve a neutral 90° angle between the tibial plateau and patella tendon.[31]

FIGURE 9. Tibial mechanical (or functional) axis **(blue line)**. This runs between the intercondylar eminence and center of the talocrural joint.

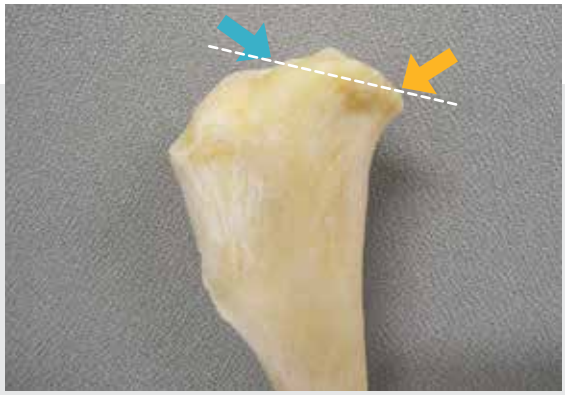

FIGURE 10. Tibial slope or plateau line **(white dotted line)**. The cranial landmark **(blue arrow)** sits just caudal to the long digital extensor groove and is where the cranial cruciate ligament inserts on the most cranioproximal aspect of the medial tibial condyle. The caudal landmark **(yellow arrow)** is the most caudoproximal point of the medial tibial condyle.

The author would not recommend TTA for a patient with a higher-than-average TPA, as this end goal is challenging to achieve with the limited cage implant sizes available.

Although studies comparing CrCL surgical techniques are difficult to interpret due to low case numbers and unique patient populations, TPLO appears to be the more favorable choice for dogs with high to excessive TPAs.[27,28,32-34] TPLO appears to be successful in most of these cases as long as the resultant postoperative TPA is below 14°,[27] with 6° as the postoperative goal in routine TPLO cases.[14] Some dogs with an excessive TPA may be better suited to other tibial osteotomies such as modified cranial closing wedge (CCW)[35,36] or a combination of TPLO or CBLO and CCW,[37,38] which allow for leveling of the plateau while maintaining a more physiologic resultant tibial conformation (**FIGURE 16**).

SUMMARY

Taking the extra time and effort to measure the TPA in patients with CrCL disease is a valuable additional step. This allows the TPA to be added to the list of considerations used to advise clients on the ideal CrCL treatment option for their pet. TVP

FIGURE 11. Tibial slope or plateau line **(green line)**. This line is drawn from the cranial to caudal aspect of the medial tibial condyle.

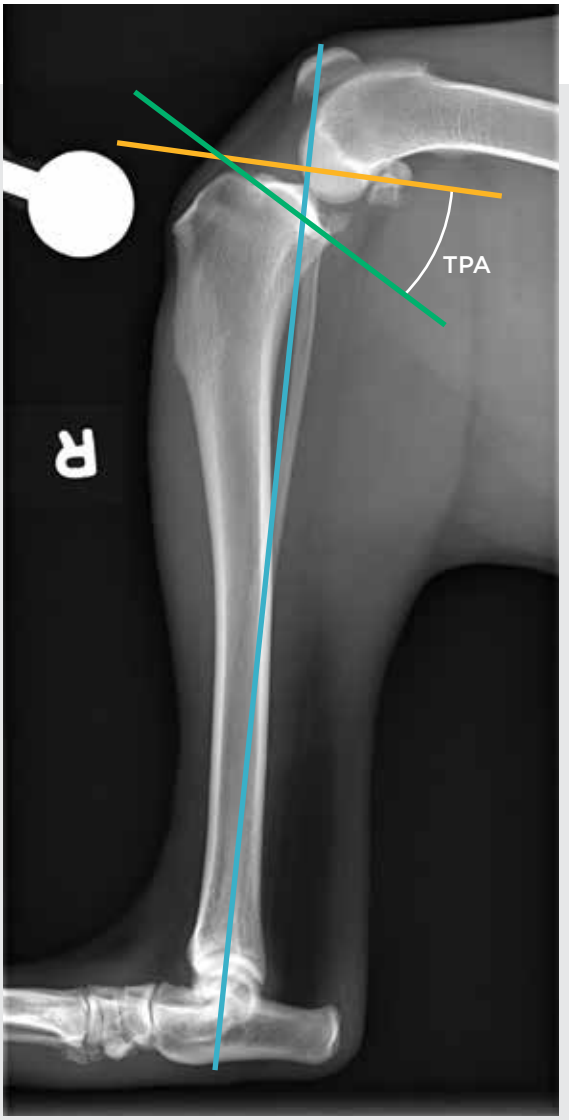

FIGURE 12. The tibial plateau angle **(TPA; white angle)** is the angle between a line perpendicular **(yellow line)** to the mechanical tibial axis **(blue line)** and the tibial plateau **(green line)**. In this example, the TPA measures 36°.

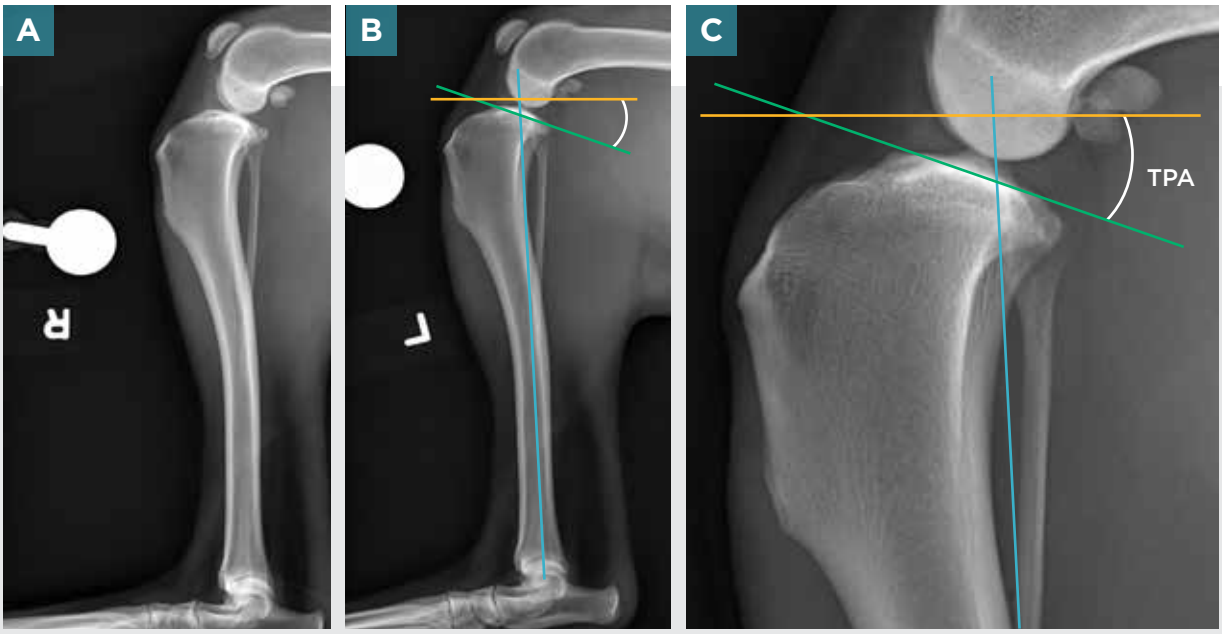

FIGURE 13. (A) Right and **(B)** left stifle radiographs of the same dog with bilateral partial cranial cruciate ligament injury. **(C)** The left stifle tibial plateau angle (TPA) landmarks are slightly clearer than the right and have been enlarged. The TPA measures 26° on both stifles. The right stifle has mild effusion and very mild secondary osteoarthritis. The left stifle has minimal effusion and osteoarthritis.

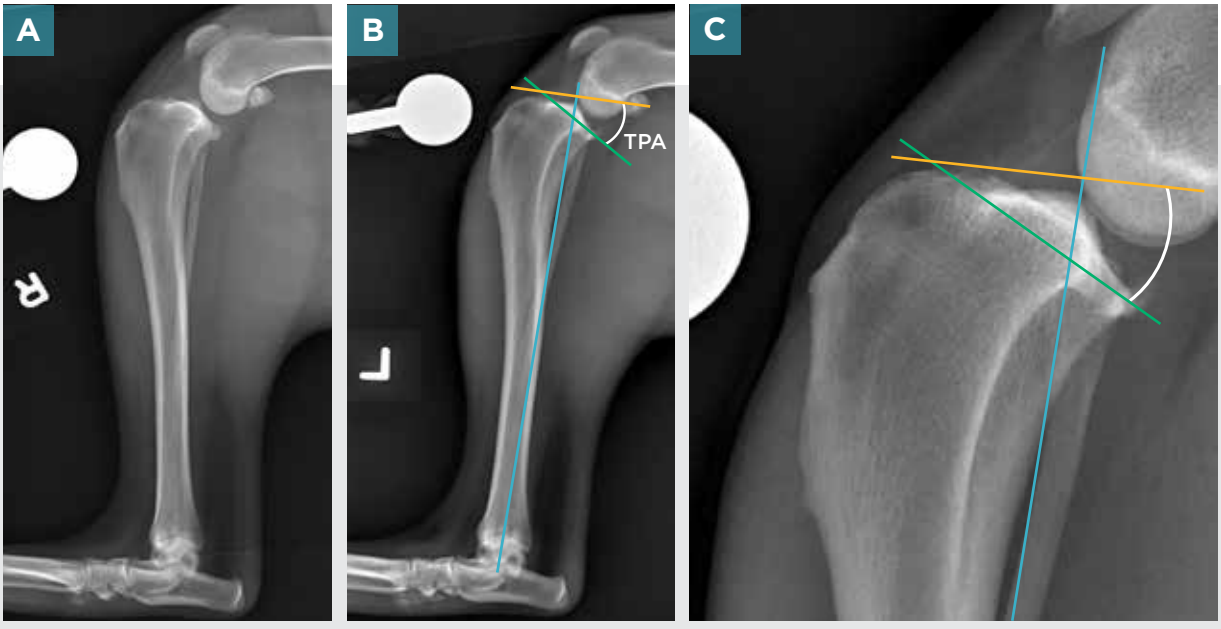

FIGURE 14. (A) Right and **(B)** left stifle radiographs of the same dog with bilateral complete cranial cruciate ligament injury. **(C)** The left stifle tibial plateau angle (TPA) landmarks have been enlarged. The TPA measures 29° on both stifles. Both stifles have moderate effusion, moderate secondary osteoarthritis, and cranial tibial subluxation.

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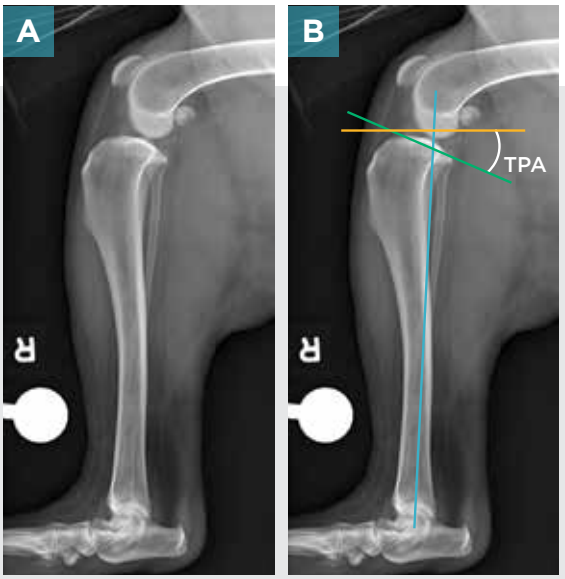

FIGURE 15. (A) Right stifle radiograph of a dog with partial cranial cruciate ligament injury. There is very mild stifle effusion and minimal secondary osteoarthritis. **(B)** The tibial plateau angle measures 24°.

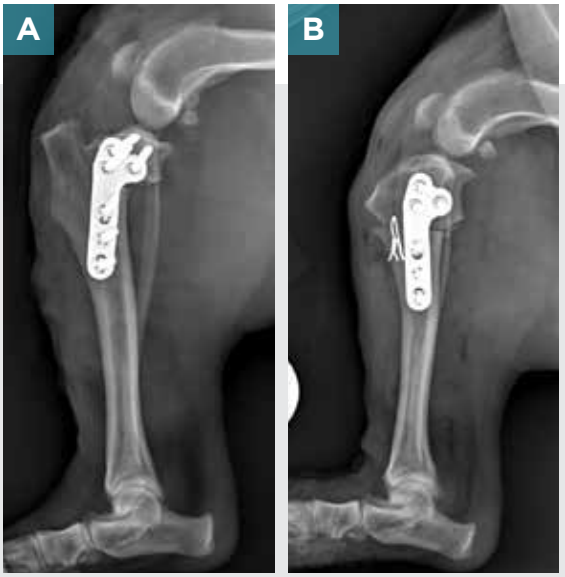

FIGURE 16. Postoperative radiographs in a bichon frise. The preoperative tibial pleateau angle (TPA) was 37° on both sides. **(A)** Right stifle after tibial plateau leveling osteotomy (TPLO). The postoperative TPA is 8°. **(B)** Left stifle after cranial closing wedge (CCW). The postoperative TPA is 5°. Note that the CCW provides a more physiologic proximal tibia than the TPLO in this excessive TPA case.

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