A retrospective study of tibial plateau translation following tibial plateau levelling osteotomy stabilisation using three different plate types

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Summary
Objective: To retrospectively evaluate mediolateral translation of the proximal tibial segment (tibial plateau) after tibial plateau levelling osteotomy (TPLO), stabilised with three types of plate.

Method: Pre- and postoperative radiographs of 79 dogs that had TPLO surgery using three different types of plates were reviewed. Two plate types incorporated non-locking screws: Slocum (22 cases) and Orthomed Delta (33 cases) plates. The third plate type incorporated locking screws: Synthes TPLO Locking Compression Plate (LCP) (24 cases). The radiographs were viewed by three Diplomate surgeons who were blinded to the type of implant used. Medial or lateral translation of the proximal tibial plateau relative to the tibial diaphysis was assessed and measured at the lateral tibial cortex at the osteotomy site.

Results: Mean lateral translation of the tibial plateau was significantly greater when using the Synthes TPLO LCP with locking screws (+2.1 mm) compared to the non-locking Slocum (+0.4 mm) or Orthomed Delta (0.0 mm) plates.

Clinical significance: The use of the Synthes TPLO LCP will maintain a malalignment of the tibial plateau. Accurate alignment of the tibial plateau must be ensured prior to application of the Synthes TPLO LCP.

Introduction
Cranial cruciate ligament rupture is a common cause of lameness in dogs and numerous surgical techniques have been reported to address the condition including fabellotibial lateral suture, intra and extra-capsular stabilisation and tibial plateau levelling osteotomy (TPLO) (1). The reported success rate of tibial osteotomies for cranial cruciate ligament insufficiency is >75% (2). In 1978, Henderson and Milton first described tibial compression and cranial tibial thrust and their relationship to stifle biomechanics (3). Later, in 1993, Slocum attempted to address the physiological cranial tibial thrust that occurs following cranial cruciate ligament rupture (4). Since the production of the original Slocum TPLO plate (Fig. 1), many variations of this plate have been manufactured. The Orthomed Delta (Fig. 2) and Slocum plates are designed for use with non-locking cortical or cancellous screws and incorporate an oval dynamic compression plate (DCP) style holes in the proximal segment to allow compression across the tibial osteotomy. Consistent with the principles of DCP application, these plates require both accurate intra-operative contouring to the shape of the proximal medial tibia (although some plates are pre-contoured, further contouring is occasionally necessary), and soft tissues have to be removed from the bone beneath the plate. Suboptimal application may lead to construct instability, implant loosening, osteotomy malalignment, or a combination of these.

In recent years, the use of locking plate technology has gained popularity in human and small animal orthopaedics. Advantages of locking technology include:

1. The screw head locks directly into the plate thereby eliminating the reliance on plate-bone friction to ensure rigid fixation.
2. The plate does not need to be accurately contoured to the underlying bone.
3. Periosteal blood flow is not disrupted as the plate is not compressed onto the bone surface.
4. Removal of soft tissue beneath the plate (e.g. the medial buttress) is not required.
5. Locking screws provide both axial and angular stability, thus reducing the risk of screw toggling and secondary loss of reduction.
6. Both implant stability and security are increased in poor quality bone.
7. Locking screws have an increased core diameter and a smaller thread profile to reduce complications associated with cantilever failure (5–7).

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Synthes produced a locking compression plate (LCP) for the TPLO procedure that was made available in the UK in 2007 and is currently available in six sizes (7). In addition to the standard benefits of an LCP, the most proximal screw hole is angled distally to reduce the risk of intra-articular screw placement.

The 3.5 mm Synthes TPLO LCP is manufactured from 316L implant grade stainless steel, it is available in standard, small or broad sizes, and is pre-contoured to the shape of the medial surface of the proximal portion of the canine tibia. There are three or four screw holes proximally through which screws are placed into the proximal tibial segment, namely the tibial plateau. These are round, threaded, stacked holes that can accommodate locking screws. In the distal segment of the plate, there are three or four holes through which screws are placed into the distal tibia. One or two of these holes is a LCP ‘combi’ hole that can accommodate either a non-locking cortical screw placed in the proximal hole of the distal segment, but to not fully tighten it. The tibial plateau was then secured using locking screws, followed by placement of compression screws distally, and subsequent tightening of the first screw.

At our institution, The Royal Veterinary College, the Synthes TPLO LCP has been used since 2007 using the above technique, but without the push-pull device. Examination of postoperative caudocranial radiographs of the tibia demonstrated lateral translation of the tibial plateau relative to the tibial diaphysis, which was not a feature that we had recognised on postoperative radiographs when non-locking TPLO plates were used.

The purpose of this study was to retrospectively assess postoperative TPLO radiographs to determine whether medial or lateral translation of the tibial plateau occurred when using locking and non-locking implants. Our null hypothesis was that there was no difference in mediolateral translation of the tibial plateau relative to the tibial diaphysis regardless of implant used.

Material and methods

A search of the electronic patient record database at our institution identified 144 dogs that had tibial plateau levelling osteotomy surgery between 2003 and 2008. Radiographs of 125 of these dogs were available for review; all radiographs were on film as digital radiography was not used at our institution at this time. Inclusion criteria for the study were:

- Completion of a TPLO using the Slocum TPLO plate, Orthomed Delta plate, or Synthes TPLO LCP.
- Original film radiographs available for examination.
- Preoperative and immediate postoperative caudocranial radiographs of the tibia with the limb appropriately posi-
tioned such that the medial cortex of the calcaneus was superimposed in part on the intertrotchlear ridge of the tibia, and the fabellae were, at least in part, superimposed on the femoral cortices.

- The distal aspect of the osteotomy could be identified on the postoperative cadocranial radiograph such that the two adjacent cut lateral tibial cortices were visible without any artefact present that could hinder accurate assessment of the lateral aspect of the tibia and osteotomy site.

Radiographs were independently assessed by two authors (NW, GA) and of the 125 radiographs originally viewed, 79 cases fulfilled the inclusion criteria and were accepted. The most common reason for radiograph rejection was sub-optimal patient positioning (25 cases) as defined above. Other reasons for rejection included: lack of postoperative cadocranial radiographs, radio-opaque ligation clips used to ligate the cranial tibial artery overlying and obscuring the lateral cortex of the tibia, fracture of the lateral tibial cortex, and poor quality of film development hindering accurate reading.

Postoperative translation of the tibial plateau was measured by three Diplomate surgeons (SC, JG, GA) at different sessions. A template was designed with a 10 mm by 17 mm hole cut in the centre to allow visual assessment of the lateral aspect of the osteotomy while obscuring both the plate and screws from view. Prior to measuring the radiographs, one author (NW) placed a template over the radiographs, thereby blinding the observers (SC, JG, GA) to the treatment.

The radiographs were presented to the surgeons in a randomised order. The surgeons assessed the positions of the proximal and distal tibial cortices at the level of the osteotomy to determine whether medial or lateral translation of the proximal tibial segment had occurred. This was measured directly from the radiograph (displacement of the proximal cortical margin in relation to the distal abaxial edge of the lateral cortex) adjacent to the osteotomy line using a transparent flexible plastic ruler. Medial translation was given a negative value and lateral translation a positive value and translation was measured to the closest 0.5 mm as this was the smallest possible measurable difference.

For each case, a mean value for the translation was calculated from the values measured by each of the three surgeons. The mean translation values were then compared between any two groups for each of the three TPLO plates using the unpaired t test using a statistics programme.b

In order to ensure that the degree of tibial translation was not influenced by size of the tibia, tibial width at the osteotomy site was also measured by a single author (NW) on a separate occasion. It was not possible to accurately measure the tibial width on the postoperative radiographs as the plate partially obscured the medial cortex. Therefore the level of the osteotomy was determined by measuring the proximodistal distance of the osteotomy from the distal aspect of the mid-

### Results

#### Tibial plateau translation

The mean translation of the tibial plateau (± SD) for the Synthes TPLO LCP was (2.1 ± 1.8 mm laterally) significantly different from the Slocum plate (0.4 ± 1 mm laterally) (p = 0.0003) and the Orthomed Delta plate (0.02 ± 1.1 mm medially) (p <0.0001) (Fig. 4). The mean proximal tibial plateau translation with the Synthes TPLO LCP (2.1 ± 1.8 mm laterally) was also significantly greater than both the non-locking plates (Slocum and Orthomed Delta) combined (0.1 ± 1 mm laterally) (p <0.0001). The difference in translation between the Slocum and Orthomed Delta plates was not significant, (p = 0.17). The ranges of tibial plate translation for each type of plate was 4.2 mm (Slocum plate), 4.5 mm (Orthomed Delta), and 6.2 mm (Synthes TPLO LCP) (Table 1).

#### Inter-observer variation

The overall mean inter-observer variation for the study was 0.4 mm. One case had a maximum inter-observer variation of 3

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**Table 1**

<table>
<thead>
<tr>
<th>Plate</th>
<th>Number of cases</th>
<th>Mean lateral translation (mm)</th>
<th>Lateral translation range (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slocum</td>
<td>22</td>
<td>0.4</td>
<td>-1.7 to 2.5</td>
</tr>
<tr>
<td>Orthomed Delta</td>
<td>33</td>
<td>-0.02</td>
<td>-2.5 to 2.0</td>
</tr>
<tr>
<td>Synthes TPLO LCP</td>
<td>24</td>
<td>2.1</td>
<td>-0.8 to 5.3</td>
</tr>
</tbody>
</table>

**Key:** TPLO LCP = Tibial plateau levelling osteotomy locking compression plate.
mm, five cases had a maximum inter-observer variation of 1 mm, and the remaining 73 cases had a maximum variation of 0.5 mm or below. The maximum and mean inter-observer variations respectively were as follows: Slocum plate (1 mm; 0.3 ± 0.3 mm), Orthomed Delta plate (1 mm; 0.3 ± 0.3 mm), and Synthes TPLO LCP (3 mm; 0.5 ± 0.6 mm).

**Mean tibial width**

The mean tibial width (± SD) measurements of the dogs in the three groups were 20.5 ± 2.7 mm (Slocum plate), 21.4 mm ± 3.2 mm (Orthomed Delta plate) and 21.0 mm ± 3.4 mm (Synthes TPLO LCP). The differences between the groups in tibial width were not significant (p = 0.56).

**Discussion**

The major finding of our study evaluating postoperative radiographs of the stifle joint of dogs after TPLO was that lateral translation of the tibial plateau with the Synthes TPLO LCP was significantly greater than that for the Orthomed Delta and Slocum plates. Thus our null hypothesis that there was no difference in mediolateral translation of the tibial plateau relative to the tibial diaphysis regardless of implant used was rejected.

There are two possible explanations for the lateral translation of the tibial plateau observed with the Synthes TPLO LCP. One explanation is that the locking plate maintained a surgically induced tibial plateau mediolateral malalignment by ‘locking’ the tibial plateau in position with respect to the tibial diaphysis. Alternatively, the process of applying the locking plate could have caused the malalignment. As our study was retrospective, it is not possible for us to conclusively differentiate between these two potential causes, but we are able to consider the potential contributory factors.

**Surgically induced malalignment**

Any malalignment of the tibial plateau caused by the surgeon during tibial plateau rotation and immobilisation prior to plate application would be maintained once the TPLO LCP was applied. This is because once a locking screw is secured in both the plate and tibial plateau, no further change in position between the tibial plateau and plate is possible. This is in contrast to what occurs when a non-locking plate (Orthomed Delta or Slocum) is used. When non-locking implants are used, the screws pull the tibial plateau medially towards the plate (8). The plate is compressed onto the bone and no further movement between the bone and plate is possible. In other words, application of non-locking screws could theoretically correct a surgically induced lateral translational malalignment of the tibial plateau; whereas application of a locking plate would maintain the malalignment. This explanation is consistent with the findings of an ex vivo study (8) that documented a larger medial translation of the tibial plateau of 1.6 mm (± 0.6 mm) when non-locking implants were used compared to a medial translation of 0.1 mm (± 0.8 mm) when locking implants were used (8). In our study, such medial (as opposed to lateral) translation of the proximal tibial segment was recorded for the Orthomed Delta plate (mean 0.02 mm medial translation) but not the Slocum plate (mean 0.4 mm lateral translation).

Malalignment of the tibial plateau could have occurred, at least in part, because of the medial buttress present on the medial aspect of the tibial plateau, which can be quite large. Consistent with recommendations for bone preparation prior to the use of non-locking plates, the medial buttress was routinely removed prior to plate application. In contrast, when the TPLO LCP was used the medial buttress was not removed. The presence of an intact medial buttress in the TPLO LCP group may have hampered accurate assessment of medial tibial cortical position, resulting in a lateral translational malalignment of the tibial plateau prior to TPLO LCP application. Such relative lateral translation of the tibial plateau would become apparent on the postoperative radiographs, but it may not have been apparent intra-operatively. However, the validity of this explanation is weakened as the surgeons knew not to attempt to exactly align the medial cortices of the tibial osteotomy during TPLO reduction, as per the recommendation of Wheeler et al. who documented that medial cortical alignment induced valgus and internal rotational deformities of the tibia (9).

**Locking-plate induced malalignment**

An alternative explanation for the lateral tibial plateau translation observed with the TPLO LCP is that incorrect application of the locking plate and screw apparatus caused the malalignment. When the push-pull device is not used with the Synthes TPLO LCP, it has been suggested to place a cortical screw in the proximal hole of the distal segment, but not to fully tighten it. The second screw is a locking screw, placed in the proximal segment. Once this locking screw is placed, no further translation can occur between that segment of bone and the plate and hence forth the tibial plateau is locked to the TPLO LCP. Subsequent insertions of a non-locking screw in the tibial diaphysis, could result in translation of that bone segment relative to the plate and by inference relative to the proximal bone segment. In other words, subsequent application of a non-locking screw may result in tibial plateau malalignment. It is well documented that the combination of locking and non-locking technology for fixation of the same fracture or osteotomy should be employed with caution (10). Whilst this does offer a theoretical explanation for the lateral tibial plateau translation, in order for a translation of 2 mm to occur, a similar sized gap between the plate and diaphyseal bone would have to be present prior to the distal non-locking screws being tightened. Arguably an experienced surgeon should not allow such a gap at implant placement and therefore such movement and translation should be avoided.

Since the cases recorded in this study were completed, the Push-Pull reduction device has become available in Europe. This is a unicortical self drilling device that is inserted through the locking screw ‘combi’ plate hole into the tibial diaphysis. When the plate has been correctly positioned on the medial tibial cortex and the
device is secured, the collet is turned clockwise to pull the plate into apposition with the bone surface thus eliminating any gap that may be present between the plate and tibial diaphysis (11). After application of the plate, push-pull device, and proximal locking screws, the non-locking compression screws are then placed distally and the push-pull device is removed. Finally a non-locking screw is placed in the ‘combi’ hole. If the lateral tibial plateau translation was partly due to inadequate compression and alignment of the TPLO LCP onto the medial cortex of the tibial diaphysis prior to placement of the first locking screw in the tibial plateau, the use of the push-pull device should eliminate potential lateral translation of the plateau.

It seems likely that the cause of the lateral tibial plateau displacement associated with TPLO LCP that we documented was due to surgically induced malalignment. This surgical error combined with the loss of medial pull associated with non-locking implants appears to have resulted in the lateral tibial plateau position.

Regardless of the actual cause of tibial plateau malalignment, the results of our study and that of Leitner et al’s study are similar and supportive of each other (8). Leitner’s ex vivo study comparing locking and non-locking plate fixation of TPLO osteotomies reported a 1.6 mm medial translation of the tibial plateau when non-locking screws were used compared to 0.1 mm medial translation with locking screws. Our study describes a 0.1 mm lateral translation with non-locking implants and a 2.1 mm lateral translation with locking implants. In other words, both studies describe a more lateral tibial plateau position of 1.5 mm (Leitner) and 2.0 mm (current study) when locking implants are used compared to non-locking implants. The difference in magnitude and absolute position of tibial plateau between the two studies may be accounted for as Leitner’s study was ex vivo and it involved the removal of all soft tissues from the tibia. By comparison, in our study of clinical patients, soft tissue dissection was limited to that necessary for TPLO surgery; in particular the medial buttress soft tissue on the tibial plateau was not removed in the TPLO LCP group. It should also be noted that the exact screw insertion sequence used in Leitner et al’s study was not reported and that this may have differed from that used at our institution though the significance of this is unclear.

Leitner et al. speculated that the average 1.6 mm translation of the tibial plateau was unlikely to have an effect on joint morbidity (8). We similarly suggest that the relatively small mean 2.1 mm lateral translation of the tibial tuberosity that we report associated with TPLO LCP use is unlikely to have a significant effect on joint or limb function or morbidity.

Our reason for presenting this information is to inform surgeons that this phenomenon does occur and may be recognised on postoperative radiographs following TPLO surgery using the TPLO LCP. The mean inter-observer variation recorded in this study was 0.4 mm, which we consider acceptable given the lower limit of observer measurement accuracy was 0.5 mm.

As with all retrospective studies, this study had a number of limitations. One such limitation was that accurate measurement of tibial plateau translation was dependent on good quality preoperative and postoperative radiographs. The authors had no control over radiographic positioning or quality as archived radiographs were used. In order that radiographic positioning did not influence the results, very strict inclusion criteria were applied; this resulted in a high rejection rate of cases (37%) which consequently reduced the sample size. Another limitation was that radiographs were taken using standard pa-

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