A comparison of outcomes following tibial plateau levelling osteotomy and cranial tibial wedge osteotomy procedures

S. A. Corr¹, C. Brown²
¹Royal Veterinary College — VCS, Hatfield, Hertfordshire, UK
²Sage Veterinary Group, Bradford, UK

Summary
The objective of this study was to determine whether clinical outcomes were superior and complication rates were lower in dogs that had had a cranial cruciate ligament rupture treated by tibial plateau levelling osteotomy (TPLO), compared to those dogs that had been treated using the original cranial tibial wedge osteotomy (CTWO) procedure. Thirty-seven client-owned dogs with cranial cruciate ligament rupture were included in the study: 19 dogs underwent a TPLO procedure, and 18 dogs underwent a CTWO procedure. The study was retrospective, with the data being obtained from medical records and a review of radiographs. The long-term outcome was assessed by means of an owner questionnaire using a visual analogue scale. For the majority of factors that were reviewed, there was not a significant difference in outcome between the dogs that had a TPLO or those that had undergone a CTWO. All of the dogs showed a rapid return to weight bearing after surgery, and at the six week re-examination, the majority of the dogs did not have any pain on stifle palpation. They displayed a good stifle range of motion and significantly lower lameness scores than those prior to surgery. The complication rates did not differ between the procedures, however, within this small sample of dogs, complications following a CTWO were more likely to require revision surgery.

Keywords
Plateau levelling, tibia, osteotomy, cruciate

Introduction
Rupture of the cranial cruciate ligament (CrCL) is common in dogs and results in lameness and secondary osteoarthritis (1). Numerous surgical techniques have been developed for the treatment of CrCL deficiency, including extra-capsular methods, such as lateral retinacular stabilisation (2) and fibular head transposition (3), and intra-capsular methods, such as the ‘over the top’ technique (4). In 1978, a paradigm shift occurred when Henderson and Milton recognised that the action of the stifle extensor (quadriceps) and flexor (gastrocnemius) muscles generates a force within the stifle joint which thrusts the tibia cranially (cranial tibial thrust) due to the slope of the plateau, unless it is resisted by an intact cranial cruciate ligament (5). The elimination of this force by alteration of the plateau slope forms the basis of the plateau-levelling techniques that were proposed by Slocum and Devine; the cranial tibial wedge osteotomy (CTWO) (6), and subsequently the tibial plateau levelling osteotomy (TPLO) (7). In the initial CTWO procedure, the biceps femoris, gracilis and semitendinosus muscles were advanced to prevent cranial drawer, however this was later abandoned on the basis that neutralising the cranial tibial thrust alone produces a functionally stable joint despite the persistence of cranial drawer (7).

In the CTWO technique, plateau levelling is achieved by removing a cranially-based wedge of bone, which shortens the tibia cranially. This alters the femoropatellar joint by lowering the patella relative to the femur, unless the stifle is relatively hyperextended to compensate for this. Such compensation may be more difficult in dogs with a more straight-legged conformation. This is avoided in the TPLO procedure, where a proximal radial osteotomy of the tibia is performed, and the segment is rotated caudally to level the plateau. The more proximal position of the TPLO should also result in a greater area of bone contact at the osteotomy site, which should theoretically result in a more stable osteotomy.

The TPLO has largely replaced the CTWO as the technique of choice, yet there is little information comparing the two techniques, in order to determine whether the benefits that are claimed for the modifications are reflected in improved clinical outcomes. The objective of this study was to compare the clinical outcome of these two techniques.

Materials and methods
The medical records of the dogs that had been treated for CrCL rupture by CTWO or TPLO at Royal Veterinary College between June 2002 and February 2005 were reviewed. All of the TPLO procedures were performed as described by Slocum and Slocum (7), other than placement of a bone graft. The osteotomy was performed using a Slocum saw and jig, and stabilised using a 3.5 mm Slocum TPLO plate, with five 3.5 mm cortical screws, and a single 4 mm cancellous screw placed in the most proximal screw hole. All CTWO procedures were based on the technique described by Slocum and Devine (6), although neither a jig was used, nor was muscle advancement performed. The osteotomy was made using a standard straight oscillating saw, and stabili-
lised with a 3.5 mm seven hole TPLO plate (Veterinary Instrumentation, Sheffield, UK) with seven 3.5 mm cortical screws. Only those cases with a complete set of medical records and radiographs taken pre- post- and six weeks post-operatively were included. The following information was extracted from the records: age, sex, breed, body weight, duration of lameness prior to surgery, lameness score, subjective assessment of stifle range of motion (normal or reduced) and response to manipulation, surgical technique, surgeon, surgical time, complications, presence of unilateral or bilateral cruciate disease, extent of CrCL rupture (partial or complete), presence or absence of meniscal damage and whether meniscal surgery (medial meniscectomy or meniscal release) had been performed. The presence of any concurrent orthopaedic problems, and whether the dogs had undergone previous CrCL surgery was also noted.

All radiographs were reviewed by a single author, C. Brown, and where evident, osteoarthritis and joint effusions were subjectively graded as ‘mild’, ‘moderate’, or ‘severe’. Osteotomy healing was graded as ‘poor’ (little evidence of healing, osteotomy line same or increased width), ‘satisfactory’ (some bridging callus, but osteotomy line still obvious), ‘good’ (healing almost complete, but osteotomy line still visible in parts), or ‘complete’. Pre- and post-operative tibial plateau angle (TPA) of the affected stifle was measured from the radiographs by one of the authors (C. Brown), according to the method described by Dejardin (8).

Follow-up information on clinical outcome was obtained from the owners by means of a questionnaire, based on the one that was developed by Innes and Barr (9). A visual analogue scale was used when answering the majority of the questions (Appendix A).

**Statistical analysis**

Descriptive statistics were used to evaluate basic properties of the data, including mean values and standard deviations. Quantitative data was analysed using either a two-sample or paired t-test. For data that was not normally distributed or when variances of the two samples were not equal, the Mann-Whitney U test (equivalent of a two-sample t-test) and the Wilcoxon signed rank test (equivalent of a paired t-test) were used instead. Qualitative data was analysed using a 2-tailed Pearson Chi-squared test or a Fisher’s exact test if assumptions were not satisfied, i.e. if the expected frequency in any of the cells was <5. For all analyses, a value of p<0.05 was considered significant.

**Appendix A: Questionnaire–surgery for cranial cruciate rupture in dogs.**

Most of the following questions use a line scale on which you should mark your response with a cross (X).

Example:

Did your dog suffer from stiffness after resting?

**Never** | **A bit of the time** | **Half of the time** | **Quite a lot of the time** | **Always**
---|---|---|---|---
No stiffness | X | X | X | X | extreme stiffness

You should mark a cross on the line, at a point which shows how much you think your dog was stiff after resting, as shown above.

**Questions:**

**Before your pet ruptured his/her cruciate ligament:**

How active was your dog BEFORE he/she had a problem?

Not at all | I always exercising

**After your pet ruptured his/her cruciate ligament but before he/she had surgery:**

How would you grade the overall disabling effect of your dog’s problem BEFORE surgery?

No disability | I complete disability

DID your dog suffer from stiffness after resting?

No stiffness | I extreme stiffness

What was the effect on the symptoms of cold, damp weather?

No effect | I much worse

How well COULD your dog jump into the car?

Unable | I no problem

**AFTER your pet had surgery:**

How soon after the operation did your dog start to consistently put his/her foot on the ground? (please tick appropriate box)

Within 2-3 days | Within 1 week | Within 2 weeks | Within 3 weeks | Longer | Please state

Approximately how long did it take for your dog to regain satisfactory use of his/her leg?

1 month | 2 months | 3 months | 4 months | 5 months | 6 months | Longer | Please state

8. Did any of the following occur after the initial surgery?

Skin wound infection | Joint infection | Surgery to remove plate/screws/pins | Repeat surgery to stabilise the ruptured ligament

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Results

General

Forty-three stifles from 37 dogs were included in the study; a TPLO was performed on 21 stifles from 19 dogs (48.8%), and a CTWO was carried out on 22 stifles from 18 dogs (51.2%). The mean age at the time of surgery was 3.9 ± 1.8 years (range: 1.5 to 8.25 years) and the mean body weight was 47.9 ± 16.5 kg (range: 18.5 to 95 kg). The majority of the dogs were medium or large breeds, with a predominance of Rottweilers (eight dogs), Bull Mastiffs (eight dogs), Labrador Retrievers (five dogs), Newfoundland (three dogs) and large crossbreeds (three dogs). 46.5% of the dogs were male (16.3% entire, 30.2% neutered) and 53.5% of the dogs were female (20.9% entire, 32.6% neutered). The mean duration of lameness prior to surgery was 3.8 ± 3.4 months (range 0.5 to 12 months). There was no significant difference between TPLO and CTWO groups in age, weight, gender, or duration of lameness before surgery.

The percentage of dogs that underwent unilateral surgery was 83.8%, and 16.2% had bilateral surgeries (mean interval between surgeries of 4.9 ± 2.3 months). At the time of surgery, 86% of dogs had a complete rupture and 14% had a partial rupture of the CrCL. In 34.9% of the dogs, a meniscal injury was identified and a partial meniscectomy was performed. In all of the other dogs, a meniscal release was performed. There was no significant difference between the groups regarding the occurrence of unilateral or bilateral disease, extent of rupture, or incidence of meniscal injury. Thirty-two percent of the dogs had concurrent orthopaedic disease, unrelated to the cruciate problem(s), but this did not significantly affect the complication rate or recovery, and was not significantly different between the groups. One dog in the CTWO group had had a previous extra-capsular repair that had failed, but this animal did not have any complications following subsequent CTWO.

The CTWO procedures were performed by six different surgeons, all of whom had a similar level of experience using the technique. In contrast, all of the TPLO procedures were performed by a single surgeon who had recently attended the TPLO training course. When all of the cases in each group had been included, the mean surgical time for the CTWO procedure (148 minutes) was significantly less (p<0.01) than that for the TPLO procedure (188 minutes). When the surgical times for the final 10 cases in each group were compared, however, the mean surgical time was not significantly different between the TPLO and CTWO procedures (177 and 161 minutes, respectively).

The mean tibial plateau angles are shown in Fig. 1. The mean pre-operative TPA of all of the dogs was 25 ± 6º (range 18 to 52º), and was not significantly different between the groups. Post-operatively, the TPA was significantly lower (p<0.001) with a mean of 7 ± 4º (range 0 to 20º). The post-operative TPA was significantly lower in the CTWO-treated dogs (mean=5 ± 4º, range 0 to 20º), however, when compared with the TPLO-treated dogs (mean=9 ± 3º, range 10 to 22º) (p<0.001). The single extreme value within the CTWO group was for a dog with a previous Salter-Harris injury (type not recorded), where malunion of the proximal tibial growth plate had resulted in a TPA of 52º; this was reduced to 20º post-operatively.

All of the dogs began weightbearing at a mean of 1.8 ± 0.5 days (range one to three days) post-operatively, with no significant difference between the groups. There was no significant difference in lameness score between the groups either pre- or post-operatively, and mean lameness score decreased significantly in both groups following surgery (p<0.001) (Fig. 2).

Radiographic and clinical findings are reported in Table 1. There was no significant difference in ‘grade’ of osteotomy healing between the two groups at six weeks. The majority of dogs also showed either no change, or a decrease, in stifle effusion between surgery and six weeks. The number of dogs in the CTWO group that showed an increased effusion was not significant. There was no significant difference in the degree of osteoarthritis when the TPLO and CTWO
groups were compared at any stage. Most of the dogs had a good range of stifle motion and minimal or no discomfort on joint manipulation, with no significant difference between the groups.

Post-operative complication rates are shown in Table 2. There was no significant difference in the complication rate between the two groups. Two dogs in the TPLO group suffered a single broken screw, but recovery progressed uneventfully without intervention. In contrast, all of the three dogs with implant failure in the CTWO group required revision surgery. In two dogs, screw loosening resulted in opening of the osteotomy, and in the third, in laceration of a popliteal vessel.

The results of the owner questionnaire are shown in Figs. 3A and B. The completed questionnaires were returned from the owners of 26 of the 37 dogs; a return rate of 70.3%. The time since surgery ranged from seven months to 3.25 years, with the follow-up time being significantly longer in the CTWO group (29.5 ± 6.8 months) compared to the TPLO group (11.9 ± 3.8 months) (p<0.001). As might be expected, all of the dogs were significantly less active than before injury (p=0.012 and p<0.018). Following surgery, dogs in both groups showed less disability (TPLO and CTWO p<0.001 and p<0.003, respectively), and an increased ability to jump (p<0.001 and p<0.016, respectively) compared to pre-operatively. The dogs that had been treated by TPLO also showed a significant decrease in stiffness after resting (p=0.002) and were less affected by cold weather (p=0.002); this was not the case with the CTWO dogs.

A comparison of the TPLO and CTWO groups at the time of completion of the questionnaire did not reveal any significant difference between the two groups in activity level, disability, or ability to jump (Fig. 4). The dogs in the CTWO group were reported to suffer significantly more from stiffness after resting (p=0.036) and were more susceptible to cold (p=0.029).

Table 3 shows the owner responses to the remaining questions. The majority of the dogs showed a rapid return to toe-touching, without any significant difference between the groups in median time to satisfactory limb use (two months), or the number of

![Fig. 1](image1)  
Fig. 1. Tibial plateau angles before and after surgery for TPLO-treated and CTWO-treated dogs. The TPA’s in both groups were significantly lower post-operatively than pre-operatively (P<0.001). The TPA’s were not significantly different between the groups pre-operatively, however, they were significantly lower in the CTWO dogs compared to the TPLO dogs post-operatively (P<0.001).

![Fig. 2](image2)  
Fig. 2. Distribution of lameness scores prior to surgery and six weeks after surgery for TPLO-treated and CTWO-treated dogs. The lameness scores were not significantly different between the two groups pre-operatively, or at six weeks. In both groups, the lameness score was significantly lower at six weeks compared to pre-operatively (P<0.001).
dogs regaining satisfactory use within one to four months (86.7%). At the time of completion of the questionnaire, the number of dogs in each group that required anti-inflammatory medication was not significantly different. Of the 26.9% of dogs receiving medication, use was constant in 11.5% and intermittent in 15.4%. The most common drug was carprofen (57%), followed by meloxicam (29%) and chondroitin and glucosamine supplements (14%).

Owner satisfaction with the outcome was high, and not significantly different between procedures. Overall, 92.3% of owners rated the outcome as ‘good’ or ‘excellent’ and 88.5% said that they would have the surgery done again on another pet with CrCL rupture.

### Discussion

The TPLO is a modification of the original CTWO procedure, and as techniques evolve, it is important to determine whether the benefits that are claimed for the modifications are reflected in improved clinical outcomes. In order to practice truly evidence-based medicine, such a question should be answered in a prospective, randomised, controlled study using objective outcome measures. The CTWO procedure is not widely performed now, which makes such a prospective study difficult. The popularity of each technique during different time periods also results in significantly longer follow-up periods for the CTWO’s cases, which may influence parameters, such as stiffness or the effect of cold. It should also be recognised that information on outcome gained through the widely accepted methods of owner questionnaire or telephone follow-up (10–12) is subjective, and therefore less robust than objective measurement, such as force plate analysis. While acknowledging these limitations, it remains useful to compare the two populations to determine whether significantly better outcomes are obtained following TPLO compared to the original CTWO procedure.

Successful clinical practice depends upon owners being satisfied with their pet’s progress post-operatively, therefore despite being subjective, the owner’s impressions of their dog’s recovery are important. Many studies therefore obtain follow-up information on long-term outcome through client questionnaires, but in order for the results to be considered valid, a minimum response rate of 60% is required (13, 14). The return rate in the present study was 70%, with 92% of owners reporting that the outcome was ‘good’ or ‘excellent’ without any difference between the procedures. This agrees with other studies, where ‘good’ to ‘excellent’ outcomes were reported for 86% of patients following CTWO (15), and 94% (7), and 98.7% (16) of patients following TPLO, based on client satisfaction. In contrast, where objective force plate analysis has been used to assess outcome, results have varied dramatically. While one study reported that all of the dogs had regained near normal peak vertical forces and vertical impulses by 18 weeks post surgery (17), another reported normal limb function in only 10.9% of TPLO-treated dogs by six months (18). Subjective ‘owner’ assessments of outcome were not available in either of the studies.

Despite being satisfied with the outcome, most of the owners in the present study did not feel that their dogs returned to pre-injury exercise levels, in contrast to other studies in which this was reportedly achieved (6, 7, 17, 19, 20). In particular, owners of the dogs that had undergone a CTWO reported that their dogs suffered from significantly more stiffness and were more affected by cold, compared to owners of the TPLO-treated dogs. This probably reflects the longer follow-up times of the

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Table 1

<table>
<thead>
<tr>
<th>Complication number (%)</th>
<th>TPLO number (%)</th>
<th>CTWO number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall complication rate</td>
<td>33.3%</td>
<td>22.7%</td>
</tr>
<tr>
<td>Complication</td>
<td>number</td>
<td>number</td>
</tr>
<tr>
<td>Tibial crest fracture</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Fibula fracture</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Implant failure not requiring revision surgery</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Implant failure requiring revision surgery</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Joint infection</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Wound infection</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Haematoma formation and bleeding post-op</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Late meniscal injury</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
CTWO-treated dogs, as both of these parameters are indicative of osteoarthritis in humans (21, 22). Despite this, the number of dogs receiving anti-inflammatory medication did not differ between the two groups.

Although a significant difference was not identified in the grade of osteoarthritis when the groups were compared six weeks post-operatively, a much longer follow-up period would be required in order to determine whether either procedure significantly alters the progression of osteoarthritis. Despite original claims that osteoarthritis does not progress following successful TPLO (7), more recent studies have reported the progression of osteoarthritis in most dogs (16, 23). The TPLO procedure may limit or slow down the development of osteoarthritis compared to extra-capsular repairs however, as a recent study reported that dogs with greater changes in osteoarthritis scores (based on radiographs taken pre-operatively and 12 months post-operatively) were 5.78 times more likely to have had an extra-capsular repair than a TPLO (24). The assessment of osteophyte development on radiographs is very subjective, however, and radiographic signs of stifle osteoarthritis have been shown to correlate poorly with clinical function (25), which perhaps explains the ‘good’ to ‘excellent’ function that was reported for most of the dogs following TPLO or CTWO.

The measurement of TPA from radiographs is also subject to variability from a variety of sources. Although a single observer measured the angles in the present study, intra-observer variability may have a standard deviation of 1.5° (26), and further variability can be introduced if the limb is positioned peripherally, rather than centrally, relative to the radiographic beam (27). A post-operative TPA of 5°–6.5° is recommended to produce stifle stability, while limiting excessive stresses on the caudal cruciate ligament (28, 29). In the present study, the post-operative TPA of the CTWO group was appropriate (5°). However, that of the TPLO group was 9°, yet neither the clinical outcome, nor the complication rate, was significantly different between the groups. This is in agreement with recent work which did not find any significant relationship between post-operative TPA and post-operative function, where the post-operative TPA was between 0°–14° (30).

As would be expected while experience is gained with a new technique, the surgical times for the TPLO procedure were initially significantly longer than those for the CTWO. After the initial nine procedures, however, the surgical times became comparable. Overall, the surgical times for both procedures reflect the teaching environment in which they were performed; in a non-teaching environment, the surgical times may be considerably shorter.

Despite the relative inexperience and longer surgical times associated with the TPLO procedure, the complication rates were not significantly different between the
two techniques in the present study. The overall complication rate of 28% is similar to the 25–28% reported by others (20, 31). A recent review of 696 TPLO’s reported a much lower complication rate of 18.8%, which perhaps reflects the experience gained from performing that number of procedures over a 30 month period (32). The complication rates for plateau-leveling techniques tend to be higher than those reported for intra- and extra-capsular techniques (31), and a much wider range of complications can be encountered, including implant failure, fractures of the tibial crest or fibula, joint infections and osteomyelitis, intra-articular screw placement, haemorrhage, patellar tendon desmitis, meniscal injuries and incisional complications (infections and wound dehiscence). Although the complication rates did not differ significantly between the groups, those with complications in the TPLO group recovered uneventfully, whereas the three dogs in the CTWO group required revision surgery. The revision rate for the CTWO group is concerning, and it is interesting to speculate as to whether this may be due to the osteotomy being inherently less stable following the CTWO procedure. The authors could not find any information in the literature comparing the biomechanical stability of the two types of osteotomy. In the present study, a single plate was used in every case, and while this is standard practice in a TPLO, other surgeons routinely double-plate in a CTWO procedure. It is unknown whether the latter technique would reduce complication rates.

Late meniscal injury was rare, which perhaps reflects the fact that all of the dogs underwent either a partial meniscectomy or meniscal release. Meniscal release was originally recommended to prevent the caudal horn of the medial meniscus from being crushed by the medial femoral condyle as cranial translation of the tibia occurs in the unstable stifle (33). Damaging an apparently normal meniscus to prevent potential future injury is counter-intuitive, and many surgeons no longer perform the procedure. As argued by Pozzi et al. (34), a stifle that has been stabilised by TPLO is no longer subject to cranial tibial thrust, therefore there may be no rational for performing a...
meniscal release. Information on the incidence of late meniscal injury following CTWO is sparse, however, a recent study reported a rate of 6.3% following TPLO (11). The latter study demonstrated that meniscal release did not reduce the subsequent rate of meniscal tears overall, and interestingly, meniscal tears still occurred in some of the dogs that had either a meniscal release or partial meniscectomy.

In conclusion, this paper compared the outcomes following CTWO or TPLO for treatment of cranial cruciate ligament rupture, and did not find any difference in most of the parameters under study. All of the dogs showed a rapid return to weight bearing after surgery, and at the six week re-examination, the majority of dogs had no pain on palpation and significantly lower lameness scores than prior to surgery of the stifle. The complication rates did not differ between the procedures, however, within this small sample of dogs, complications following a CTWO were more likely to result in a revision surgery. It would be interesting to determine whether the results of the present study would be supported in a larger prospective study, using objective outcome measures.

References