Comparison of radiographic arthritic changes associated with two variations of tibial plateau leveling osteotomy

A retrospective clinical study

J. A. Lineberger¹, D. A. Allen¹, E. R. Wilson¹, T. A. Tobias², L. G. Shaiken¹, J. T. Shiroma³, D. S. Biller⁴, T. W. Lehenbauer⁵

¹Mission MedVet, Mission, Kansas, U.S.A.
²Memphis MedVet, Memphis, Tennessee, U.S.A.
³MedVet, Columbus, Ohio, U.S.A.
⁴Department of Clinical Sciences, Kansas State University, Manhattan, Kansas, U.S.A.
⁵Department of Veterinary Pathobiology, Oklahoma State University, Stillwater, Oklahoma, U.S.A.

Summary
Osteoarthritis (OA) progresses in the canine cranial cruciate ligament (CCL) deficient stifle. Progression of OA is also documented in canine patients after various surgical repair techniques for this injury. We evaluated the radiographic arthritic changes in canine stifle joints that have sustained a CCL injury, and compared radiographic OA scores between Tibial Plateau Leveling Osteotomy (TPLO) surgery patients receiving a medial parapatellar exploratory arthrotomy for CCL remnant removal versus those receiving a limited caudal medial arthrotomy without removal of the CCL remnants. Medial/lateral and caudal/cranial stifle radiographs were obtained before surgery, immediately following TPLO surgery and at 7–38 months (mean 20.5) after surgery. Sixty-eight patients (72 stifles) were included in the study. The cases were divided into two groups. The patients in group 1 (n = 49 patients, 51 stifles) had a limited caudal medial arthrotomy, and patients in group 2 (n = 19 patients, 21 stifles) had a medial parapatellar open arthrotomy. A previously described radiographic osteoarthritis scoring system was used to quantify changes in both of the groups. The age, weight, OA scores, initial tibial plateau angle, final tibial plateau angle, and the change in angle were compared between the groups. The results showed that there was significantly less progression of OA in the group that had the limited caudal medial, arthrotomy, versus a medial parapatellar open arthrotomy. There was a significant advancement of the OA scores of patients that had TPLO surgery.

Introduction
Cranial cruciate ligament (CCL) injury is one of the most common canine musculoskeletal injuries. Many surgical procedures have been described for repair of the CCL deficient stifle (1, 5, 9, 21). Three primary surgical goals are limiting the progression of osteoarthritis (OA): preserving normal range of motion and a rapid return to good function. Surgical techniques can be divided into two major categories: intracapsular and extracapsular. The more commonly applied operations include the over-the-top procedure and its various modifications, fibular head transposition (FHT) or a lateral fabellar suture (LFS) (4). None of the surgical techniques have been proven to be superior.

Progression of OA after canine CCL injury has been shown to occur with conservative management or surgical intervention (4). The continued joint instability and the presence of ligamentous remnants of the CCL have been considered as possible sources leading to OA (3, 13, 17, 23). Intracapsular and extracapsular techniques have been shown to provide limited stifle stability over time (6, 7, 14).

Tibial Plateau Leveling Osteotomy (TPLO) is a relatively new technique developed for the treatment of CCL deficient stifles. Unlike other surgical techniques, the TPLO surgery does not try to limit cranial tibial thrust in the passive state. It is intended to provide joint stability during active joint loading. It is theorized that improved joint stability during weight bearing would lead to decreased OA development. Slocum described five criteria to evaluate success of a TPLO surgery (20). These criteria include: a normal ‘sit test’, full development of musculature in the operated limb, lack of inflammation, a halt in the progression of osteoarthritis, and most importantly, early return to full function (20). TPLO can be performed concurrently with an open arthrotrony and removal of the CCL remnants and a medial meniscal releasing incision, or with a limited caudal medial arthrotrony to perform a medial meniscal releasing incision.

The purpose of this paper was to compare radiographic OA changes of canine patients between two variations of TPLO surgery. We evaluated whether TPLO surgery alleviated the radiographic progression of OA in the cruciate deficient stifle, and compared radiographic OA changes in open versus limited arthrotomy patients.

Material and methods
Criteria for selection of cases
The records of dogs presented for TPLO surgery to two private veterinary referral hospitals (Mission MedVet and Memphis MedVet) between July 1, 2000 and June 31, 2001, were reviewed. Sixty-eight dogs met...
the criteria of having adequate quality radiographs both pre- and post-operative and were available to return for follow-up radiographs.

Procedures

Radiographs (medial/lateral & caudal/cranial views) were obtained immediately prior to surgery, immediately post-operatively and at follow-up. In order to assess the initial tibial plateau angle and score for any pre-existing OA, pre-operative radiographs were reviewed. The immediate post-operative radiographs were reviewed to assess the new angle of the tibial plateau and reassess the OA score. The follow-up radiographs were reviewed to assess the OA score. The radiographs were reviewed by three board-certified radiologists (Shaiken, Shiroma and Biller). Radiographic signs of OA were graded using a previously described system (4).

- Grade 4: no detectable OA
- Grade 3: mild (i.e. periarticular osteophytes)
- Grade 2: moderate (i.e. periarticular osteophytes and bone sclerosis)
- Grade 1: severe (i.e. periarticular and intrarticular osteophytes, bone sclerosis, and subchondral bone lysis).

The results of radiographic assessments were tabulated to quantify the initial tibial plateau angle, the final tibial plateau angle, the change in tibial plateau angle, initial OA score, post-operative OA scores and 7–38 month follow-up OA scores (Table 1). The results were compared between groups in order to determine the following: differences based on initial angle, the final angle, the change in tibial plateau angle, and the type of TPLO surgery (limited versus open arthroscopy) in the progression of OA. So that possible effects due to shorter or longer follow-up periods could be evaluated, a follow-up period of 12 to 30 months was also used to select a subset of cases for evaluating OA scores and changes within this limited period.

Non-parametric statistical methods were used to evaluate the ordinal OA scoring system data for significant differences. Wilcoxon signed ranks tests were applied when paired or related samples of OA scores were being evaluated (15). Two-sample Kolmogorov-Smirnov tests were used to compare OA scores between dogs receiving different types of TPLO surgeries (Group 1 and 2) (11). For evaluation of variables comprising continuous data, appropriate T-tests were used to evaluate means for investigations involving either one or two samples (19). Unless explicitly stated otherwise, comparisons involving OA scores were always based upon the corresponding average values, which were comprised from the three radiologists’ independent assessments. The change in OA scores at the extended follow-up period was determined by subtracting follow-up scores from the corresponding initial OA score prior to surgery. An additional variable was calculated to evaluate the extent of OA increase following surgery. This variable was calculated as a proportion between a numerator which was the change in OA score described previously and a denominator which was determined by subtracting a value of 1.0 from the initial OA score in order to represent the maximum amount of OA deterioration that could potentially occur in the joint following surgery if the joint were to reach the worst OA score of 1.0 at the follow-up examination. This proportion was expressed as a percentage (percentage of potential decline). Linear associations between variables were evaluated with Pearson correlation coefficients and two-tailed P-values (19). Weighted kappa correlation coefficients were calculated to measure agreement beyond chance between the three radiologists’ scores (12). A Chi-square analysis was used to determine any significant difference in the number of partial meniscectomies between groups. The results were considered to be significant for P-values ≤ 0.05. All of the statistical calculations were performed using commercially-available software.a, b

Table 1  Tibial plateau angles, time to follow-up, and osteoarthritis scores for both groups. Values shown are reported as mean +/− SD.

<table>
<thead>
<tr>
<th></th>
<th>Initial tibial plateau angles in degrees</th>
<th>Post-op tibial plateau angles in degrees</th>
<th>Time after surgery to follow-up in months</th>
<th>Pre-op OA scores</th>
<th>Follow-up OA scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 n = 51</td>
<td>25.78 ± 3.36</td>
<td>6.18 ± 3.02</td>
<td>19.00 ± 6.60</td>
<td>3.12 ± 0.57</td>
<td>2.43 ± 0.60</td>
</tr>
<tr>
<td>Group 2 n = 21</td>
<td>25.62 ± 4.10</td>
<td>4.95 ± 3.77</td>
<td>24.13 ± 6.86</td>
<td>3.25 ± 0.53</td>
<td>2.52 ± 0.48</td>
</tr>
<tr>
<td>Group 1 (12-30 mo follow-up) n = 39</td>
<td>25.59 ± 3.65</td>
<td>6.21 ± 3.07</td>
<td>21.74 ± 4.87</td>
<td>3.16 ± 0.48</td>
<td>2.53 ± 0.51</td>
</tr>
<tr>
<td>Group 2 (12-30 mo follow-up) n = 17</td>
<td>26.47 ± 4.09</td>
<td>4.82 ± 3.73</td>
<td>21.75 ± 5.05</td>
<td>3.24 ± 0.57</td>
<td>2.51 ± 0.53</td>
</tr>
</tbody>
</table>

The records were reviewed to determine age, sex, breed, weight, limb(s) affected and type of surgery performed. The values are reported as mean +/− standard deviation unless otherwise stated. The age at the time of follow-up was 71.4 +/− 31.0 months for all dogs. The sexes included three intact males, 22 neutered males and 43 spayed females. The body weight at the time of surgery was 36.6 +/− 11.7 (kg) for all the dogs. Group 1

---

a SPSS for Windows, Rel. 10.0.7. SPSS Inc., Chicago, IL.
b StatXact-5, Rel. 5.0.3. Cytel Software Corp., Cambridge, MA.
Two variations of tibial plateau leveling osteotomy

Dogs (n = 49 dogs, 51 stifles) had TPLO surgery and a limited caudal medial arthroscopy to allow for a medial meniscal releasing incision and partial meniscectomy (n = 2) as indicated; Group 2 dogs (n = 19 dogs, 21 stifles) had TPLO surgery and complete exploration of the stifle joint via a medial parapatellar approach with removal of the ruptured CCL remnants and partial meniscectomy (n = 3) as indicated. Two patients in each group had bilateral surgery. They had either the limited arthroscopy or the medial parapatellar arthroscopy performed on both stifles.

The post-operative follow-up period ranged from 7 to 38 months with an average period of 20.5 months. The dogs in the limited arthroscopy treatment group had a mean post-operative evaluation period of 19 months which was significantly shorter than the mean period of 24 months for dogs receiving the standard arthroscopy procedure (P < 0.01). When the follow-up period was restricted to a range of 12 to 30 months after surgery, the number of stifles, which were evaluated in Group 1, was reduced from 51 to 39 and the number in Group 2 was reduced from 21 to 17. The mean follow-up period became 22 months for both groups after imposing this selection criterion. There were not any significant differences between the treatment groups concerning age or weight for the entire study group (n = 72) or the restricted subset of dogs (n = 56) (P > 0.05).

Significant differences were not observed in the radiographic evaluations for open vs. the limited arthroscopy at either the initial (pre-surgery) nor the immediate post-operative comparisons (P > 0.15). All of the dogs showed either a lack of changes or a worsening in OA scores during the extended follow-up period; likewise, none of them showed any improvement in OA evaluation following the operations. Both TPLO surgical procedures showed a significant decline in OA scores for extended post-operative evaluations when compared to the initial OA scores (P < 0.001). For all of the cases, there was a significant difference between Group 1 and Group 2 dogs for both the follow-up OA score and the change in OA score between initial and follow-up (P ≤ 0.03). The central values tended to be slightly higher for both of these variables for Group 2 compared to Group 1. However, the significant differences which resulted would more likely reflect differences in the overall distributions of these variables between Group 2 and 1. The OA follow-up scores were significantly skewed toward lower values for Group 2 (P < 0.05), but Group 1 values were not significantly skewed. The changes in follow-up OA scores tended to peak at relatively lower values which indicated less decline in OA scores for Group 1 compared to Group 2. Even though these Group 2 dogs tended to initially have slightly healthier joints based upon radiographic evaluation at the time of surgery, they had significantly greater declines in OA scores at the extended follow-up period compared to dogs in Group 1 (Figs. 1, 2). A similar finding was obtained from the analysis of data for the subset of dogs with a follow-up period ranging from 12 to 30 months. The change in OA scores was significantly greater for dogs in Group 2 when compared to Group 1 (P = 0.02). The distribution of change in OA scores was positively skewed for dogs in Group 1 (P < 0.05).

In Group 1 there was a significant correlation between the percentage of potential decline, which was observed and three other

Fig. 1 Histogram of average osteoarthritis scores in the limited arthroscopy/TPLO group.

Fig. 2 Histogram of average osteoarthritis scores in the open arthroscopy/TPLO group.
variables: immediate post-operative OA score, average OA follow-up score, and the change in OA scores between initial and extended follow-up radiographic evaluations ($r = -0.32$, $-0.82$, and 0.77, respectively; $P<0.03$). For Group 2 dogs, the following variables had highly significant correlations with the percentage of potential decline in OA scores which was observed at follow-up: initial OA score, immediate post-operative OA score, and the extended follow-up OA score ($r = -0.56$, $-0.55$, and $-0.83$, respectively; $P<0.001$). There were not any significant correlations detected for either treatment group between OA scores or changes in scores after follow-up and age, weight, or duration of the follow-up period ($P>0.10$). Chi-square analysis did not show any significance between the groups in the number of meniscectomies performed.

A significant change in the mean tibial plateau angle of 20 degrees was measured following the operations for all dogs ($P<0.001$), but there was not any significant difference in either the initial angle, final angle, nor the change in angle between the open and limited arthrotomy groups ($P>0.15$). All of the weighted kappa coefficients were significant for agreement beyond chance among the three radiologists evaluating the initial, postoperative, and follow-up radiographs ($P<0.01$).

**Discussion**

There was a significant difference between the open arthrotomy and limited arthrotomy groups in our study. The open arthrotomy group began the study with better OA scores, and they advanced more over time when compared to the limited arthrotomy group. The calculation of percentage of decline was used to better evaluate the data set. A patient entering the study with significant OA could potentially advance only a small amount when compared to a patient with a very healthy appearing joint. Thus, the potential for change is much greater in a joint starting with minimal OA, when compared to a more advanced OA scored joint. Correlation relationships between the potential change in OA scores further supported the difference between open vs. limited arthroscopy.

The results of our study suggest that OA advanced after TPLO surgery irrespective of the type of arthrotomy performed. Our study suggests that OA progression occurred regardless of age, weight, or tibial plateau angles (pre- or post-operation). Numerous studies of various animal models have shown that OA is progressive over time (2, 17, 23). We selected a subset of patients that equalized post-operative time for both groups. The subset of patients demonstrated significant differences between open versus limited arthrotomy.

Joint instability has been shown to be present after various surgical techniques used to treat the canine CCL insufficient stifle (6, 7, 14). A major premise of the TPLO is that it limits joint instability during the weight-bearing phase (20). This may be true. Our study did not compare OA changes associated with the TPLO versus other surgical techniques.

Experimental sectioning of the CCL induced development of OA in multiple animal models (2, 3, 17). Based on the premise that the remnants are the source of OA progression, many surgeons have performed open arthrotomies to excise CCL remnants. Arthrotomy without sectioning of the CCL has been shown to lead to the progression of OA in animal models (13). The induction of inflammatory pathways associated with a surgical arthrotomy without the presence of instability in the stifle has a role in the onset of OA (13). Our study suggests that an extensive arthrotomy with removal of CCL remnants predisposed to increased development of OA. This finding is supported by a recent study that demonstrated less joint morbidity associated with a limited arthrotomy performed for arthroscopic joint surgery when compared to an open arthrotomy (11).

Instability associated with CCL injury can result in damage to the medial meniscus. Medial meniscal injuries secondary to injury of the CCL in canine patients has been reported anywhere from 20–80% (10, 18, 22). Meniscal injuries are commonly treated with a partial meniscectomy. The number of meniscectomies in our study was minimal and similar in both groups.

Our study suggests that TPLO does not halt the progression of OA in dogs weighing 36.6 +/- 11.7 kgs. Treatment of the canine CCL insufficient stifle continues to evolve as surgeons strive to reach a defined optimal outcome. Further studies need to be performed to objectively compare clinical outcome of TPLO with other surgical techniques.

**References**


11. Hoelzler MG, Millis DL, Francis DA, Weigel JP. Results of arthroscopic versus open arthrotomy.


Correspondence to:
Dr. Jayce Lineberger
Mission Med Vet
5914 Johnson Drive, Mission,
Kansas, Missouri, 66202 USA
Phone/Fax: +1 913 722 5566, Ext. 203
E-mail: j.lineberger@mmv-kc.com