Concurrent bucket handle meniscal tear treated with arthroscopic partial meniscectomy does not influence midterm outcomes after tibial plateau leveling osteotomy

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OBJECTIVE
To assess the effect of arthroscopic partial meniscectomy in dogs with bucket handle meniscal tears and tibial plateau leveling osteotomy (TPLO), compared with dogs with cranial cruciate ligament rupture and no meniscal tear treated by TPLO alone.

ANIMALS
30 client-owned dogs with cranial cruciate rupture treated by either TPLO and arthroscopy alone if the meniscus was normal (normal meniscus [NM] group, n = 14) or by TPLO and an arthroscopic partial meniscectomy if a bucket handle tear was diagnosed (meniscal tear [MT] group, n = 16).

METHODS
Medical records, lameness score, and symmetry gait analysis parameters were retrospectively collected from patient records preoperatively (PreO), then at 1, 3, and 6 months postoperatively (M1, M3, and M6, respectively). Osteoarthritic (OA) radiographic score was performed and compared at PreO and M6.

RESULTS
PreO gait analysis parameters were lower in the MT group ($P < 0.005$). In the MT group, the lameness score significantly improved between PreO and M1, and there were no significant differences between groups at M6. OA score was significantly higher in the MT group at PreO and M6. However, postoperative progression of OA did not differ between the 2 groups ($P = 0.16$).

CLINICAL RELEVANCE
Treatment for meniscal tear results in a significant improvement in lameness, with postoperative outcomes at 6 months comparable with dogs with intact menisci. Despite having significant osteoarthritic lesions at all time points, the progression of osteoarthritis is similar between dogs with meniscal tears and those with intact menisci.

Keywords: arthroscopy, gait analysis, meniscal tear, stifle, TPLO
cartilage injury. Excellent short-term outcomes have been reported when postliminary meniscal tears were treated arthroscopically by partial meniscectomy in dogs already treated for a CCL-deficient stifle, with improvement or resolution of the lameness in 96.5% of cases. Nevertheless, a meniscal injury requiring meniscectomy can increase the risk of developing osteoarthritis (OA) and lameness in the long term.

Kinetic gait analysis is increasingly used in day-to-day practice because it is an effective method to identify and objectively quantify lameness by studying the ground reaction force and symmetry during walking in normal or lame dogs. Previous studies have compared gait analysis data using force plates in dogs with and without meniscal tears where they note exacerbation of the lameness when a meniscal tear is present. However, there exists a limited body of literature providing that combines osteoarthritis and lameness in the early postoperative period.

The aim of this study was to compare the midterm clinical and functional outcomes of dogs with CCL-deficient stifles without meniscal tears treated by TPLO, with those of dogs with CCL-deficient stifles and concurrent bucket handle tear of the caudal horn of the medial meniscus treated by TPLO and arthroscopic partial meniscectomy. A second objective was to identify the progression over 6 months of radiographic osteoarthritis between the 2 groups. The first hypothesis is that treatment of bucket handle meniscal tear by arthroscopic partial meniscectomy would lead to similar outcomes at 6 months as those seen in dogs without meniscal tears. The second hypothesis is that osteoarthritis will progress the same amount in both groups.

Methods

Case selection

The medical records from our academic institution of dogs with unilateral unstable CCL-deficient stifle without other orthopedic conditions treated with TPLO and exploratory arthroscopy were examined from December 2015 to July 2017. The patient that had normal meniscus or bucket handle tears of the caudal horn with an intact peripheral rim of the medial meniscus treated by partial arthroscopic meniscectomy of the torn part were reviewed. Dogs with other types of meniscal tears or concomitant orthopedic conditions at the clinical exam or the radiographic exam were excluded. The following data were required for a case to be included in the study: medical records (age, sex, breed, body weight at the time of consultation, duration of lameness, grade of lameness, and side affected) with complete orthopedic exam; preoperative medio-lateral and cranio-caudal digital radiographs with a recorded preoperative TPA; postoperative medio-lateral and cranio-caudal digital radiographs with a recorded postoperative TPA and known size of the TPLO locking plate; arthroscopy images from surgical reports; gait analysis data from a pressure walkway (with at least 1, 3 and 6 months’ time points). Dogs were divided into 2 groups: the meniscal tear stifle (MT) group and the normal meniscus stifle (NM) group based on arthroscopic observation of the meniscus.

Preoperative evaluation

Palpation of each joint was performed to excluded pain or swelling in the other joints. A meniscal click was recorded after manipulation of the affected stifle. Lameness while walking was graded by a board-certified surgeon using a 5-tiered scale: 0 = no lameness; 1 = slight lameness; 2 = obvious weight-bearing lameness; 3 = severe weight-bearing lameness; 4 = intermittent nonweight-bearing lameness; 5 = continuous nonweight-bearing lameness. A pressure walkway (GaitRite; Biometrics) was used for gait analysis at a walking pace. A valid run was defined as a straight and constant speed walk along the entire length of the pressure walkway. Five valid runs were performed. The mean of the 5 valid runs was used for gait parameters analysis. Symmetry index (SI) between healthy and affected limbs for the relative stance time during the gait cycle (SII) was collected as well as the ratio of SI to total pressure (SI/TP) and the ratio of SI to the number of sensors activated (SI/NS). With this evaluation system, the gait is defined as symmetric if the ratio between the affected limb and the normal limb is 1. Medio-lateral and cranio-caudal radiographs were obtained before surgery. On the medio-lateral radiograph, the stifle and tarsus were flexed at 90° to calculate the TPA in preparation for surgery. An osteoarthritis radiographic score was calculated on both radiographs using a previously established scoring system by assessing osteophyosis/enthesophyosis, subchondral sclerosis, and joint effusion in various anatomical compartments of the stifle. Two of the authors trained by a board-certified radiologist analyzed radiographs blinded to group assignment. All the radiographs were shuffled before reading and read randomly. The median score for the 2 different readers was calculated.

Surgical technique

All procedures were performed by the same board-certified surgeon. Dogs underwent standard arthroscopic evaluation of the stifle with a 2.4-mm arthroscope (Arthrex GmbH). CCL rupture was confirmed and debridement of the torn CCL was performed with a motorized shaver. Meniscus evaluation was performed by direct visualization and probing. If a bucket handle tear was present, a partial meniscectomy was performed, under arthroscopic guidance, by removing the torn parts of the caudal horn of the medial meniscus. Meniscectomy was performed with a punch and a motorized shaver. The extent of the meniscectomy was adapted to the size of the lesion. Images of the different compartments...
(femoral condyles, tibial plateau, troclear groove, and patella) were recorded and articular cartilage was scored based on the modified Outerbridge grading scale with 5 levels of severity: 0 = no lesions; 1 = softening of the cartilage based on probing; 2 = minor fraying or fragmentation; 3 = severe fraying or fragmentation; 4 = exposed subchondral bones. All dogs then underwent standard TPLO according to the Slocum procedure. TPLO anatomical contoured locking plates (Depuy Synthes, Johnson & Johnson) were used in all cases. Intraoperative complications were recorded. Cranio-caudal and medio-lateral digital radiographs were performed immediately after surgery to assess implant positioning and calculate the postoperative TPA.

**Follow-up**

Follow-up was performed at 1 month, 3 months, and 6 months postsurgery. Six months correspond to a midterm period for outcomes. Complications were defined as catastrophic (death of the animal or amputation), major (requiring supplementary medical treatment or revision surgery), or minor (resolution without additional treatment). At each follow-up, dogs underwent palpation of the stifle to assess the absence of tibial thrust, a lameness score, and kinetic gait analysis at walking pace as previously described. Dogs were sedated for orthogon al radiographs and an OA score was performed at 6 months. Radiographic OA progression score was defined as the difference between the OA score preoperatively and at 6 months postsurgery.

**Recorded data and statistical analysis**

All data underwent descriptive analysis. In each set of data, a Shapiro-Wilk normality test was performed between the groups. Signalmnt data (age, sex, body weight, duration of lameness, and side affected), preoperative data (meniscal click, lameness score PreO, TPA preO, OA radiographic score PreO, and gait analysis parameters PreO), Surgical procedure data (Arthroscopic score, TPA postop) and follow-up data (M1, M3, and M6 lameness score; M6 OA radiographic score; evolution of OA radiographic score; M1, M3, and M6 gait analysis parameters) were statistically analyzed using Student’s t-test if the data were normal and Wilcoxon-Mann-Whitney’s U-test if the data were not normally distributed. Chi-squared test was used to test the proportion of complications between groups.

**Results**

**Study population**

Thirty dogs met the inclusion criteria; 16 in the MT group and 14 in the NM group. The age at presentation varies from 6.2 ± 3.2 and 3.6 ± 1.8 years for MT and NM, respectively. Eleven dogs were female (6 intact, 6 spayed) and 5 dogs were male (all intact) for MT and 10 dogs were female (7 intact, 3 spayed) and 4 dogs were male (all intact) for NM. Mean body weight ranged from 36.9 ± 13.3 and 35.2 ± 10.4 for MT and NM, respectively. There were 13 breeds represented, with mixed breed (6), golden retriever (5), cane Corso (5), and Labrador retriever (3) most commonly represented between groups. Duration of lameness was 1.5 ± 1.2 and 2.6 ± 1.6 months for MT and NM, respectively. In the MT group, lameness was left-sided for 11 dogs and right-sided for 5 dogs. In NM groups, lameness was left-sided for 11 dogs and right-sided for 3 dogs. Dogs in the MT group were significantly older than dogs in the NM group (P < .05). The duration of lameness before surgery was significantly longer in the MT group, compared with the MT group (P < .05).

**Preoperative evaluation**

Meniscal click was significantly (P < .05) more prevalent in the MT group than in the NM group, it was present in 9/16 dogs and absent in all dogs, respectively. Preoperative lameness score was 3 [2–5] and 3 [1–4] in MT and NM groups, respectively. No significant difference was found (P = .85) (Table 1). For preoperative TPA, there was no significant difference (P = .28) in MT and NM groups, respectively 22.8 ± 4.0° and 24.1 ± 2.1°. In contrast, OA score was significantly higher in the MT group in comparison to the NM group (P < .05) (Table 2). Preoperative gait analysis data were all significantly lower in MT group in comparison to NM group, reflecting a significant asymmetrical gait and greater lameness (Table 3).

**Surgical procedure**

The median Modified Outerbridge arthroscopic score was 2 [1–4] and 1 [1–3] for MT and NM group, respectively, and was significantly greater in the MT group than in the NM group (P < .05). The mean postoperative TPA was 5.6 ± 1.9 and 6.27 ± 2.36 for MT and NM groups, respectively, and there was no significant difference between the groups (P = .41). All procedures were similar, using either standard, mini, or broad 3.5 mm TPLO plates. No intraoperative complications occurred in either group.

<table>
<thead>
<tr>
<th>Time points</th>
<th>MT</th>
<th>NM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>2 [0–3]</td>
<td>2 [1–4]</td>
<td>.62</td>
</tr>
<tr>
<td>M3</td>
<td>1 [0–3]</td>
<td>0 [0–3]</td>
<td>.44</td>
</tr>
<tr>
<td>M6</td>
<td>0 [0–2]</td>
<td>0 [0–1]</td>
<td>.24</td>
</tr>
</tbody>
</table>

Lameness score in graded from 0 to 5. PreO = Preoperative period. M1 = 1 month postoperatively. M3 = 3-months postoperatively. M6 = 6 months postoperatively.

<table>
<thead>
<tr>
<th>Time points</th>
<th>MT</th>
<th>NM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PreO</td>
<td>17 ± 9</td>
<td>11 ± 5</td>
<td>.03</td>
</tr>
<tr>
<td>M6</td>
<td>29 ±7.2</td>
<td>18.3 ± 8.6</td>
<td>.001</td>
</tr>
</tbody>
</table>

Evolution of OA radiographic score

Evolution of OA radiographic score

See Table 1 for key.
Postoperative complications

There were no immediate postoperative complications in either group. Furthermore, no catastrophic complications occurred in either group. There were no significant differences in the rate of major or minor complications between the groups (P = .74 and P = .92, respectively). In the MT group, major complications occurred in 3 dogs: 2 dogs had superficial surgical site infections, treated with a 2-week course of antibiotics, and 1 dog had deep surgical site infection at 1-month postsurgery, treated with a 6-week course of antibiotics and plate removal at the time of healing. In the NM group, major complications (superficial surgical site infections) occurred in 2 dogs and both were treated with a 2-week course of antibiotics. There was 1 minor complication (a fibular fracture) in the MT group and, likewise, 1 minor complication (patellar desmitis) in the NM group. No postliminary meniscal tears were observed in any of the dogs.

Follow-up

All the stifles have negative tibial thrust at M1, M3, and M6.

Lameness score—The lameness score at M1, M3, and M6 was not significantly different between groups. In the MT group, the lameness score significantly improved between the preoperative time point (PreO) and M1 (P < .05) and between PreO and M6 (P < .05). In the NM group, there was no significant difference in the PreO and M1 lameness scores (P = .09); however, there was a significant improvement between PreO and M6 (P < .05) (Table 1).

Radiographic score—Radiographic score was significantly higher at M6 in comparison to preoperative evaluation for both groups. Furthermore, the M6 radiographic score was significantly higher for the MT group than the NM group. However, there was no significant difference in radiographic OA progression score between the 2 groups (P = .56) (Table 2).

Gait analysis—Gait analysis data were similar between groups at M1, M3, and M6 (Table 3). For the MT group, there were significant differences in SI-TP (P < .05) and SI-NS between PreO and M1 (P < .05), but no significant difference in SIs between PreO and M1 (P = .08). There were also significant differences in SIs, SI-TP, and SI-NS between PreO and M6 (P < .05).

For the NM group, there was no significant difference in SIs between PreO and M1 (P = .8). Similarly, there were no significant differences in SI-TP (P = .72) and SI-NS between PreO and M1 (P = .32). However, there were significant differences in SIs, SI-TP, SI-NS between PreO and M6 (P < .05) (Figure 1).

<table>
<thead>
<tr>
<th>Time points</th>
<th>MT</th>
<th>NM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI/%</td>
<td>PreO 0.84 ± 0.10</td>
<td>0.92 ± 0.10</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>M1 0.91 ± 0.13</td>
<td>0.91 ± 0.09</td>
<td>.20</td>
</tr>
<tr>
<td></td>
<td>M3 0.92 ± 0.08</td>
<td>0.96 ± 0.06</td>
<td>.11</td>
</tr>
<tr>
<td></td>
<td>M6 0.97 ± 0.03</td>
<td>0.99 ± 0.04</td>
<td>.17</td>
</tr>
<tr>
<td>SI/TP</td>
<td>PreO 0.54 ± 0.20</td>
<td>0.72 ± 0.24</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>M1 0.74 ± 0.19</td>
<td>0.77 ± 0.12</td>
<td>.52</td>
</tr>
<tr>
<td></td>
<td>M3 0.84 ± 0.11</td>
<td>0.93 ± 0.19</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td>M6 0.96 ± 0.12</td>
<td>0.98 ± 0.16</td>
<td>.94</td>
</tr>
<tr>
<td>SI/NS</td>
<td>PreO 0.65 ± 0.18</td>
<td>0.79 ± 0.19</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>M1 0.82 ± 0.14</td>
<td>0.88 ± 0.15</td>
<td>.29</td>
</tr>
<tr>
<td></td>
<td>M3 0.90 ± 0.08</td>
<td>0.94 ± 0.11</td>
<td>.39</td>
</tr>
<tr>
<td></td>
<td>M6 0.94 ± 0.08</td>
<td>0.98 ± 0.08</td>
<td>.32</td>
</tr>
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There are significant differences between all the gait parameters preoperatively between meniscal tear (MT) and normal meniscus (NM) groups whereas the gait analysis parameters are all similar at 6 months. See Table 1 for the key.

Figure 1—Evolution of the functional outcomes at the 4 different time points (PreO, M1, M3, and M6) of gait analysis parameters for Symmetry index (SI) between healthy and affected limbs for the relative stance time during the gait cycle (SI%), the ratio of SI to total pressure (SI/TP) and the ratio of SI to the number of sensors activated (SI/NS) between MT and NM. * means significant differences between groups.
Discussion

Based on the results of this study, dogs with bucket handle meniscal tears treated by arthroscopic partial meniscectomy had similar midterm functional outcomes to dogs with CCL-deficient stifles without meniscal tears treated with TPLO alone. The outcomes were similar despite the fact that the meniscal tear group had more severe osteoarthritis and cartilage lesions at the time of surgery than dogs without meniscal injury.

In our study, dogs in the MT group were significantly older than those in the NM group (6.2 ± 3.2 years and 3.6 ± 1.8 years, respectively). These results are consistent with a recent study showing that the risk of a medial meniscus tear increases by 1.1 times with each year of age.28 However, the duration of lameness before surgery was significantly longer in the NM group compared with the MT group. These results are not consistent with previously published data showing that the risk of meniscal tear increases by 2.6% with each additional week of lameness.29 This discrepancy may be because it is difficult for owners to accurately detect early-stage lameness. Moreover, owners may tend to underestimate lameness in dogs without meniscal tears compared with dogs that have a meniscal tear as it has been described as they were more willing to wait before presentation for surgery when the lameness was less severe. Therefore, the owner-reported onset of lameness may not be scientifically accurate.

Pressure-sensitive walkways with a symmetry index can be used to objectively measure paired limbs and evaluate lameness.30–32 Force plates are generally used to objectively evaluate lame limbs, however, this method can only assess 1 limb at a time.33 Indeed, with pressure walkways, animals tend to exhibit more natural and unrestrained gaits compared with force plates, which may be more restrictive or intimidating for some animals.34 It can record several steps during the walk of the dog. This can provide a better representation of the animal’s typical gait pattern as well as its extended lengths, capturing the animal’s gait over a longer distance, allowing for the assessment of changes in pressure distribution and timing throughout the entire stride cycle.35 However, Force plates typically offer higher resolution and sensitivity, enabling the detection of subtle changes in force distribution and weight-bearing patterns.34,35 Lameness score, even performed by experienced clinicians remains a subjective evaluation of the animal’s gait.36 As demonstrated by Waxman et al, subjective evaluation of gait varies among evaluators and shows weak correlation with objective measures of limb function and caution should be exercised when interpreting subjective gait evaluations as an outcome measure.36 At our institution, kinematic gait analysis is routinely performed to calculate a symmetry index. Stance time, total pressure, and number of activated sensors are calculated and correlated with kinetic and temporal parameters.37 In this study, preoperative lameness scores did not differ between groups, however, preoperative symmetry gait analysis showed that dogs with a bucket handle tear were more lame. These results are similar to several previous studies using force plates to show that peak vertical force and vertical impulse were significantly lower in CCL-deficient dogs with meniscal tears than in dogs without meniscal injuries.35

Menisci have important functions in weight bearing, stabilization, and load transmission in mammals.38 As the meniscus provides concavity to the convex tibial plateau, it increases the congruity of the femorotibial joint.39 In CCL-deficient stifles, the caudal horn of the medial meniscus acts as a wedge that stabilizes the femur from excessive subluxation and acts as a joint stabilizer.40 Bucket handle tears are associated with loss of function of the meniscus, resulting in increased load transmission to the stifle cartilage, and ultimately inducing degenerative changes of the cartilage.41 Cartilage stiffness is 28% lower in dogs with induced meniscal tears than in normal stifles.42 This is consistent with the results of our study where arthroscopic cartilage scores at the time of surgery were significantly higher in the MT group than in the NM group. However, a recent study does not corroborate those results and shows that at the time of surgery, there was no connection found between medial meniscus lesions and more severe arthroscopic articular cartilage injuries in the medial joint compartment.43 The present study does not delve into these associations, as they are beyond its scope. Further investigation and case numbers would be warranted.

Our results suggest that treatment of meniscal tears by partial meniscectomy is important to rapidly improve lameness in these dogs. In this study, we record the symmetry between the 2 hindlimbs studying the ratio of symmetry index of the number of sensors activated in the walkway pressure corresponding to the number of sensors activated by each paw and the ratio of symmetry index of the total pressure characterized as the total of peak pressure values detected by individual sensors in a paw when it contacted the mat. While there were no significant differences in SI-NS and SI-TP between the MT and NM groups, there were significant differences between SI-NS and SI-TP at 1-month postsurgery, compared with the preoperative time point in the MT group. In contrast, in the NM group, there were no significant differences in SI-NS and SI-TP at 1-month postsurgery, compared with preoperative measurements. These data demonstrate that preoperative lameness was more severe in dogs with meniscal tears than in dogs without tears and that partial meniscectomy allowed rapid improvement of lameness so that at 1-month postsurgery, lameness parameters were similar in both groups. Similarly, the gait analysis parameters at 3 months postsurgery were similar between groups. One possible hypothesis is that the NM group, characterized by milder gait analysis abnormalities during pre-O evaluation, may not show a significant difference when comparing the 2 time points (pre-O and M1). In contrast, the MT group, which initially had more pronounced gait analysis abnormalities, may exhibit a significant
difference at 1-month postsurgery. Lameness significantly improved at 6 months postsurgery in both groups, compared with preoperative measurements, and there were no differences between the groups. Overall these results indicate that partial meniscectomy combined with TPLO rapidly improved lameness in the MT group, allowing similar clinical outcomes as the NM group at 6 months postsurgery.

The radiographic osteoarthritic score used in this study described by d’Anjou et al.\textsuperscript{23} permits objective identification of osteophytopsis/osteophytosis and subchondral sclerosis in the different compartments of the stifle. The osteoarthritic score at the time of surgery was significantly higher in MT group than in NM group. A recent study corroborate those results where they find an association with severe osteoarthriti and medial meniscal tear.\textsuperscript{26} In both groups, the OA score was significantly higher at 6 months postsurgery, compared with the preoperative evaluation, showing that, as previously reported, OA progresses even after surgery.\textsuperscript{45–48} This suggests that proinflammatory humoral, mechanical, or surgical factors continue to persist after stifle stabilization.\textsuperscript{46} In our study, the progression of OA was similar between the groups, suggesting that treatment may mitigate the adverse effects of bucket-handle meniscal tears in the progression of OA.

This study has several limitations. The most evident limitation stems from the retrospective nature of the study itself. While the signalment was similar in both groups, the study population was small and the follow-up period was relatively short and less representative than in a larger patient cohort with possible statistic bias. Because the lesions were studied retrospectively, there are no detailed data on the size and extent of bucket-handle meniscus tears or on the percentage of torn menisci removed, which would have provided interesting data to study the evolution of lameness as a function of lesion severity.

Although this study demonstrated the progression of OA over a period of 6 months, it does not accurately depict the long-term changes that occur in cases of deteriorating OA over the course of several years and how it can impact the quality of life of dogs.

In conclusion, midterm outcomes in dogs with CCL rupture and bucket handle meniscal tear of the caudal horn of the medial meniscus treated by arthroscopic partial meniscectomy and TPLO are comparable to kinematic gait outcomes in dogs with CCL rupture alone treated by TPLO. Both groups of dogs had similar radiographic progression of osteoarthritis after surgery, even though the meniscal tear group had significantly worse cartilaginous and radiographic lesions at the time of surgery than dogs without meniscal tears. Dogs with meniscal tears improve rapidly to the level of intact dogs 1 month after surgery and then appear to have a similar progression over the following 6 months.

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