Tibial plateau levelling osteotomy implant removal: A retrospective analysis of 129 cases

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Keywords
Tibial plateau levelling osteotomy, tibial plateau levelling osteotomy complication, TPLO plate

Summary
Objective: To evaluate a cohort of dogs undergoing tibial plateau levelling osteotomy (TPLO) implant removal to determine key clinical features, prevalence, and indications for implant removal.

Methods: Medical records of dogs undergoing TPLO implant removal at a private referral practice (Dallas Veterinary Surgical Center) between 2004–2008 were reviewed. Patient signalment, implant type, presence of concurrent medical disease, surgeon, antibiotic use, aerobic bacterial culture result, and operative findings were recorded. Data were analyzed using paired t-test, Fisher’s exact test, and Wilcoxon-rank sum test. Statistical significance was set at p <0.05.

Results: The TPLO implants were removed from 126 dogs (n = 129, 4.8% of TPLO procedures) during the study period. Average time interval from TPLO to implant removal was 16.0 ± 17.8 months. The most common clinical signs were the presence of an open wound (n = 80), draining tract (n = 64), and lameness (n = 59). Culture of tissue or fluid from the implant bed or implants was positive for bacterial growth in 95/115 cases. A significantly greater proportion of the implants removed were Slocum TPLO plates (n = 109; 6.1%) when compared to other TPLO plate types (n = 20; 23.3%) (p <0.0001). No association was identified between a positive bacterial culture and measured variables.

Clinical significance: Local bacterial infection and clinical signs of inflammation were the most common reasons for TPLO implant removal. There may be an increased implant-associated complication rate for Slocum TPLO plates in the study population.

Introduction
The tibial plateau levelling osteotomy (TPLO) was first described by Slocum in 1993 and has become widely utilized for treatment of the canine cranial cruciate ligament (CCL) deficient stifle; complication rates following TPLO range from 18.8% to 28% for unilateral or staged bilateral procedures (1–4). Reported complications include haemorrhage, infection, fracture of the tibia or fibula, implant failure, fixation failure, patellar desmitis, patellar luxation, and implant-associated sarcoma (1–8). An increased complication rate has been associated with dogs having a high preoperative tibial plateau angle, those undergoing single-session bilateral TPLO, standard parapatellar arthrotomy, the Rottweiler breed, and a postoperative craniocaudal tibial crest width <1cm (1–10).

Information regarding TPLO implant removal is lacking in the veterinary literature. Implant-associated infection and inflammation may influence patient morbidity and clinical outcome and may be affected by surgical technique, implant properties, and patient factors. Infection has been documented in 3%-7.9% of patients undergoing TPLO surgery, although the individual contribution of local soft tissue infection, septic arthritis, and osteomyelitis in these percentages is not well described (2, 3). Tibial plateau levelling osteotomy implant characteristics have been proposed as a cause of local complications related to adverse tissue response. Previous analysis of explanted Slocum® TPLO plates revealed intra- and extracellular inclusions within tissue adjacent to the implants; it has been suggested that surface irregularities and microchemical content predispose the cast implants to corrosion and subsequent local tissue reaction (7, 11). These previous studies raise important questions regarding the correlation between clinical factors and implant-associated complications, and suggest a need for investigation into this relationship.

To the authors’ knowledge, there have been no previous reports specifically evaluating dogs undergoing TPLO implant removal. An understanding of factors related to implant-associated complications is essential; as such complications may necessi-
tate revision surgery, and increase patient morbidity and client expenditure. The purpose of this study was to identify the prevalence of and clinical indications for TPLO implant removal. We hypothesized that 1) implant-associated infection would be the most common reason for TPLO implant removal, that 2) older dogs and those with concurrent medical disease would have a higher prevalence of infection, and that 3) a greater proportion of Slocum TPLO plates would be removed when compared to New Generation TPLO plates.

Materials and methods

The surgical database of a private multicenter veterinary referral practice (Dallas Veterinary Surgical Center) was searched for dogs having TPLO surgery between August 1, 2004 and August 1, 2008. The total number of dogs having TPLO surgery was recorded, and the medical records of dogs undergoing TPLO implant removal were identified and reviewed. Patients were included if the initial TPLO surgery and implant removal were performed at the same practice and if the implant type could be determined. Based on hospital protocol, dogs undergoing TPLO prior to June 16, 2007 were implanted with a Slocum TPLO plate and screws. Dogs having TPLO surgery after July 16, 2007 and those treated with a 3.5 mm broad plate were implanted with New Generation TPLO plates and screws. Patients treated during the period of plate transition (54 procedures, 3 implant removals) were excluded from the study due to the inability to confidently identify the plate type used.

The medical records were reviewed and data were collected regarding the initial TPLO surgery including: patient signalment, presence of concurrent medical disease, surgeon, prophylactic antibiotic administration, presence and treatment of meniscal injury, implant style used, and available follow-up (time interval from TPLO to end of study period). Data which were collected pertaining to implant removal included: time interval from TPLO surgery, affected limb, clinical signs, duration of signs, the presence of implant failure, and bacterial culture and sensitivity results.

Using a classification system adapted from previous studies, duration of clinical signs was classified as acute (lasting ≤14 days) or chronic (lasting >14 days), and extrapolated into number of days when a specific time frame was indicated in the medical record (3, 4). Infection was defined as positive bacterial growth documented by aerobic bacterial culture testing performed by a commercial reference laboratory.

Radiographs taken at the time of TPLO implant removal were reviewed for all available cases. Using an ordinal scale of 0 to 10 (0 = normal and 10 = most severe change possible), the following features were graded on mediolateral and craniocaudal radiographic projections of the stifle by a single observer (AT): periarticular osteophyte formation, soft tissue swelling, lysis around the bone plate or screws, and new bone formation around the plate. Periarticular osteophyte formation was evaluated on the apex of the patella, femoral trochlear ridges, distal aspect of the femur, and tibial plateau. Lysis and new bone formation around the implants were evaluated based on the proportion of the implant surface involved. Degree of osteotomy healing was graded on a scale of 0 to 10 (0 = no activity and 10 = complete healing), based on the presence of lucency, cortical continuity and remodelling at the osteotomy site. Intra-articular soft tissue opacity was graded on a scale of 0 to 3 (0 = normal, 1 = mild, 2 = moderate, 3 = severe).

Antibiotic therapy

Prophylactic antibiotic therapy was decided upon by the surgeon. Cefazolin (22 mg/kg) alone or a combination of cefazolin (22 mg/kg) and enrofloxacin (5 mg/kg) was administered intravenously, 20–30 minutes prior to the initial skin incision for antimicrobial prophylaxis. If the procedure exceeded two hours, cefazolin administration was repeated at the initial dose rate at two hour intervals. The type and duration of postoperative oral antibiotic treatment was determined by the surgeon, and specific reasons for their decisions were not recorded in the medical record.

Implant removal procedure

The TPLO implant removal was performed after osteotomy healing was deemed adequate by radiographic evaluation. Implants were exposed through a medial skin incision using a combination of blunt and sharp dissection, allowing the plate and screws to be removed. In cases of screw fracture, bone adjacent to the fractured screw was removed with a high speed drill to allow for exposure and retrieval of the screw shaft. When clinical concern for implant-related infection existed, tissue samples from the area adjacent to the implant or direct swab of the implant bed or
implants, or a combination of these, were submitted for microbiologic evaluation. All samples were evaluated by the same reference laboratory for aerobic bacterial culture and sensitivity testing.

### Statistical analysis

Data were analyzed using commercial software. Descriptive statistics were performed to characterize clinical features evaluated (signalment, presence of meniscal injury, meniscal treatment, perioperative antibiotic use, time interval between TPLO surgery and implant removal, clinical signs, duration of clinical signs, bacterial culture result). Correlations between a positive bacterial culture and presence of concurrent medical disease, plate type, surgeon, perioperative antibiotic selection, or the use of postoperative antibiotics were examined using Fisher’s exact test. Slocum and New Generation groups were compared using two-sample t-test for continuous responses (patient age) or two-sample Wilcoxon rank-sum test for nonparametric responses (time interval between TPLO and implant removal, surgeon experience, follow-up). Kaplan Meier survival analysis was performed to compare the proportion of Slocum and New Generation plates removed relative to the time after surgery, based on cases undergoing implant removal. A p-value of <0.05 was considered significant.

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Table 1 summarizes postoperative oral antibiotics prescribed following initial tibial plateau levelling osteotomy (TPLO) surgery in dogs undergoing TPLO implant removal. Duration of treatment and dose are reported as mean (range). Note that a combination of ciprofloxacin and amoxicillin was administered to one patient.

<table>
<thead>
<tr>
<th>Postoperative antibiotic</th>
<th>Number of dogs</th>
<th>Duration (days)</th>
<th>Dose (mg/kg)</th>
<th>Dosing interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cephalexin</td>
<td>24</td>
<td>8.0 (3.0 - 15.0)</td>
<td>22.7 (15.4 - 37.2)</td>
<td>Every 8-12 hours</td>
</tr>
<tr>
<td>Cefpodoxime</td>
<td>11</td>
<td>9.1 (5.0 - 12.5)</td>
<td>5.8 (3.9 - 8.3)</td>
<td>Every 24 hours</td>
</tr>
<tr>
<td>Ciprofloxacin</td>
<td>5</td>
<td>8.7 (5 - 10)</td>
<td>14.5 (4.7 - 23.7)</td>
<td>Every 12-24 hours</td>
</tr>
<tr>
<td>Amoxicillin</td>
<td>1</td>
<td>12.5</td>
<td>23.4</td>
<td>Every 12 hours</td>
</tr>
<tr>
<td>Amoxicillin Clavulanate</td>
<td>1</td>
<td>7</td>
<td>14.6</td>
<td>Every 12 hours</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>1</td>
<td>8</td>
<td>3.8</td>
<td>Every 24 hours</td>
</tr>
</tbody>
</table>

**Results**

A total of 129 TPLO plate removal procedures (126 dogs) met the inclusion criteria. Three dogs underwent staged, bilateral TPLO plate removal. Thirty-three breeds were represented; mixed breed dogs (n = 32), Labrador retrievers (n = 28), and Rottweilers (n = 13) were most common. There were 63 females (62 spayed) and 63 males (57 neutered). Mean age (± SD) of the dogs undergoing TPLO surgery was 5.0 ± 2.6 years, and mean body weight was 36.5 ± 10.9 kg. Twenty-six TPLO were performed by two experienced, residency-trained surgeons and 103 TPLO were performed by six ACVS Diplomates. Concurrent medical disease was documented prior to TPLO surgery in 18 dogs (14.0%); the most common diseases were allergic skin disease (n = 10), and hypothyroidism (n = 2). Information regarding perioperative antibiotic selection was available for 121/129 cases. Cefazolin was administered in 32 cases and a combination of cefazolin and enrofloxacin was administered in 89 cases. Postoperative antibiotics were prescribed in 42 cases (32.6%) (Table 1). Overall mean duration of postoperative oral antibiotic treatment was 8.4 ± 2.8 days (range: 3.0–15.0 days). The intraoperative condition of the menisci was recorded in 118 cases. Medial meniscal injury was present and treated with a caudal pole medial hemimenisectomy in 46 cases. In cases without gross meniscal lesions (n = 72), medial meniscal release was performed in 59 cases, and no meniscal treatment was performed in 13 cases. Thirty-two dogs experienced incisional complications and 19 dogs experienced non-weight bearing or progressive lameness during the first eight postoperative weeks.

Implant removal was performed 16.0 ± 17.8 months (mean ± SD) following TPLO surgery. Seventy implants (54.3%) were removed from the right stifle, and 59 (45.7%) from the left stifle. Duration of clinical signs prior to implant removal was documented in 93 cases, of which 57 records indicated a specific time frame. Signs were considered acute in 14 dogs and chronic in 79 dogs. Mean duration of clinical signs was 95.7 ± 130.2 days. Patients presented for evaluation of clinical signs including the presence of a partial thickness cutaneous wound over the plate (n = 80), draining tract (full thickness cutaneous defect with communication to the surgical site and active drainage (n = 64), lameness (n = 59), swelling (n = 24), and pain (n = 3). Forty-eight dogs were evaluated for a single clinical sign, while two clinical signs were reported in 44 dogs, and 29 dogs presented with three or more signs. Implant failure was present in 11 cases, including screw loosening (n = 7) and screw breakage (n = 4). In two cases a broken screw shaft could not be retrieved despite removal of the surrounding bone. Patients with implant failure presented for draining tract, lameness, or swelling, and seven out of 11 had positive bacterial cultures. Postoperative meniscal injury was documented at the time of implant removal in four dogs. One dog with postoperative meniscal injury had a positive bacterial culture. Tissue biopsy at the time of plate removal revealed osteosarcoma in three dogs (2 Rottweilers, 1 Labrador retriever). All three dogs had a Slocum TPLO plate applied an average of 6.5 years prior to implant removal.

Radiographs were available for review in 48 cases, and were performed a mean of 9.8 ± 7.0 months following TPLO surgery. Clinical union was achieved in all dogs, with an average score of 9.8 ± 1.3 for degree of osteotomy healing. Mean score for periarticular osteophyte formation and intraarticular soft tissue opacity was 3.3 ± 1.8 and 1.8 ± 0.8, respectively. The most common radiographic changes were soft tissue...
swelling over the plate (n = 18), new bone formation around the plate (n = 17), and lucency around the implants (n = 15). Local soft tissue swelling (n = 12) and lucency under the plate (n = 8) were frequently identified at the distal 1/4 to 1/2 of the bone plate, whereas new bone formation was located distal to the plate in 11/17 cases (Fig. 1). Other findings included screw loosening (n = 7), healing fibular fracture (n = 3), and healing tibial tuberosity fracture (n = 1).

Tissue samples obtained from the area adjacent to the implant or a direct swab of fluid from the implant bed or implants were submitted for aerobic bacterial culture in 115 cases. Implants were included in samples submitted for culture in 40 cases. Culture results were negative in 20 cases (17.4%) and positive in 95 cases (82.6%). A single organism was identified in 92.6% of positive bacterial cultures. Bacterial isolates are summarized in Table 2. No association was identified between a positive culture and increasing age, presence of concurrent medical disease, plate type, surgeon, perioperative antibiotic choice, or postoperative antibiotic use (Table 3).

During the study period, 2673 TPLO procedures were performed, with 1793 Slocum and 880 New Generation TPLO plates implanted. Average time interval to TPLO implant removal was longer (p = 0.039) for Slocum plates (17.5 ± 18.9 months) than New Generation plates (8.2 ± 5.2 months). Kaplan Meier survival analysis for TPLO plates removed revealed that the Slocum survival population was significantly greater than New Generation at a given time (log rank value = 0.0057) (Fig. 2). A significantly greater proportion (p <0.0001) of Slocum TPLO plates (n = 109, 6.1%) were removed when compared to New Generation plates (n = 20, 2.3%). Available follow-up for Slocum plates (43.5 ± 22.3 months) was longer than for New Generation implants (21.3 ± 11.4 months) (p <0.0001). There was no significant difference in signalment, presence of concurrent medical disease, or prevalence of infection between Slocum and New Generation groups.

Discussion

In this study of a large number of dogs undergoing TPLO surgery, the prevalence of implant removal was 4.8%. While the clinical findings in dogs undergoing TPLO plate removal included implant-associated infection, local inflammation, implant failure, and meniscal disease, the clinical signs were similar in the two groups. In the current study, the prevalence of implant removal is higher than that recently reported for 1000 TPLO procedures performed by a single surgeon (2.7%) (13). This finding may be related to surgeon experience, differences in operative protocol or implants used, or variability in study population and available follow-up.

The population of dogs in this study was similar in signalment and body weight to other TPLO cohort studies (2–5, 9, 10). Clinical signs necessitating implant removal were chronic in most cases, and implant removal was performed an average of 16 months after TPLO surgery. Potential reasons for this long time interval between initial surgery and the onset of adverse clinical signs include low-grade implant infection, bacterial seeding from distant infection, suppression of signs with medical management, delayed medical evaluation, and systemic immune or inflammatory disease (14–17).

Radiographic evaluation at the time of TPLO plate removal commonly revealed local soft tissue swelling, as well as new bone formation and lucency around the bone.

**Table 2** Bacterial species isolated from tissue samples taken from the area adjacent to the implant or direct swab of the implant bed or implants in dogs undergoing tibial plateau levelling osteotomy plate removal. Samples were submitted to a commercial reference laboratory (IDEXX Laboratories, Inc.) for aerobic bacterial culture and sensitivity testing.

<table>
<thead>
<tr>
<th>Bacterial Isolates</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulase positive Staphylococcus spp.</td>
<td>64</td>
</tr>
<tr>
<td>Pseudomonas spp.</td>
<td>16</td>
</tr>
<tr>
<td>Coagulase negative Staphylococcus spp.</td>
<td>9</td>
</tr>
<tr>
<td>Beta Haemolytic Streptococcus spp.</td>
<td>5</td>
</tr>
<tr>
<td>Corynebacterium spp.</td>
<td>2</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>1</td>
</tr>
<tr>
<td>Enterococcus spp.</td>
<td>1</td>
</tr>
<tr>
<td>Acinetobacter spp.</td>
<td>1</td>
</tr>
<tr>
<td>Stenotrophomonas spp.</td>
<td>1</td>
</tr>
<tr>
<td>Bacillus spp.</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 3** Summary of results when measured variables were analyzed for correlations with a positive bacterial culture. Results are for Fisher’s exact test, unless otherwise indicated. Statistical significance was set at p <0.05. *Results are for two sample t-test.

<table>
<thead>
<tr>
<th>Clinical variable</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient age</td>
<td>0.259*</td>
</tr>
<tr>
<td>Concurrent medical disease</td>
<td>1.0</td>
</tr>
<tr>
<td>Plate type</td>
<td>0.514</td>
</tr>
<tr>
<td>Surgeon</td>
<td>0.141</td>
</tr>
<tr>
<td>Perioperative antibiotic selection</td>
<td>0.146</td>
</tr>
<tr>
<td>Postoperative antibiotic use</td>
<td>0.287</td>
</tr>
</tbody>
</table>

Fig. 1 Cranial radiographic projection of the right stifle of a 6.5-year-old castrated male Doberman Pinscher that was presented for evaluation of a draining tract, swelling, and lameness 29.5 months after tibial plateau levelling osteotomy surgery. Note the soft tissue swelling over the distal aspect of the plate. Periosteal new bone formation is present over the central aspect of the plate, as well as proximal and distal to the plate.
plate. These findings may be a result of local bone and soft tissue reaction to the implant, or be related to infection. Periarticular osteophyte formation was often mild, although immediate postoperative radiographs were not available to document progression. Soft tissue opacity within the joint space was noted to be moderate in most cases, and may reflect thickening of the periarticular soft tissue structures, synovitis, stifle joint effusion, or less likely the presence of a soft tissue mass. Considering this finding, synovial fluid analysis and culture should be considered in patients undergoing implant removal following TPLO.

The most common reason for TPLO implant removal from dogs in this study was local bacterial infection, supporting our hypothesis. No association between measured variables and the presence of infection at the time of plate removal was identified. It is possible that dogs were treated at other veterinary facilities, owners elected long-term medical management, or medical evaluation was not pursued in all cases; thus the prevalence of infection in the study population may be underestimated. A variety of subjective measures have been utilized to define postoperative infection in the veterinary literature (18–20). Due to the broad overlap of clinical signs related to infection and inflammation, clinical diagnosis of surgical site infection remains complicated. In the present study, the use of bacterial culture was selected as an objective measure for diagnosis of infection, although the limitations of operative cultures, including sample contamination, culture of surface organisms, variable bacterial growth patterns, and influence of prior antimicrobial therapy, are acknowledged. Considering the limitations associated with subjective and objective assessment of surgical site complications, a combination of clinical and microbiological data should be considered for diagnosis of infection following TPLO.

Fig. 2
Kaplan Meier curve of New Generation and Slocum tibial plateau levelling osteotomy (TPLO) plates removed from dogs between August 2004 and August 2008. Data points represent the proportion of implants remaining in situ relative to time after TPLO surgery.

Risk factors for surgical site infections in humans include obesity, diabetes mellitus, remote infection, and increasing age (17, 21). An increased risk of postoperative infection in animals has been related to surgical site clipping prior to anaesthesia, use of propofol in the anaesthetic protocol, and increased duration of surgery and anaesthesia (18, 19, 22–24). One study revealed that animals with endocrinopathies were 8.2 times more likely to develop postsurgical infections following clean-contaminated procedures (23). Another recent study of patients undergoing TPLO surgery did not find any significant correlation between duration of anaesthesia or surgery with rate of infection (13). The hypothesis that increasing age and pre-existing medical disease would increase the prevalence of infection in dogs undergoing TPLO implant removal was not supported by our findings. Patients in the study may have had underlying medical conditions that were not reported or documented at the time of surgery. Taking into account the small number of cases with concurrent medical disease, introduction of a type II error is also possible.

Perioperative antimicrobial prophylaxis has been shown to reduce postsurgical infection rates in humans and animals, and is indicated when orthopaedic devices are implanted (17, 19, 20). Historically, cephalosporins have been utilized for antimicrobial prophylaxis due to their wide safety margin, reasonable cost, bactericidal properties, and spectrum of activity against common contaminants (17). In this study, the prevalence of infection in patients undergoing TPLO implant removal was not different for patients receiving perioperative cefazolin alone versus a combination of cefazolin and enrofloxacin. The lack of a control population precludes an analysis of the influence of these two protocols on infection rate following TPLO.

Although guidelines for human surgery recommend discontinuation of antimicrobials within a few hours of skin closure for clean procedures, there are differing conclusions among veterinary reports regarding the consequence of antibiotic use beyond the perioperative period (17). Brown et al. reported an increased wound infection rate for patients receiving antibiotic therapy more than two hours prior to, or more than 24 hours after surgery (18). Conversely, two recent reports found that administration of postoperative oral antibiotics reduced the rate of surgical site infection and inflammation following CCL surgery in dogs (13, 25). In the current study, the use of oral antibiotics after TPLO surgery did not significantly influence the prevalence of infection in patients undergoing implant removal. The indications for postoperative antibiotic therapy were not recorded, and it is possible that patient factors or breaks in aseptic technique may have influenced the decision to implement oral antibiotics, and contributed to the development of postsurgical infection. Controlled studies are necessary to determine the affect of antibiotic therapy on the prevalence of infection and need for implant removal following TPLO.

Patients undergoing TPLO implant removal presented with open wounds, drainage, swelling, or pain related to the area around the implant. Considering the aforementioned limitations of microbiologic testing, it remains difficult to differentiate surgical site infection from inflammation alone. Local tissue response may be affected by patient factors, surgical technique, and implant properties. There is conflicting evidence in
the veterinary literature regarding the potential influence of TPLO plate properties on the development of implant-associated complications. Previous work by Boudrieau and colleagues documented particulate debris within the tissue adjacent to the implant, surface irregularities, high ferrite content, and magnetic properties on examination of Slocum TPLO plates removed from clinical cases (7, 11, 12). It has been suggested that these implants, which were made in a casting process, may be predisposed to corrosion which was associated with evidence of local tissue reaction. In contrast, microchemical and surface analysis of explanted Slocum TPLO plates in another study did not reveal any surface pitting or corrosion (26). Additionally, the potential change in ferrite content correlated to reduced nickel content was not considered significant enough to affect corrosion resistance of the implants.

In the current study, patients treated with Slocum TPLO plates were significantly more likely to have their implants removed than those implanted with New Generation plates. The inclusion requirement of implant removal during the study period allowed for inclusion of dogs having TPLO surgery prior to the four year interval. When data analysis was limited to TPLO plates implanted and removed during the study period, there remained a higher implant removal rate for Slocum plates when compared to New Generation plates (p = 0.012). In the absence of an association between plate type and infection, there may be an increased prevalence of local inflammation associated with the use of cast Slocum TPLO plates in the study population. Histopathological evaluation of tissue samples from the implant bed was not available; this would be necessary to understand the character and aetiology of local tissue reaction. It is possible that other variables may have influenced implant removal in these groups, including patient factors, failure of aseptic technique, surgical technique, and attending surgeon.

Based on the time from TPLO to implant removal, there was shorter follow-up available for dogs implanted with New Generation TPLO plates, and this may have influenced the comparison of the two implant groups. However, New Generation plates in the study were implanted an average of 21.3 months prior to conclusion of the study period, which we felt was reasonable follow-up considering that the mean time interval from TPLO surgery to implant removal was 17.5 and 8.2 months for Slocum and New Generation groups, respectively. It remains conceivable that a higher implant removal rate might be identified for patients treated with New Generation plates, given a longer follow-up period. The finding that New Generation plates were removed earlier than Slocum plates may be related to heightened awareness of and thus improved diagnosis and treatment of implant-associated complications. Other factors that may have influenced this finding include variable follow-up time, operative technique, implant properties, and population variability.

The development of implant-associated sarcoma following TPLO has been previously documented, and it has been suggested to occur more frequently with the cast Slocum TPLO plate (7, 8). In the current study, osteosarcoma was diagnosed from tissue biopsied from around the Slocum TPLO plates in three dogs that were presented for localized swelling (n = 2) and a draining tract (n = 1). Our study design probably underestimates the prevalence of tibial sarcomas in the overall study population due to the inclusion requirement of implant removal, diagnosis by referring veterinarians, or failure to seek medical evaluation. Considering the predilection for osteosarcoma in the proximal tibia, study interval of four years, and the extended time interval between TPLO surgery and sarcoma formation, major conclusions cannot be drawn. Additional investigation into this observation is needed.

The limitations of this study include its retrospective design, and its reliance on the completeness of medical records. Some factors that may have influenced postoperative infection rate were not recorded, including body condition, anaesthetic protocol, total anaesthetic and surgical time, and indications for postoperative antibiotic use. The lack of surface evaluation of explanted plates, and histopathology of tissue from the implant bed are considered important limitations of this study. No age matched control group was evaluated, and thus we were unable to determine risk factors for infection and TPLO implant removal. Additionally, no standardized sample was established for bacterial culture, which potentially affects the sensitivity and specificity of this testing. Finally, no long-term follow-up was available to document clinical outcome for patients undergoing TPLO implant removal.

Complications after TPLO surgery influence patient morbidity and may necessitate additional surgical treatment. Based on this study, implant-associated infection and clinical signs of inflammation are the most common reasons for TPLO implant removal. While no correlation between clinical features of dogs undergoing TPLO implant removal and a positive bacterial culture was identified, patients treated with Slocum TPLO plates were more likely to have the implants removed when compared to patients implanted with the New Generation plates. This finding may be related to an increased implant-associated complication rate for cast Slocum TPLO plates in the study population. Further investigation into this association is warranted.

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Conflicts of interest
None declared.

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