Short-Term Prospective Clinical Evaluation of a Polyglycolic Acid Tibial Tuberosity Advancement Cage Implant

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ABSTRACT
This study investigated the short-term radiographic healing of the osteotomy following tibial tuberosity advancement (TTA), maintenance of patellar tendon angle (PTA), and complications in dogs receiving a polyglycolic acid (PGA) TTA cage. Patients diagnosed with unilateral cranial cruciate ligament disease requiring a 9- or 12-mm TTA cage were included. Twenty-six consecutive client-owned dogs were prospectively selected for this clinical study. Age, weight, sex, breed, cage size, surgery date, and follow-up time were recorded. Radiographs were scored for healing and measured for PTA immediately, at 6 wk, and at 10 wk postoperatively. All stifles were assessed for complications throughout the study period. Stifles with PGA cages had similar overall healing scores compared to previously reported values for metallic cages, and the PTA was well maintained at 6 and 10 wk postoperatively. Polyglycolic acid cages were associated with a higher complication rate (10/26, 38%; 95% confidence interval, 0.19–0.61) compared with previously reported complication rates for metallic cages. Despite favorable healing scores and overall PTA maintenance, PGA cage use resulted in a high complication rate. Proposed advantages offered by this particular implant over currently used metallic cages are offset by this high complication rate. Additional investigation of bioabsorbable materials and implant design should be considered. (J Am Anim Hosp Assoc 2018; 54:85–94. DOI 10.5326/JAAHA-MS-6532)

Introduction
Complete or partial rupture of the cranial cruciate ligament (CrCL) is the most common disorder of the stifle joint in dogs and represents one of the most common veterinary orthopedic conditions.¹ A ruptured CrCL results in unrestrained translational stifle instability (tibiofemoral shear), causing debilitating pain, lameness, and progressive articular cartilage injury. Tibial tuberosity advancement (TTA) is a frequently used surgical treatment for CrCL disease that neutralizes cranial tibiofemoral shear force by advancing the insertion of the patellar ligament until it is perpendicular to the tibial plateau with the joint in extension. This 90° patellar tendon angle (PTA) is typically maintained by stabilizing the osteotomy of the proximal tibia with procedure-specific stainless steel (SS) or titanium (Ti) plate and cage implants.² The TTA plate and cage function together like a tension-band wire construct, with the plate neutralizing distractive forces while the cage prevents collapse of the osteotomy gap and loss of desired PTA. Progressive postoperative healing of the osteotomy site occurs such that the implants serve only a temporary role in maintaining TTA stability and PTA.

Elective orthopedic implant removal contributes to almost 30% of planned orthopedic procedures in industrial countries and is one of the most common human surgical procedures performed...
worldwide. Because the majority of devices serve only a temporary role in the body to facilitate anatomic bone healing, their removal is meant to prevent long-term implant-associated morbidity including stress shielding, implant corrosion, carcinogenic potential, infection nidus, and interference with future radiologic imaging. By contrast, elective or “prophylactic” implant removal is less often performed in veterinary patients. A common nonelective reason for implant removal in veterinary patients is short- or late-term postoperative infection. Reported TTA postoperative infection rates range from 2.6 to 8.7%. As with any orthopedic device, bacteria may form biofilms on metallic TTA implants, which make them highly resistant to host immune responses and antibiotic administration. Such conditions can make antimicrobial therapy unsuccessful for definitive infection resolution and removal of the associated implants may be required. Although TTA plate removal should be relatively simple and an unlikely cause of significant patient morbidity, cage removal is more technically challenging because of its location within the osteotomy site and a design that promotes fibrous and osseous tissue ingrowth. Additionally, the defect left in the tibia following a cage removal could serve as a potential source for a tuberosity fracture. Lastly, surgical removal of the TTA implants, and any associated morbidity, are an additional expense for owners. Given all of these considerations, a TTA cage that provided sufficient mechanical support for osteotomy healing, while gradually resorbing in situ, would have considerable appeal.

There has long been a strong interest for developing surgical implants that degrade within a predetermined time frame. Numerous biocompatible, degradable polymers have been tested for different human and veterinary orthopedic applications with mixed success. A major limitation of some polymer-based implants is their inferior strength and stiffness characteristics when compared with their metallic counterparts. Most of the studied veterinary applications have focused on trauma-related polymer implants, which have to resist a complex variety of mechanical forces acting upon a repaired fracture site. By contrast, the TTA cage may be better suited for polymer composition because it functions primarily to transfer the compression component of the patella ligament force from the tibial tuberosity to the metaphysis. Polyglycolic acid (PGA) is a commonly used bioabsorbable polymer that has been utilized for decades in a variety of surgical applications. Polyglycolic acid polymers have proven biocompatibility, consistent resorptive properties, high initial mechanical strength, and a projected degradation period of 6–12 mo. The objectives of this study were to evaluate the short-term radiographic TTA osteotomy healing and maintenance of PTA in dogs receiving a cuttable PGA TTA cage (Figure 1). In addition, we aimed to report any radiographic and clinical complications encountered. Prior to this clinical study, the time-dependent viscoelastic properties of the PGA cage were evaluated in vitro using the American Society for Testing and Materials

FIGURE 1 Cuttable bioabsorbable tibial tuberosity advancement cage made of polyglycolic acid and stainless steel wings.
standard testing method for reproducing plastic aging by way of time and temperature superposition shift soaks.\textsuperscript{15} Additionally, the cages were tested using standard methodology for resistance to compression loads at various levels of molecular weight loss.\textsuperscript{16} The proprietary results of these tests supported a favorable functional time for the PGA device in vivo. Our hypothesis was that the PGA cages would result in similar radiographic healing scores and complications as previously reported for SS cages. A second hypothesis was that PGA cages would maintain the postoperative PTA over time following TTA.

**Materials and Methods**

**Patients**

The inclusion criteria for this prospective clinical study consisted of the following: consecutive client-owned dogs with unilateral CrCL disease; a TTA was performed with either a 9- or 12-mm PGA cage; immediate, 6-, and 10-wk postoperative lateral stifle radiographs were available for review; and no previous stifle surgery had been performed. All dogs also had to be skeletally mature and weigh >15 kg.

Owners whose dogs met the inclusion criteria were counseled on the management of canine CrCL disease and typical TTA surgery. Care was taken to ensure owners understood that the PGA cage implant was novel and had not been tested in a clinical setting and no outcome data was available for reference. Informed consent was obtained from each owner prior to surgery. Owners received financial incentive for their participation.

Patient information gathered for analysis included age, sex, breed, body weight (kg), TTA cage size, date of surgery, dates of follow-up radiographs, and any observed complications (radiographic or clinical).

**Preoperative Evaluation**

A full physical and orthopedic examination was performed on all dogs to confirm the diagnosis of CrCL disease and exclude other orthopedic disease that could affect the stifle. A diagnosis of unilateral partial or complete CrCL rupture was made on the basis of stifle joint effusion, signs of pain and swelling, and by evidence of cranial drawer motion and/or cranial tibial thrust in dogs with a complete CrCL rupture. Dogs >6 yr had complete blood count and serum biochemical profiles obtained preoperatively. Preoperative lateral fully-extended stifle radiographs were taken under general anesthesia for TTA measuring and exclusion of any other radiographic abnormalities of the stifle.\textsuperscript{17}

**Surgical Procedure**

The anesthesia protocol was not standardized. All dogs were premedicated with a combination of hydromorphone\textsuperscript{b} (0.1 mg/kg) and either midazolam\textsuperscript{c} (0.1 mg/kg) or acepromazine maleate\textsuperscript{d} (0.1 mg/kg) IV 15–20 min prior to induction with propofol\textsuperscript{e} (4 mg/kg IV). Anesthesia was maintained with isoflurane\textsuperscript{f} and oxygen. Every dog received a perioperative injection of cefazolin\textsuperscript{g} (22 mg/kg) IV, and a morphine\textsuperscript{b} (0.1 mg/kg) and bupivacaine\textsuperscript{h} (0.5 mg/kg) epidural. The TTA procedures were performed as described previously using “forkless” plates and without any grafting of the osteotomy sites.\textsuperscript{9} Patients received either a 9 or 12 mm PGA TTA cage\textsuperscript{a} (Figure 1) with SS wings, which was placed in the same fashion as a metallic cage. Cranio-caudal and mediolateral immediate postoperative digital radiographs were taken to assess implants and the osteotomy (Figure 2). All surgeries were performed by a single surgeon (M.D.B.).

**Postoperative Care**

Postoperative pain management consisted of 0.5 mg/kg IV or intramuscular morphine \textit{q 4–6 hr} as needed for the first 12–18 hr after surgery. A nonsteroidal anti-inflammatory drug and cephalaxin\textsuperscript{i} (22 mg/kg orally \textit{q 8 hr}) were started the evening after surgery and continued for 5–7 days after surgery. Tramadol\textsuperscript{j} (3–4 mg/kg orally \textit{q 8 hr}) was started the evening after surgery and continued for 4 days. All dogs were discharged the day after surgery. Skin staples or

![FIGURE 2](attachment:image.png) **FIGURE 2** Immediate postoperative lateral radiograph of a tibial tuberosity advancement using a polyglycolic acid tibial tuberosity advancement cage.
sutures were removed at 10–14 days. Dogs were restricted to leash-based activities for the first 6 wk postoperatively and a progressive return to normal activities during the following 4 wk.

**Follow-Up Evaluation**

Dogs were evaluated at 6 and 10 wk following surgery and lateral stifle radiographs were performed on awake patients. All radiographs were randomized and evaluated by a single board-certified radiologist (A.T.W.) blinded to patient information and postoperative time frames. Healing of the osteotomy site was scored using a previously published 0–4 scale: 0, no osseous healing; 1, early bone production without bridging between the tibial tuberosity and the shaft of the tibia; 2, bridging bone formation at one site; 3, bridging bone at two sites; and 4, bridging bone at three sites. The three osteotomy sites evaluated were proximal to the cage, between the cage and the plate, and distal to the plate (Figure 3).6

Immediate (time 0), 6-, and 10-wk postoperative PTAs were measured using the common tangent method as previously described.18

**Complications**

Any complications that occurred within the 10-wk postoperative period were included in this study. Complications were classified as minor or major based on previously published recommendations.19 Major complications were those that required treatment with a second surgical procedure, whereas minor complications resolved without additional surgery or extended medical care.

**Statistical Analysis**

All statistical analyses were performed using statistical software1. Statistical summaries of the continuous variables such as age, body weight, PTA, and healing scores included the mean, standard deviation (SD), and a 95% confidence interval (CI) for the mean. Patellar tendon angle measurements for individuals were compared between time 0 and 6 wk postoperatively, and measurements between time 0 and 10 wk postoperatively were analyzed using paired t tests. A Wilcoxon signed-rank test (nonparametric) was used in place of the paired t test for any cases in which the underlying assumptions were not met for these tests. Two-sample t tests were used to compare the means of the various variables for patients with and without broken wings. A nonparametric Mann-Whitney-Wilcoxon test was used for comparison for cases in which the assumptions required for t test validity were not met. Categorical variables (complication presence) were summarized using percentages, with 95% CIs. Comparing percentage measurements between groups was done using a Fisher exact test for a two-by-two contingency table. Significance was set at P < .05 for all testing.

**Results**

**Patient Data**

Twenty-six client-owned dogs who were treated for unilateral CrCL disease with a TTA between November 2011 and March 2013 met the study inclusion criteria. Patient age ranged from 1 to 10 yr (mean, 6.2 yr), and mean weight was 32.8 kg (18.7–48.1 kg). The study included 8 (31%) male (7 neutered, 1 intact) and 18 (69%) female (17 spayed, 1 intact) dogs. Breeds included 9 Labrador retrievers (35%), 7 golden retrievers (27%), and the remaining 10 dogs (39%) were other medium-to-large breeds and mixed breeds. Seventeen (65%) stifles received a 9-mm cage, and the remaining 9 (35%) received a 12-mm cage.

**Re-Evaluation**

All patients were re-evaluated by physical examination and a lateral stifle radiograph at 6 wk and 10 wk postoperatively. The mean time to the 6- and 10-wk re-evaluations was 42 and 77 days, respectively.
Healing Scores
All 6- and 10-wk postoperative radiographs were scored for osteotomy healing. The median osteotomy healing score was 2 (mean, 2.3; range, 0–4) at 6 wk and 3 (mean, 3.0, range, 1–4) at 10 wk following surgery (Table 1). The mean healing scores were an average of 0.7 points higher at 10 wk compared with 6 wk postoperatively, which was statistically significant ($P = .002$).

Patellar Tendon Angle
All postoperative radiographs at the 0-, 6-, and 10-wk time points were measured to determine PTAs (Table 2). Time 0 PTAs ranged from 86–101$^\circ$ (mean, 92.5$^\circ$; SD, 3.6; 95% CI, 91.1–93.9$^\circ$); at 6 wk after surgery, PTAs ranged from 83–104$^\circ$ (mean, 92.5$^\circ$; SD, 5.2; 95% CI, 91.2–93.8$^\circ$); at 10 wk after surgery, PTAs ranged from 84–104$^\circ$ (mean, 94.3$^\circ$; SD, 6.1; 95% CI, 92.0–96.6$^\circ$). The time 0- and 6-wk PTAs were not significantly different (mean, 0.6$^\circ$; SD, 6.0$^\circ$; 95% CI, −1.0$^\circ$–2.1$^\circ$ [P = .48]). The PTAs between time 0 and 10-wk (mean change, 2.0$^\circ$; SD, 7.6$^\circ$; 95% CI, −0.9$^\circ$–4.0$^\circ$) were not significantly different ($P = .18$). Lastly, there was no significant change in PTA measurements over time in dogs that developed broken cage wings (mean, 1.7$^\circ$) compared with those whose wings remained intact (mean, 2.0$^\circ$) from 0 to 6 wk ($P = .91$), nor from 0 to 10 wk after surgery (broken wings: mean, 4.8$^\circ$; intact wings: mean, 1.2$^\circ$ [P = .32]).

Complications
Of the 26 stifles in this study, 10 developed complications (38%; 95% CI, 0.19–0.61) with a mean time following surgery of 33 days. All complications occurred between the immediate and the 6-wk postoperative radiographs, with the exception of one major complication that occurred at 9 wk following surgery. Four dogs developed more than one complication; therefore, there were a total of 14 complications recorded. Twelve of the complications (86%) were classified as minor and two (14%) were major. Minor complications included broken wings (6/26 [23%]; Figure 4), seroma formation (4/26 [15%]), a broken plate (1/30 [3%]), and an acute onset of nonspecific lameness (1/26 [4%]), which resolved with medical treatment. The broken plate was considered a minor complication because this dog did not require any additional treatment, and both the 6-wk and 10-wk postoperative radiographs revealed progressive healing and minimal change in PTA (Figures 5A, B). Five of the six dogs who developed broken wings did not require any specific intervention and were discovered on planned postoperative radiographs. The remaining patient with broken wings went on to develop a major complication in the form of a broken plate, which led to loss of internal fixation stability and subsequent marked cranio-proximal displacement of the tuberosity (Figure 6). Revision surgery with a metallic cage was required to correct the complication. The other major complication was an implant infection caused by self-mutilation of the incision 16 days after surgery. A methicillin-resistant *Staphylococcus pseudintermedius* was cultured and ultimately all metal implants (plate, screws, and wings), but not PGA cage, required removal for infection resolution. All dogs who developed complications ultimately were deemed to have satisfactory outcomes.

Discussion
We report on the first use of a PGA TTA cage and found that although it provided similar osteotomy healing scores compared to previously reported metallic cages, and maintained PTA over time, it produced a high rate of complications. Polyglycolic acid was selected for this study over other polymers because of its strength, well-documented biologic compatibility, and projected degradation period of 6–12 mo. This degradation period was hoped to provide sufficient support of the osteotomy site while offering the benefit of complete absorption once the healing process was complete.

The mean 6- and 10-wk healing scores of 2.3 and 3.0 in this study compare favorably with those previously reported using the same TTA plate design but with SS cages, with mean healing scores in that study of 2.3 and 3.0 at 6 and 10 wk, respectively. When mean values were analyzed separately, PGA patients who developed broken wings actually had a slightly higher mean 6-wk healing score (2.5) than PGA patients without broken wings (2.3; $P = .33$). The mean healing score at 10 wk for patients with broken wings was also higher (3.2) than patients with intact wings (3.0; $P = .75$), suggesting that broken cage wings did not delay healing.

A basic assumption of the TTA technique is that stable internal fixation of the advanced tibial tuberosity by technique-specific implants will maintain the immediate postoperative PTA at approximately 90$^\circ$ until the osteotomy gap has healed. However, we are unaware of any previous studies that have compared immediate postoperative PTAs with those weeks after TTA surgery. The results
of this study revealed that the use of a PGA cage resulted in a PTA that was well maintained from 0 to 6 wk (mean, 1.7°), and 0 to 10 wk (mean, 2.0°) following surgery. Interestingly, when evaluated separately, presumed partial loss of internal stabilization (broken wings) had no adverse effect on 6-wk PTA maintenance (mean, 0.8°) as compared with angles when wings remained intact (mean, 2.0°; P = .56). Although the mean change in 10-wk PTA was greater for the broken-wing patients (4.8°) compared with intact cage wings (1.2°), it was not statistically significant (P = .32). Although we did not specifically evaluate the clinical impact that a change in PTA over time might have, the small changes reported are unlikely to be of any significance given that PTAs of 90° ± 9° have been shown to effectively neutralize cranial tibial thrust in vitro.20 Additionally, differing postoperative TPAs are reported to have no significant impact on ground reaction forces produced by dogs following tibial plateau leveling osteotomy surgery, and both tibial plateau leveling osteotomies and TTAs limit tibiofemoral shear by producing PTAs of 90°.21,22 However, the impact these minor changes in PTA could have on the incidence of postoperative meniscal tears is unknown but should be considered.

The overall patient complication rate was 38%; however, if the total number of complications (14) are evaluated, the rate would be 54%. These numbers are higher than those previously reported using metallic TTA cages (11–31.5%).5,9,10,23,24 Broken cage wings was the

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*Stifles with broken wings.
†Stifle with broken wings and a broken plate without revision surgery.
PTA, patellar tendon angles.
most common complication encountered and appears to be a direct consequence of the PGA cage use, given that it has not been reported previously as a single complication when using metallic cages. Presumably, differences in the cage material properties and/or the PGA implant design were primarily responsible for these complications. The majority of the complications were minor, and were discovered incidentally on the 6-wk recheck radiographs, which revealed no or minimal change in PTA, and progressive osteotomy healing. Additionally, these cases were without associated abnormal physical exam findings, nor a postoperative history suggesting clinical impact and were allowed to follow the same recovery plan as those dogs who did not experience any complications. The precise reasons for the wing and plate failures is not known, but implicating the PGA cage is logical. Some potential contributing factors to cage-related failures could include a more rapid than expected in vivo degradation of the PGA cage, stress risers generated between the metallic wings and PGA, and the fixed nature of the imbedded metallic wings, which contrasts with the more rotationally mobile wings in SS cages. Failure of the cage support could have led to excessive concentration of bending forces on the TTA plate and subsequent breakage. One of these dogs surprisingly did not require revision surgery to have a satisfactory outcome despite the implant failure. This dog was presented 39 days following surgery for a scheduled routine recheck examination and had physical examination findings that were within acceptable limits for the stage of recovery. Additionally, 6- and 10-wk radiographs revealed minimal proximal patella displacement, consistent maintenance of the PTA, and progressive osteotomy healing. The second dog experienced catastrophic implant failure at 9 wk following surgery, which resulted in marked loss of TTA reduction and required additional surgery to remedy (Figure 6). Revision surgery with all SS TTA implants provided a successful outcome. This complication occurred after the study was closed to new patients. The authors have questioned whether osteotomy grafting could have reduced the chances of implant failure by promoting faster gap healing. Although previous studies have reported the minimal to complete lack of benefit autogenous cancellous bone grafting has on TTA healing and complications rates, those procedures were all performed with metallic cages.\textsuperscript{9,25,26} Perhaps grafting would play a more important role in osteotomy gap healing when an absorbable cage implant is used versus a permanent metallic one. Further studies are required to evaluate this consideration. The other major complication was a deep surgical site infection that followed self-mutilation of the incision. Removal of all metal implants approximately 9 wk following surgery and tailored antibiotic therapy were required for resolution. The PGA cage likely played little role in the infection because it ultimately resolved despite the PGA block remaining in situ. The inability of bacteria to persist on a material that ultimately resorbs completely is one of the proposed advantages of absorbable versus permanent implants.\textsuperscript{27}

Our study has some limitations. Although a published scoring system for healing scores exists, there is still an inherent subjectivity for both healing score determination and measurement of PTA. To improve the consistency and eliminate interobserver variability for these measurements, we used a single, board-certified radiologist (A.T.W.) for all radiographic evaluations, who was blinded to patient parameters and postoperative time frames. Additionally, this is the first report measuring PTA following a TTA over time. Although the TTA procedure assumes that stable metallic implants maintain the PTA during the healing period, this has not been specifically documented to our knowledge. Inclusion of a control group receiving metallic TTA cages prospectively evaluated alongside the PGA group would have strengthened this assumption. However, given the lack of significant PTA change over time using an absorbable PGA cage, the authors feel that it is unlikely that use of a metallic cage would allow for any such change. Lastly, although...
pre-trial in vitro degradation profile analysis and compressive strength for the PGA cages at various levels of degradation was determined, only the PGA block was evaluated. The testing of the cage in situ within a full TTA construct for both compression and cyclical evaluations may have better predicted our clinical observations compared with the compressive strength data derived from placing the PGA block between a fixed bearing block and the testing machine as dictated by standardized material testing methodology.16

The designation of complications as major (requiring revision surgery) and minor (no further surgery required) did leave room for anomalies; meaning that some problems could have been classified into one category or another based on their subjectively perceived clinical impact. For example, the patient whose broken wings led to the failure of the TTA plate could have been deemed a major complication by some standards. However, given our aforementioned observations and reliance on published recommendations, it was designated as a minor complication.19 Another limitation was the variation in patient positioning for postoperative and follow-up radiographs. Although true laterally positioned stifle radiographs were the goal, slight variations in positioning at the various time frames could have affected PTA and healing score measurements. Additionally, although the authors routinely obtain only a lateral radiograph for follow-up evaluation of TTA patients, it is possible that additional implant-related complications could have been discovered if an orthogonal view was also obtained.

FIGURE 5 (A) A routine 6-wk postoperative lateral radiograph of this stifle revealed broken wings and plate. Despite the partial loss of internal stabilization, the patellar tendon angle remained essentially unchanged (92°) and the dog did not require any specific treatment. (B) The 10-wk postoperative lateral radiograph of the same dog in A. This stifle received a healing score of 4 and had a change in patellar tendon angle of 8° (time 0 to 10 wk).
The results of this study were presented in poster format at the ACVS Surgical Summit in San Diego, California, October 2014. The authors thank the Securos Orthopedic Institute for supporting this study. Dr. Barnhart is a paid lecturer for Securos and receives royalties from the sale of some Securos products.

FOOTNOTES

a Polyglycolic acid cage; Securos, Fiskdale, Massachusetts
b Hydromorphone; West-Ward Pharmaceutical, Eatontown, New Jersey
c Midazolam; Hospira, Inc., Lake Forest, Illinois
d Acepromazine maleate; Vetone for MWI, Boise, Idaho
e Propofol; Abbott Laboratories, North Chicago, Illinois
f Isoflurane; Vetone for MWI, Boise, Idaho
g Cefazolin; West-Ward Pharmaceutical, Eatontown, New Jersey
h Morphine; West-Ward Pharmaceutical, Eatontown, New Jersey
i Bupivacaine; Hospira, Inc., Lake Forest, Illinois
j Cefalexin, 250 mg caps; West-Ward Pharmaceutical, Eatontown, New Jersey; Cefalexin, 500 mg caps; Alkem Laboratories, LTD, Mumbai, India
k Tramadol; Amneal Pharmaceutical, Bridgewater, New Jersey
l SAS version 9.4; SAS Institute, Cary, North Carolina

REFERENCES


14. Tepic S. Cranial tibial tuberosity advancement (TTA) for the cruciate deficient stifle. Proceedings from the 2nd World Orthopedic Veterinary Congress/33rd Veterinary Orthopedic Society Meeting; 2006; Keystone, CO. p. 44.


17. Tepic S. Principles and execution of tibial tuberosity advancement. Kyon Symposium; April 18–19, 2008; Technopark, Zurich, Switzerland.


