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Centerline canine cementless total hip arthroplasty as an alternative implant system; results in 17 dogs (2015–2020)

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OBJECTIVE
To evaluate the clinical outcomes associated with the Biomedtrix Centerline canine cementless total hip arthroplasty implant (C-THA).

ANIMALS
17 dogs (20 hips) surgically implanted with C-THA to treat coxofemoral pathology.

CLINICAL PRESENTATION AND PROCEDURES
Dogs with C-THA (2015 through 2020) with follow-up of ≥ 6 months were evaluated. Data included signalment, complications, management of complications, radiographs (bone implant interface), and clinical outcomes. Outcomes were assessed radiographically and subjectively via surgeon orthopedic examinations.

RESULTS
15 of 20 (75%) with long term radiographic follow-up had an excellent outcome. 5 hips (25%) had postoperative complications: femoral neck fracture (n = 1; 5%), aseptic loosening (2; 10%), and septic loosening (2; 10%).

CLINICAL RELEVANCE
C-THA can restore function in dogs with coxofemoral pathology. This novel procedure showed outcomes comparable to initial reports of other traditional THA implants (cemented, cementless, and hybrid) but complications occurred at a higher rate than recent outcomes of other long-standing THA procedures. Increased case numbers and surgeon experience with this novel implant system may eventually yield results comparable to other accepted THA systems.

Introduction

Canine Hip Dysplasia (CHD) is the most common inherited orthopedic coxofemoral disease with a reported prevalence in 19.7% of purebred dogs and 17.7% of mixed breed dogs.[1] Loss of function and pain associated with the coxofemoral joint is the most common reason for total hip arthroplasty (THA).[2] THA has been used as a treatment for a variety of coxofemoral pathologies, including osteoarthritis (OA), congenital and traumatic hip luxation, proximal femoral head and neck fractures, proximal femoral tumor excision, and CHD.[3] CHD and associated OA are commonly diagnosed on physical exam in addition to ventrodorsal hip-extended radiographs. Additional radiographic techniques can be utilized to add diagnostic information regarding hip laxity and overall conformation.[4] CHD is commonly managed conservatively via weight loss, activity modification, physical therapy, anti-inflammatory medications and/or supplements.[5,6] For patients that fail conservative management or have severe disease affecting quality of life, surgical intervention with either femoral head and neck excision (FHNE) or THA is recommended. FHNE has incurred inconsistent results regarding outcomes following the procedure.[7–9] THA has become the gold standard with upwards of a 95% success rate.[2,10–12]

Currently, there are 2 main categories of THA: cemented and cementless, with a hybrid combination available. Reported complications of all THA systems include infection, septic and aseptic implant loosening, coxofemoral luxation, femoral fracture, femoral implant subsidence, femoral medullary infarction, pulmonary embolism, metallosis, and sciatic neurapraxia. Complication rates range from 5% to 30% depending on the THA system employed and duration of study follow-up.[2,12–21] Femoral fracture, which can be created during the reaming process of the femoral canal is a risk factor/complication of both cemented and cementless THA with a reported incidence of 2.9%.[22] Aseptic loosening is another possible complication that can occur with THA.[23] Finally, a complication of cementless THA includes subsidence which is the settling or distal migration of the femoral component with respect to surrounding bone.[24,25]

The Centerline THA (C-THA; Biomedtrix) system **(Figure 1)** is a cementless system that was

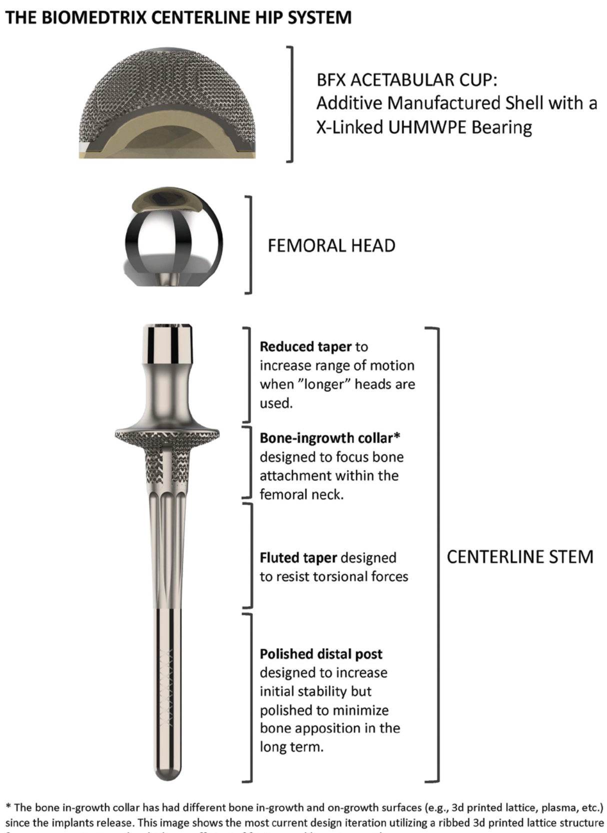

Figure 1—Illustration of the components of the Biomedtrix Centerline total hip arthroplasty (THA) system. UHMWPE = Ultrahigh-molecular-weight polyethylene.

initially developed to specifically treat dogs with proximal femoral deformities, where access to the femoral medullary canal for reaming associated with traditional THA was not possible.[26] While most THA systems create a coxofemoral angle around of 135 degrees, the C-THA replicates the angle of the femoral neck (144.7 degrees)[27,28] The C-THA has been shown to be biomechanically stiffer than comparative THA procedures in an ex-vivo study. Within this study, the C-THA showed significantly greater compressive stiffness and less displacement at peak load compared to the collared, collarless and lateral bolt THA (Biomedtrix) systems. Also, the C-THA had a significantly higher torque when compared to a collarless THA.[29] To the best of the authors' knowledge, there has been no report of the long-term clinical results and complications associated with the C-THA system in a clinical series. The objective of this study was to evaluate the long-term clinical and radiographic outcome associated with the C-THA implant in a population of client owned dogs that would be candidates for traditional THA. Our hypothesis was that the C-THA would have similar clinical outcomes as traditional THA systems, while avoiding complications such as subsidence and femoral fracture.

Materials and Methods

Inclusion criteria

Dogs free of all other orthopedic/neurologic disease that received a C-THA and had complete medical records (including preoperative and postoperative radiographs as well as at least a 6-month follow-up) were included in this study. Records of C-THA procedures performed at a single veterinary referral hospital and performed by a single board-certified surgeon (DS) during the years 2015 through 2020 were included. Dogs aged 5 years and younger with radiographic diagnoses of CHD were included. Client consent to perform the procedure and utilize medical records was obtained in all cases. Institutional care and use committee review was not required for the purposes of this study.

Medical record

Data from the medical records (using the term "centerline" to identify cases) including age, weight, sex, indication for THA, side of hip replacement, acetabular cup size, stem size, femoral neck length, and femoral head prosthesis size, were obtained in all cases **(Supplementary Table S1)**. Range of follow-up from time of surgery to final follow-up date was recorded for all cases. Lameness score, signs of pain on palpation, and range-of-motion of the coxofemoral joint were recorded form orthopedic examination of the THA limb for each dog. Complications, revision/explantation surgical procedure, date of procedure, and outcome were also recorded.

Clinical evaluation

Possible outcomes included excellent, good, and poor modified from Guerrero et al.[2] This grading scale and clinical outcome were determined by the attending board certified surgeon, as well as the need for revision surgery if warranted. An excellent outcome was defined as no overt lameness, pain, or decreased range of motion on physical exam, with no need for revision at final recheck examination (a minimum of 6 months post-operative). A good outcome was defined as a post-operative lameness, pain, or decreased range of motion which required surgical revision of the C-THA. A fair outcome was defined as a post-operative lameness, pain, or decreased range of motion which required surgical revision with an alternative THA implant to provide resolution or mitigation of clinical signs. Finally, a poor outcome was defined as lameness, pain, or decreased range of motion post operatively requiring full explantation to provide resolution or mitigation of clinical signs. Post-operative complications limited to the stem component were defined as major if surgical revision was warranted and minor if the complication was managed medically.[30]

Subjective lameness score which was assessed and graded at the time of presentation for surgery and upon all subsequent follow-up exams. The lameness grading scores were modified from a study by Guerrero et al[2] but were modified as listed below. A 0 represented a poor score where pain was easily detected during manipulation, range of motion was severely reduced, or a constant non–weight-bearing lameness was noted. A 1 represented a fair score with moderate pain during manipulation of the hip joint, reduced range of motion, or intermittent to persistent lameness. A 2 represented a good score with no pain noted on manipulation of the coxofemoral joint, mild reduced range of motion (mainly in extension), and a clinically normal gait. Finally, a 3 represented an excellent score with no pain on manipulation of the coxofemoral joint, normal range of motion, and no clinically detectable lameness. All scorings were performed by board-certified veterinary surgeons or a veterinary resident supervised by board-certified surgeons prior to surgery and then evaluated at each recheck. The final score was then compared to initial scores.

Radiographic measurements

All radiographs were digital and were adjusted for magnification using a 100 mm calibration marker. Pre-operative and post-operative radiographs were performed on all cases at all time points. All preoperative measurements were performed by the investigator (DS) using Biomedtrix centerline templates and BFX acetabular cup templates.[26] The normal or natural angle of inclination in the canine proximal femur intersects the axis of the femoral neck at approximately 144.7 degrees.[27] The proximal femoral long axis was determined by first identifying the center of the proximal femoral diaphysis at 3 points distal to the lesser trochanter, approximately 1 cm apart. The line connecting these points was drawn, defining the proximal femoral long axis.[31] The center of the femoral neck was determined by identifying a single point at the center of the femoral head. A line connecting this point and the fovea capitis was created and then extended laterally until it exited the lateral cortex of the proximal femur **(Figure 2)**.[27] The distance from the proximal, lateral aspect of the greater trochanter to where the line scribed through the center of the femoral neck is then measured. This point serves as a landmark for insertion of the drill guide at surgery and where the C-THA stem should exit the lateral cortex of the femur (Figure 2).[26]

Radiographic evaluation

Radiographs at all time points were evaluated and compared with immediate postoperative films and were calibrated with reference bars or spheres placed at the level of the region of interest. All radiographs were reviewed by a board-certified veterinary surgeon and radiologist, who were not blinded to the patient, for signs of loosening, infection, subsidence, fracture, and luxation. At least 2 radiographic projections of each C-THA were available.

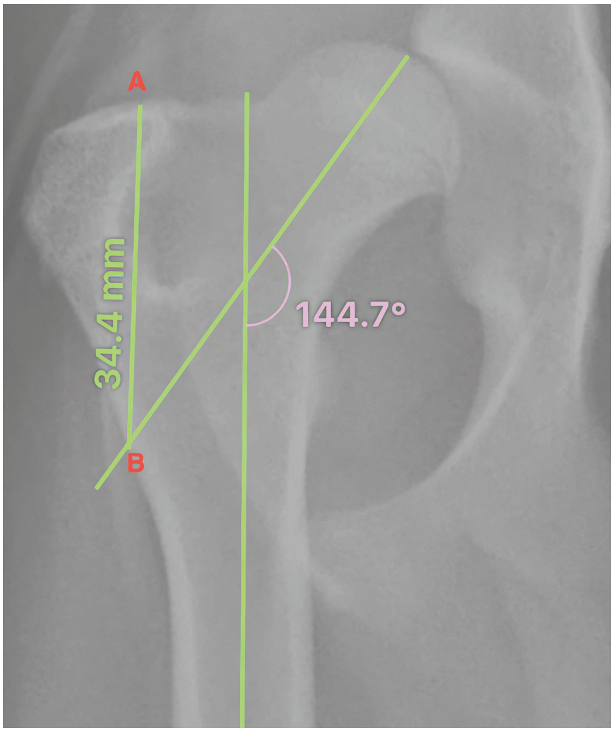

Figure 2—Measurement for lateral exit and angle of inclination. The proximal femoral long axis and the center of the femoral neck lines were created as described above. The bisecting line of the anatomic axis of the femur and the angle of inclination create a 144.7°angle. The lateral exit point (B) for the Centerline THA is then measured from this point proximally to the proximal aspect of the greater trochanter (A).

Radiographs were assessed for signs of implant failure, migration, prosthesis luxation, signs of bone remodeling secondary to nondetected bone fractures or infection, and for radiolucent zones between the implant and bone. Acetabular component/prosthesis loosening or instability was defined as the presence of a complete uneven radiolucent zone around the metallic components with or without signs of implant migration. Stem stability was defined by bone remodeling around the femoral component and was characterized according to the definitions proposed in a study by DeYoung and Schiller.[32] These features included absence of cortical atrophy at the proximomedial aspect of the femur, cancellous hypertrophy, periosteal proliferation, absence of lucency around the stem or any other focus of extracortical new bone formation **(Figure 3)**. Stem instability was characterized by the presence of a radiolucent zone around the prothesis and the bone; in addition to a progressive increase in the gap between stem and bone as well as loss of proximal medial bone **(Figure 4)**.[12,13,17]

Surgical technique

All patients were anesthetized and placed in lateral recumbency **(Figure 5)**. After shaving and

Figure 3—Radiographic evidence of bone in-growth and stable implants as indicated by absence of lucency around the implants and bone growth over the collar of the implant.

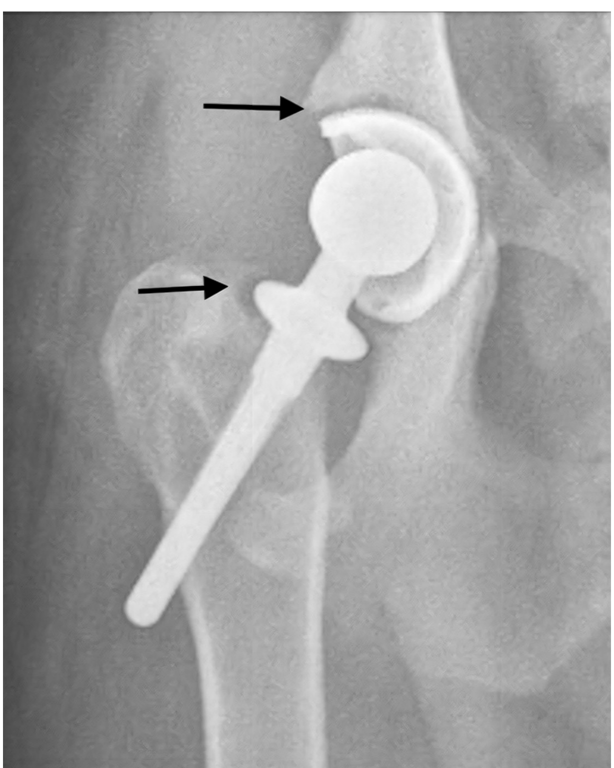

Figure 4—Bone lucency around both the acetabular cup and the proximal portion of the femoral neck surrounding the stem component, indicating unstable implants.

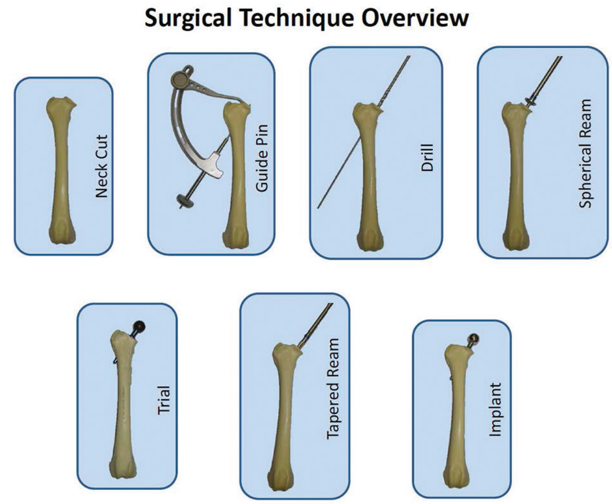

Figure 5—Overview of surgical technique showing step-by-step method of procedure. Figure courtesy of Biomedtrix.

sterile preparation, a standard lateral approach to the hip joint via partial tenotomy of the deep gluteal tendon was performed.[33] The femoral head was exteriorized and a femoral head ostectomy was performed using a sagittal saw. The femoral head ostectomy was performed at the junction of the femoral head and neck, preserving the entire femoral neck, along a line perpendicular to the long axis of the femoral neck. Any osteophytes along the femoral neck were removed with rongeurs to allow for better visualization of the true center of the femoral neck for proper prosthesis placement.

The acetabulum was reamed and the acetabular prosthesis was placed in routine fashion using a traditional BFX acetabular cup system.[26] A point was measured from the greater trochanter distally along the lateral aspect of the femur. This point was obtained from preoperative radiographs as stated previously and is typically located at the level of the third trochanter. A small pilot hole was made at this point with a K-wire and the drill guide's point was placed within this hole. The cannulated portion of the drill guide was then engaged into the center of the cut surface of the femoral head/neck between the inner surfaces of the neck cortices. A 3/32-inch pin was placed from proximal to distal. The drill guide was removed, and a cannulated drill bit was placed over the pin and a hole was drilled from the cut surface of the femoral neck out through the lateral cortex. In each case, the drill bit and reamer sizes used corresponded to the size of C-THA stem templated on preoperative radiographs. Next, the spherical reamer was placed in the drill hole and the femoral neck was reamed appropriately for proper fit of the C-THA stem.

At this point, trial stems were placed to allow for approximately 5 mm of the stem to beyond the lateral cortex. Once a trial stem was selected, a trial head was placed. Trial reductions were then performed ensure tension, reduction and absence of impingement of the implant stem and the acetabulum. All trial implants were removed, and a tapered reamer was inserted through the prepared hole in the femoral neck. The depth at which the tapered reamer was applied varied in each case based on the quality and integrity of the cancellous bone, such to ensure a drive distance of between 8 to 10 mm for the press fit centerline stem. The appropriately sized determined from preoperative templating was then inserted and impacted into the femoral neck, followed by the appropriately sized head impacted onto the stem. Cultures were obtained and the surgical area was irrigated. The joint capsule was closed using an interrupted suture pattern. The overlying tissues were closed routinely. Postoperative lateral, open leg lateral and ventrodorsal radiographs were taken for assessment of prosthesis placement.

Statistical analysis

Microsoft Excel was used to record all case data. Descriptive statistics were computed and analyzed to determine age, weight, and follow up times with medians and ranges being evaluated. Lameness scores were calculated as the difference from preoperative score to final follow-up scores.

Results

Animals

Seventeen dogs had a C-THA (3 dogs had bilateral C-THA at different time intervals) for a total of 20 C-THA implanted hips. C-THA was performed for hip dysplasia in all 20 cases. The median age was 1.45 years old (range, 1 to 5 years). The median body weight of dogs in this study was 34.25 kg (range, 23.6 to 50.3 kg). The median final follow-up was 621.5 days (range, 183 to 2,350 days).

Complications

No minor complications were noted within this study. Five (25%) cases had major complications associated with the C-THA as described below. Complications occurred between 16 and 870 days postoperatively with a median of 520 days post-operative. Three of the 5 major complications occurred in dogs with bilateral THA. One dog had a major complication associated with both hips and the second with a single side.

Outcomes

Out of the 20 C-THA implants placed in 17 dogs, 15 implants had an excellent outcome (75%). All 15 implants with excellent outcomes achieved radiographic evidence of osteointegration of both cup and stem at 12 weeks postoperatively. The median increase in lameness scores from pre-operative to final recheck was 3 (range, 0 to 3) during a period of 183 to 2,350 days.

The 2 fair outcomes, 1 patient (2 protheses), required revision with bilateral Biomedtrix BFX THA due to aseptic loosening. Three out of the 20 (15%) C-THA implants had poor outcomes. Two patients acquired postoperative luxations and following revision surgery developed septic loosening of the implants resulting explantation and FHNE. The final patient with a poor outcome was the result of eccentric drilling of the femoral neck. This resulted in the implant fracturing through the caudomedial cortex of the femoral neck 2 weeks postoperatively necessitating explantation and FHNE.

Discussion

The goal of this descriptive case series was to evaluate the long-term clinical outcomes associated with the C-THA implant in dogs. Twenty C-THA procedures were performed in 17 dogs. Overall, a good to excellent outcome was noted in 17 of 20 implants (85%). A good outcome was given to a patient who required revision surgery of the implant or conversion to a traditional THA. The need for revision surgery was still graded as good to show the versatility of the C-THA implant system as it allows for ease of conversion to a traditional THA system if needed.[2]

All 5 complications occurred in the first 10 cases of this current study. In a study by Hayes et al[18] it was noted that proficiency was achieved after performing 44 total hip arthroplasty procedures with a cemented system. Although the primary surgeon had performed at least this number of THA's prior to undertaking a new implant prosthesis, a total number of 44 cases was never achieved with the C-THA. As the primary surgeon's experience progressed; the incidence of complications decreased. A future study to help determine the number of procedures required to achieve proficiency with this procedure specifically would be advantageous.

Rashmir-Raven et al[25] reported a strong relationship between mean, middle, and distal percentages of canal fill and the force required for implant subsidence in the cadaveric specimens. Their study's results supported the hypothesis that implants with a higher percentage of canal fill are less likely to subside than implants with a lower percentage of canal fill.[25] As the lateral potion of C-THA stem exits the lateral cortical femur in the region of the third trochanter, it is never reliant on the inner cortices to prevent subsidence. A recent study to evaluate the biomechanical advantages of THA procedures by Ordway et al[29] showed that with a short stem design, ultimate failures occurred at 6 to 7 times of a normal simulated gait load. In addition, the C-THA showed significantly greater compressive stiffness and less displacement at peak load in comparison to the lateral bolt, collarless and collared THA systems.

Historic complication rates for THA are underreported due to the short to medium-term times follow-up associated with most studies. Complication rates with traditional cementless and short-stem designs range from 5% to > 30% depending on the study.[2,12–21] This cohort revealed a similar complication rate to other short-stem design that range from 27% to 39%.[12,19] A study by Denny et al[12] showed a 20% rate of aseptic loosening of the implant, which was thought to be secondary to a lack of osteointegration onto the implant. The C-THA is designed to help prevent stress shielding of the proximal calcar region by allowing for small amounts of micromotion at the lateral cortex **(Figure 6)**. If correctly per-

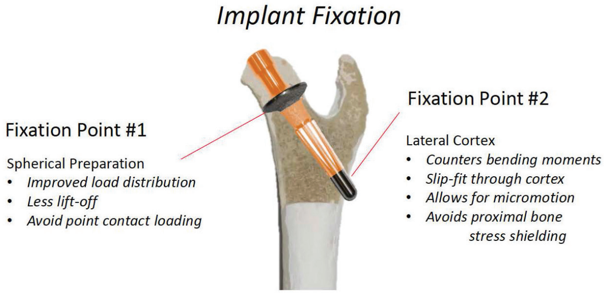

Figure 6—Design concept showing placement of Centerline THA within the proximal femur. Figure courtesy of Biomedtrix.

formed the C-THA should only extend 5 mm beyond the lateral cortex of the femur. This lateral opening counters any bending moments associated with the C-THA stem and was not shown to be associated with any pain, impaired mobility or seroma formation within this case series.

Septic loosening is a known complication related to any procedure that involves placement of implants.[10,14,15,20] This is considered a severe complication with a poor prognosis, as all implants that develop septic loosening will likely require explantation. Duration of surgical procedure length of over 90 minutes has previously been described as a risk factor for septic loosening.[34] Duration of surgical procedures were not evaluated in our study, but the 2 cases that developed septic loosening were both dogs that had undergone secondary revision surgeries following luxations. Guthrie et al[35] reported that antibiotic impregnated beads placed in a single-stage revision of a known septic loosening resulted in a good outcome 5 years post-operatively. As a result, considering placement of antibiotic beads for prolonged procedures or during revision surgeries may help to decrease the amount of septic loosening noted in future procedures.

As reported by Skurla et al,[36] aseptic loosening of cemented THAs was documented in 63.2% of dogs on post-mortem exam. Previously published studies report a rate of aseptic loosening from 0% to 11%.[2,10,37] Aseptic loosening is thought by some to be the most common long-term complication of cemented-THA.[38] Within our study, this occurred to 2 of 20 (10%) of the THAs in this study. This may be secondary to the extended follow-up as both occurred 302 or more days after implantation. In humans, it has been reported that infections related to THA contain a variety of colony variants and conventional culture techniques frequently do not detect the specific causative organism, therefore infected implants may have been missed.[38]

One limitation of the study is its retrospective nature. The retrospective design introduced a lack of uniformity in timing of follow-up orthopedic and radiographic examinations. Most outcomes were subjective in nature and were not standardized given the retrospective nature of this study. More traditional measurements such as Liverpool Osteoarthritis in Dogs (LOAD) and The Canine Brief Pain Inventory (CBPI) were unavailable for the majority of patients. Future studies may benefit from objective measurements such as force plate analysis. Furthermore, there was no standard control to determine owner compliance and activity restrictions following patient discharge from hospital. In addition, there was no guarantee of owners returning for reevaluation when complications did occur and as a result, complications and poor outcomes may have been missed. The design of the C-THA is unable to correct for inherent femoral anteversion and therefore could have contributed to the 2 hip luxations in our series. Finally, the surgeon was not blinded when performing follow-up lameness and radiographic evaluations, which could have allowed for potential bias in outcome measures.

In conclusion, the C-THA provides a novel implant system for management of coxofemoral pain and osteoarthritis in dogs. The findings of this study support our assumption that no femoral body fractures or subsidence would be identified within this short case series. The short stem design of the implants and preservation of the femoral neck allow for conversion to traditional THA systems if complications do occur post-operatively. This study showed that the Centerline Total Hip Arthroplasty (C-THA) system had an overall excellent success rate of 75% (15 out of 20). A complication rate of 25% (5/20) is within previously reported rates of traditional THA systems which range between 5% and >30%.[2,10–15,26–28] However, it is significantly higher than more recent reported outcomes in a large case series of cemented, cementless and hybrid systems.[39] All complications occurred within the first 10 procedure in this short case series. An increase in surgeon experience with this novel implant system should help to reduce technical surgical errors resulting in better outcomes and consequently reduced rate of complications.

Acknowledgments

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Supplementary Materials

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