Total hip arthroplasty outcomes assessment using functional and radiographic scores to compare canine systems

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Summary
A retrospective multi-centre study was carried out in order to compare outcomes between cemented and uncemented total hip arthroplasties (THA). A quantitative orthopaedic outcome assessment scoring system was devised in order to relate functional outcome to a numerical score, to allow comparison between treatments and amongst centres. The system combined a radiographic score and a clinical score. Lower scores reflect better outcomes than higher scores. Consecutive cases of THA were included from two specialist practices between July 2002 and December 2005. The study included 46 THA patients (22 uncemented THA followed for 8.3 ± 4.7M and 24 cemented THA for 26.0 ± 15.7M) with a mean age of 4.4 ± 3.3 years at surgery. Multivariable linear and logistical regression analyses were performed with adjustments for age at surgery, surgeon, follow-up time, uni- versus bilateral disease, gender and body weight. The differences between treatment groups in terms of functional scores or total scores were not significant (p > 0.05). Radiographic scores were different between treatment groups. However, these scores were usually assessed within two months of surgery and proved unreliable predictors of functional outcome (p > 0.05). The findings reflect relatively short-term follow-up, especially for the uncemented group, and do not include clinician-derived measures, such as goniometry and thigh circumference. Longer-term follow-up for the radiographic assessments is essential. A prospective study including the clinician-derived outcomes needs to be performed in order to validate the outcome instrument in its modified form.

Keywords
Hip, arthroplasty, canine, outcome assessment

Introduction

Total hip arthroplasty (THA) is a successful surgical treatment for debilitating conditions of the coxofemoral joint, providing excellent hip joint function in 80% to 98% of canine THA patients (1–5). THA is indicated for the treatment of painful conditions of the coxofemoral joint, such as osteoarthritis, chronic or irreducible coxofemoral luxations, irreparable fractures or malunion of the femoral head/neck and/or acetabulum, avascular necrosis of the femoral head and failed excisional arthroplasties (1–3, 5–18). Contraindications for THA in canine patients include: concurrent neurological or orthopaedic disease affecting the pelvic limbs, or recurrent infectious disease, or any combination of these problems.

Human THA was revolutionized in the 1950s by Sir John Charnley with the introduction of polymethylmethacrylate (PMMA) and the high-density polyethylene acetabular component to produce a stable, low-friction cemented THA (19, 29). PMMA was applied in order to improve early stability and to evenly distribute forces across the prosthesis/bone interface (16, 21, 22). Although THA has proved to be successful in most patients, periprosthetic osteolysis and late implant loosening remain problematic. Aseptic loosening was originally thought to be associated with PMMA debris, and the process was termed cement disease (5, 6, 23–28). In order to address this perceived problem, cementless (synonymous with uncemented) THA fixation was developed to avoid the use of bone cement, however, aseptic loosening continued despite removing PMMA from the periprosthetic environment (29, 30).

Subsequent studies identified sub-micron-sized wear particles of polyethylene that are liberated into the periprosthetic environment as being a major contributor to the periprosthetic osteolysis leading to aseptic loosening (29–37). Metal corrosion and debris, as well as PMMA debris in particular form, may also contribute to osteolysis. Particulate disease occurs when sub-micron-sized particles of polymer and/or metals (that are resistant to enzymatic degradation) enter the effective joint space (the periprosthetic regions accessible to joint fluid and thus to particulate debris [31]) to progressively activate macrophages by phagocytosis. The process involves not only the release of enzymes that may destroy surrounding bone directly, but cytokines that induce osteoclastic activity leading to bone loss causing loosening of the implant from its surrounding bone bed (30, 38).

Currently, the canine specific THA implants most commonly used in Australia are the cemented fixation (CFX, BioMedtrix Ltd., Allendale, NJ, USA) and uncemented biological fixation (BFX, BioMedtrix Ltd., Allendale, NJ, USA) systems. Cemented fixation relies on a mantle of PMMA bone cement acting as a grout between the bone and implant (Fig. 1). The CFX system yields immediate prosthesis fixation as well as providing a consistent fit regardless of femoral size, femoral curvature or accuracy of bone bed preparation (39). However failure of the cement mantle may contribute to
aseptic loosening. The PMMA debris may also migrate between the low-friction polyethylene cup and the femoral head, leading to abrasions and production of polyethylene particles in a process called third-body wear (23, 32, 40–42). Cemented THA results are excellent in the short-term but decrease over time (43); rates of loosening reported in the human literature are approximately 1% for each year post surgery.

Uncemented arthroplasties rely on osseous and/or fibrous tissue ingrowth in order to achieve fixation (44). Bony ingrowth provides a mechanical barrier to wear debris in the implant-bone interface, reducing the extent of the effective joint space (31), potentially reducing the exposure of peri-prosthetic tissue to the osteolytic debris particles. Early subsidence of the femoral component may occur due to inadequate initial stability or with unrestricted early weight bearing before osseous integration has occurred. Subsidence is more likely in straight femora that are lacking an isthmus (so-called ‘stove-pipe’ femora), and with femoral implants that are undersized with respect to the medullary canal or inserted without adequate preparation of the bone bed (45).

One of the initial canine uncemented THA systems used was the canine Porous Coated Anatomic system (PCA, Howmedica, Rutherford, NJ, USA) (7, 46–48) with anatomic stems that conformed closely to the geometry of the proximal femur (i.e. the stems specifically fit the left or right femora). The BFX system, introduced in 2003, was based on the PCA system. However in the BFX system, the anatomic stem was replaced by a symmetric design that could be fitted to either the left or right femur, eliminating the need to stock side-specific implants (Fig. 2) (44).

Surface wear of polyethylene is inevitable following metal-on-polyethylene THA. Wear of the acetabular cup produces approximately 500,000 particulates per gait cycle in humans assuming one million gait cycles per year (32). It has also been demonstrated in canine patients that implants of longer duration in-situ experience greater wear (40), thus increasing the particulate debris load and subsequent aseptic loosening risk over time. Until biomaterials with superior wear resistance replace the current polyethylene bearing surfaces, aseptic loosening is likely to remain the major cause of long term failure of THA implants in vivo, with reported rates of 2.1% to 7.2% in clinical canine THA patients (3, 6, 8, 9, 11, 18, 39, 46, 49, 50) and up to 63.2% in post-mortem retrieved THA implants (40, 51). The incidence of aseptic loosening in clinical patients may be expected to increase as longer follow-up studies emerge.

Other major complications of canine THA surgery include: luxations (occurring in 4–13% of implants, with the majority occurring within the first month), infection (0–11%) and femoral diaphyseal fractures (2–13%), whilst complications such as acetabular cup displacement, sciatic neuropraxia, patella luxation, extrasseous cement granuloma and pulmonary embolism are reported much less frequently, resulting in an overall complication rate of 6% to 30% for canine THA (5, 18, 42, 46, 49, 52–56). Revision surgery is undesirable due to the difficulties associated with removing failed components, cement or both, as well as the lack of bone stock available for the reinsertion of new implants. Subsequently, complication rates for revision arthroplasties are higher than for primary THA surgery (5, 6, 57, 58).

Although numerous studies have detailed the short- and long-term outcomes for case series of a particular THA, to the authors’ knowledge, there have not been any studies that directly compare functional outcome between cemented and uncemented THA in clinical canine patients (1, 2, 5, 9, 18, 46, 47, 59–63). The objective of our study was to devise and test a quantitative scoring system in order to enable outcome comparison between cemented and uncemented THA to guide the surgeon in clinical decision making. Due to the retrospective nature of this study, objective measures of function (such as limb girth and goniometry) could not be obtained. Patient function was assessed using a questionnaire based on the owners’ scoring of physical function and behaviour. Radiographic outcomes were also scored, with the combined scores contributing to an overall outcome score. There are currently canine orthopaedic outcomes assessment instruments that focus on patient pain but none that incorporate radiographic outcomes (64–69). We hypothesized that there would not be any significant difference in clinical outcome between CFX and BFX treated patients.
This hypothesis was tested by combining a clinical score with a client assessment score, to compare functional outcomes between the two treatment groups.

**Materials and methods**

This study used a novel scoring system conceptually based on the outcomes measured for human arthroplasty patients, including both radiographic and client-based assessment scores. A multi-centre retrospective study was conducted in order to compare the functional outcomes between cemented (CFX) and uncemented (BFX) methods of fixation for THA in canine patients. The study was conducted across four veterinary specialist centres in Australia. Two veterinary specialist practices performed the surgical procedures whilst two other specialist centres analysed the radiographs and conducted owner assessment questionnaires.

**Subject selection**

The medical records of all of the dogs that underwent primary THA surgeries (cemented or uncemented) between July 2002 and December 2005 were provided by two veterinary specialist practices. Two surgeons (TB and CP) from these two unrelated specialist practices performed either cemented or uncemented THA surgeries. The selection of prosthesis design was initially based on availability and later on femoral conformation. Dogs with ‘stove-pipe’ femora were implanted with a cemented stem in order to avoid subsidence of the femoral component (45). All consecutive THA cases for which follow-up information could be obtained were included. The follow-up data required for each subject were the availability of postoperative radiographs and contact with the owner for telephone interviews. The only exclusions were dogs that received hybrid systems, where a mixture of cemented and uncemented implants was used, as these cases could not be scored radiographically. This hybrid modification was required due to complications arising from femoral fracture propagation during surgery.

| Table 1 | Part I. Clinical assessment scoring scheme as performed by the clinician. Higher scores reflect poorer outcomes or function. Questions #8–11 were not included in this retrospective study. |

<table>
<thead>
<tr>
<th>Patient name</th>
<th>Assessmen date</th>
<th>Age</th>
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<tbody>
<tr>
<td>Age at surgery</td>
<td>Breed</td>
<td>Gender</td>
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<tr>
<td>Age at follow-up</td>
<td>Weight</td>
<td>Joint affected</td>
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| Radiographic assessment for 1-6 inclusive, other assessments 7-13 |
|---------------|---|---|---|---|---|
| 1 Canal fill of stem - Score by number based on percentage canal fill |
| 0 => >50%, 1 = 45-50%, 2 = 40-44%, 3 = 35-39%, 4 = <35 |
| 2 Cement mantle width - Cup and stem, 0 = complete white out to cortex, 1 = only small areas without white out, 2 = all of mantle greater than 2 mm, 3 = most more than 2 mm, 4 = most less than 2 mm |
| 3 Presence of radiolucent line around the acetabular component either cemented or uncemented. |
| 0 = none, 1 = <33% and < 2 mm wide, 2 = <33% and ≥ 2 mm, 3 = 33 and <2 mm wide, 4 = >33% and > 2 mm wide |
| 4 Cement porosity, 0 = no pores seen, 1 = 1 bubble, 2 = 2 bubbles, 3 = 3 bubbles, 4 = multiple porosities within the cement |
| 5 (i) Position of stem |
| 0 = neutral, 1 = antversion, 2 = varus, 3 = valgus, 4 = retroversion |
| (ii) Position of cup |
| 0 = slight retroversion and dorsal closure 40°, 1 = minor deviation from same, 2 = moderate deviation, 3 = severe deviation, 4 = extreme deviation |
| 6 Uncemented systems - subsidence, 0 = none noted, 1 = less than 2 mm, 2 = 2 to 3 mm, 3 = 3-4 mm, 4 = >4 mm |
| 7 Uncemented system |
| i) Endosteal reaction, 0 = trabecular pedestal complete, 1 = marked new endosteal bone, 2 = moderate endosteal reaction, 3 = scalloping near the tip, 4 = no immediate bone in the area of the tip |
| ii) Periosteal reaction |
| 0 = none, 1 = trivial, 2 = non trivial but not needing further surgery, 3 = fracture, dislocation, 4 = requires revision surgery |
| 8 Thigh circumference: 0 = same as opposite limb, 1 = within 2 mm, 2 = within 4 mm, 3 = within 6 mm, 4 = >6 mm difference between limbs |
| 9 Goniometry - Degree of flexion contracture: 0 = none to 4 = extreme restriction |
| 10 Goniometry of hip in adduction (as above) |
| 11 Pain on deep palpation of the hip area |
| 12 Early complications: 0 = none, 1 = trivial, 2 = non trivial but not needing further surgery, 3 = fracture, dislocation, 4 = requires revision surgery |
| 13 Late complications: 0 = none, 1 = mild lameness not requiring medications, 4 = required revision surgery |

**Total score for clinical assessment (out of possible 52 points)**
or in the immediate postoperative period during weight bearing.

Population data
A search of the medical record database produced 64 THA cases (56 dogs; eight bilateral THA) between July 2002 and December 2005 from the surgical specialist practices of two of the authors (TP and CP) who had performed the primary THA surgeries. All of the dogs suffered from debilitating osteoarthritis of one or both coxofemoral joints. Postoperative or follow-up radiographs were available for all of the dogs identified. Seven patients were lost to follow-up, resulting in a final 49 dogs with 57 primary THA (eight bilateral) that met the selection criteria for the study. Three of these subjects that had a hybrid THA, comprising a BFX cup with a CFX stem, were excluded. The final cohort analysed in this study included 46 patients (eight bilateral), with 22 patients in the BFX group and 24 patients in the CFX treatment group.

Outcome assessment
An orthopaedic outcome assessment scoring system (Tables 1 and 2) was modelled on the Western Ontario and McMaster University Osteoarthritis Scoring Index (WOMAC score) (64) in order to assign a numerical score to allow comparative analyses amongst centres as well as between treatment types in terms of functional outcome. The scoring system was designed such that a five point numeric score (from 0 to 4) was given for each question with lower scores having better outcomes than higher scores (score of 0 being normal, 1 = mild dysfunction, 2 = moderate, 3 = severe, 4 = extreme dysfunction). The scoring system consisted of two parts: (i) a clinical score (based upon various radiographic and clinical parameters) and (ii) a client score (based upon function as determined by owner questionnaire). The scoring system was designed to combine the two components so as to produce a total score out of a possible 100, however, due to the retrospective nature of our study, four questions relating to clinical function (goniometry, muscle mass, pain) were omitted resulting in a total score out of a possible 84, where a score of 0 would reflect the best possible clinical outcome and 84 the worst. To eliminate the confounding effects of bilateral THA, only the data from the most recent, primary THA were evaluated.

The clinical score (radiographic score) (Table 1: Clinical assessment)
The clinical component of the scoring system consisted of questions relating to radiographic outcome, range of motion, muscle mass and pain on palpation. The radiographs were assessed and scored based upon our scoring scheme by one author (GA). The radiographic assessment consisted of radiographic parameters that could be objectively assessed. There were nine radiographic questions in total. Six of the radiographic questions were common to both CFX and BFX (Q1, 3, 5(i), 5(ii), 12 and 13), while three additional questions of similar radiographic significance were specific to either CFX (Q2(i), 2(ii) and 4) or BFX (Q6, 7(i) and 7(ii)). Due to the retrospective nature of this study, the two questions relating to goniometry and muscle mass were not included, thus the clinical score in this study consisted of radiographic questions only. The total radiographic score was out of a possible 36 points and was derived from the sum of scores from each question.
Total hip arthroplasty outcome assessment

The client score (Table 2: Functional assessment)

The owners’ responses to a questionnaire that was conducted by telephone interview formed the second part of the instrument. Each owner was asked 12 questions relating to function, at varying time periods post-THA surgery. The telephone questionnaire was performed by a person who was not connected to the primary surgeon’s practice. The questions covered related to a range of activities, such as walking, running, jumping, climbing stairs, sitting position, pain and persistence of limping. The owners were asked to direct their answers to the dog’s condition at the time of the telephone questionnaire. The owners were reminded of the numeric scoring system and asked to assign a score (ranging from 0 to 4) for each question. Lower scores reflect better function than higher scores. The total owner-assessment score was out of 48 points. The radiographic and client scores were combined for a total outcomes score out of 84 points.

Statistical analyses

All statistical analyses were performed using commercial software (Stata Intercooled software, version 9.2, Statacorp LP, TX, USA). Multiple linear regression analyses were performed in order to observe differences between treatment groups for client score, radiographic score and total score data. Variables such as body weight, age at surgery, follow-up time (from surgery to client questionnaire), uni-lateral versus bilateral disease and the surgeon performing the procedure, were adjusted into every model of regression analysis performed. The outcome scores were analysed to identify patients with complications and to compare them to patients without complications.

The radiographic scores were compared to the functional outcome scores (client scores) by performing multiple linear regression analyses with client scores as the main outcome variable separately for each treatment group. The individual radiographic questions were also examined via linear regression to observe whether a particular radiographic parameter predicted functional outcome (client score). For radiographic questions where scoring increments appeared to be less continuous were categorized (namely radiographic questions 3, 4, 5, 7, 12 and 13). The radiographic questions were further analysed by dividing scores into either ‘normal’ to ‘mild’ (score of 0 or 1) or ‘moderate’ to ‘severe’ (score of 2 or higher) changes. The client questions were similarly analysed by categorizing scores into two different classes of responses according to the severity of clinical findings, into either ‘normal’ to ‘mild’ (scores of 0 or 1) or ‘moderate’ to ‘severe’ signs (scores of 2, 3 or 4). The follow-up times were also analysed after being categorized into three time periods, namely zero to six months (group 1), seven months to 12 months (group 2) and more than 13 months (group 3). Categorized data were analysed by multiple logistical regression analyses. To investigate the usefulness of the client assessment questions that asked owners to observe similar characteristics of function and behaviour in different settings (e.g. climbing stairs versus getting in to a car), a Spearman’s rho test was conducted to observe patterns of similarity amongst the 12 questions asked of the owners (p values < 0.05 were considered statistically significant).

Results

The final cohort analysed in this study included 46 dogs (eight bilateral), with 22 dogs (nine males, 13 females) in the BFX group and 24 dogs (11 males, 13 females) in the CFX treatment group. Prior to primary THA surgery, four dogs had undergone other surgical procedures of the pelvic limbs; three dogs (6.5%) had previously undergone triple pelvic osteotomy (TPO) surgery, one on the ipsilateral side to the THA, one in the contralateral side, and one dog had had bilateral TPO surgery. One dog (2.2%) had previously undergone tibial plateau levelling osteotomy surgery in the contralateral stifle for treatment of a ruptured cranial cruciate ligament.

The breeds of dogs most commonly treated included Golden Retrievers (n = 10; 20.4%), Labrador Retrievers (n = 10; 20.4%), German Shepherd Dogs (n = 8; 16.3%) and Rottweilers (n = 3; 6.1%). Other breeds were represented by only one or two animals (Fig. 3). The mean age of dogs in the CFX group (n = 24) was 5.5 ± 3.8 years (range: one-14 years) and in the BFX group (n = 22) was 3.3 ± 2.3 years (one – nine years). Mean body weight of dogs in the CFX group (33.8 ± 7.3 kg; range: 20.0 to 50.0 kg) was not significantly different to those in the BFX group (35.4 ± 6.7 kg; range: 20.0 to 44.0 kg). Mean follow-up times after primary THA surgery for the CFX group was 26.0 ± 15.7 months (range: two to 68 months), while for the BFX group mean follow-up times were significantly shorter at 8.3 ± 4.7 months (range: one week to 22 months) (p < 0.05).

An apparent trend towards a negative correlation between body weight at surgery and the client score, such that every 10 kg of...
body weight at the time of surgery was associated with a reduction in the client score by 3.4 points (95% confidence interval –7.2 to 0.4 points), was non-significant ($p = 0.08$). All of the population variables (such as gender, age at the time of surgery, body weight, follow-up times) were adjusted into every regression analysis model that was performed. Although each regression model was adjusted for these variables, the interaction terms were not shown to be significant during multiple and exclusion (linear and logistical) regression analyses and did not significantly impact on the clinical outcome of the patient in this study.

**Surgeons**

The differences between surgeons in outcomes for the THA procedures were not significant. Surgeon one performed 30 THA (16 CFX; 14 BFX) with a mean total outcomes score of 19.9 ± 8.7, whilst surgeon two performed 16 THA (8 CFX; 8 BFX) with a mean total score of 19.6 ± 11.3 out of a possible score of 84.

**Complications**

There were six dogs (13.0% overall) with reported complications (four CFX; two BFX). These included: implant sepsis and loosening from the CFX group ($n = 2$), implant luxation ($n = 2$, 1 CFX, 1 BFX) and implant failure or fracture ($n = 2$, 1 CFX, 1 BFX) (Fig. 2). One dog in the BFX group demonstrated radiographic signs of femoral stem subsidence that was not associated with clinical signs at any stage during the study.

**Outcome scores**

The differences between the two treatment groups for either the client score or the total score when adjusted for all variables (CFX mean = 21.7, BFX mean = 17.6) were not significant ($p > 0.10$, Fig. 4). The other scores did not demonstrate any significant differences between treatment types.

The analysis of individual questions from the client score did not reveal any significant differences in scores between the two treatment groups ($p > 0.3$). Questions from the client score which provided the most variable responses were questions of everyday function, namely Q4, Q10 and Q11 (relating to power and strength), followed by questions Q1, Q2 and Q8 (relating to progression of osteoarthritis). Conversely, questions with the least variability in their responses (reflecting less clinical relevance or sensitivity) included Q5 (sleep disruption) and Q6 (vocalisation), followed by Q3 (posture for toileting), Q9 (off leash activity) and Q12 (tolerated walking distance). A Spearman's rho analysis of the client questions revealed a strong similarity in responses between Q4 and 8, Q5 and 6, Q10 and 11, and Q7, 8 and 12. Modification of the client questionnaire to omit Q5 and Q6 has been made. Logistical regression analyses on categorized data did not reveal any significant differences between BFX and CFX groups. Categorising the follow-up time (time from surgery to client score) to three time periods (0 to six months, seven to 12 months, greater than 13 months) did not demonstrate any significant differences between treatment types.

**Radiographic score analysis**

When radiographic questions were individually analysed, the extent of cement mantle around the stem (radiographic score questionnaire, Q2, part (i)) demonstrated a significant negative correlation with the client score. Non-white out cement mantles with scores of 2 or higher, were associated with a lower client score by 13.2 points ($p < 0.05$, 95% confidence interval –25.6 to -0.8). The other radiographic questions did demonstrate some significant correlations to the client score (CFX or BFX). Analyses of radiographic questions that were common to both treatment groups (Q1, 3, 5, 12 and 13) revealed a small but significant difference between treatment groups for question 1 (percentage canal fill of the stem prosthesi), with CFX THA scoring higher by 1 point. The other scores did not demonstrate any significant differences between treatment types.

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**Discussion**

Although a multitude of clinical reports published in the veterinary literature documented the outcomes and complications of several particular types of THA systems (1, 2, 5, 9, 18, 46, 47, 58–63), to the authors’ knowledge, there have not been any studies that have attempted to directly compare functional outcomes between cemented and uncemented hip arthroplasties in clinical patients. Clinical outcome studies are required to assess potential differences in functional outcome amongst different surgical techniques in order to aid the surgeon in decision making and to outline relative
indications and contraindications for their use. Our study reports the first use of a scoring scheme modelled on a validated human scoring system (70) in an attempt to directly compare functional outcomes between the BFX and CFX THA systems in dogs in Australia. Validation of this system will necessitate multi-site use of the instrument, modification to delete redundant items (as has already been started) and ideally comparison with other canine systems. Ultimately, validation is only possible when multiple scoring systems are available for use (71–74).

The choice between either THA system for each patient was originally based on availability, and later on femoral canal shape. Dogs with a ‘stovepipe’ femur, without a distinct isthmus, were implanted with a CFX THA in order to avoid the complications of subsidence of the femoral component that may occur with un cemented stems in dogs with this anatomic feature (45). The shape of the canine femur appears to be influenced by age and breed, with younger adults having a tapered femoral diaphysis which develops into a more ‘stovepipe’ or straighter configuration with age (45). Mature German Shepherd Dogs and Rottweilers frequently have straight femora that are at greater risk for stem subsidence, and therefore the canal flare index (the degree of femoral canal tapering) should be determined in order to evaluate their suitability for un cemented THA (45).

There were not any significant differences demonstrated between BFX and CFX THA in terms of owner perceived functional outcome in this study. There was a significant difference in follow-up times between the two treatment groups, which reflects the relatively recent introduction of the BFX system (introduced in 2003 [44]) in comparison to the CFX THA which has been in clinical use since the mid 1990s (39). Although this difference was adjusted in each model of regression analysis performed, it is possible that with longer follow-up times a difference in functional outcome may emerge, such that BFX THA may result in longer duration and less long-term complications in comparison to CFX THA. This presumption is based upon the nature of the osseous integration that may be achieved with un cemented implants where bony ingrowth may provide a mechanical barrier to wear debris in to the implant-bone interface to reduce the effective joint space. It is anticipated that this would reduce the exposure of periprosthetic tissue to the osteolytic debris particles and therefore reduce the incidence of aseptic loosening with time. Studies of human prostheses demonstrated that un cemented components stabilized by complete bone ingrowth did not reveal any subsequent deterioration and loss of fixation at the bone-implant interface (75). However, not all un cemented implants undergo complete osseous integration and un cemented THA are still susceptible to some aseptic loosening.

The BFX cases in this study included the early experiences with the un cemented system that were performed during the period of the surgeons’ ‘learning curve’ with the BFX implants. It is possible that this factor may have negatively influenced outcomes. Fewer complications and improved outcomes over time are likely as the surgeon becomes more experienced in patient selection, surgical technique and postoperative management (4, 5, 18, 43). It is reasonable to assume that longer term follow-up studies of BFX THA performed by experienced surgeons may achieve better outcomes with fewer complications.

The two infected implants in this series were both from the cemented group and necessitated implant removal, giving an overall infection rate of 8.3% for the CFX group. Implant infection has been reported to occur in up to 11% of THA patients (3–5, 8) and the risk of infection is related to the duration of each surgery, as well as the number of surgeries performed on any particular patient (5, 6). Positive bacterial cultures at the time of surgery have been reported to occur in up to 31% of patients, with Staphylococcus species being the most commonly isolated pathogen. However, antibiotic-resistant Pseudomonas were the micro-organisms that were cultured almost exclusively from implants removed due to infection (18). Infected implants require explantation and aggressive antibiotic therapy based upon culture and sensitivity results prior to cautious reimplantation of any biomaterials.

The overall incidence of implant luxation in our series was 4.3%. Luxation has been reported to occur in approximately 10% of canine THA patients, with the majority luxating within the first four weeks postoperatively (5, 6, 18, 46, 49). Luxations may result from surgical inaccuracy (mal-alignment of the stem or cup prostheses, or PMMA contacting the femoral neck acting as a fulcrum), inappropriate postoperative care (unrestricted activity during the first eight to 12 weeks postoperatively) or after major trauma. During the first postoperative month, the joint capsule gains sufficient strength to stabilize the joint, such that luxations after this time result from excessive force (5). Femoral fissures occurred in two cases in this series for an overall rate of 4.3% lying well within the reported range of 2% to 6% of cemented (7, 52) and 3% to 28% of un cemented femora (48) during THA surgery. They are created either during reaming/broaching or femoral stem seating, with 23% to 45% of fissures propagating in to fractures (52). Any recognized fissures should be stabilized throughout their entire length with cerclage wires. Overall, the outcome of THA cases that were associated with complications was not significantly different to uncomplicated cases. This finding is consistent with previous reports of complications that have undergone revisional surgery, with more than half of patients ultimately achieving satisfactory function or better (3, 5, 7, 50).

Patients that underwent bilateral THA did not have a different client- or total score than those patients undergoing unilateral THA. Although many patients undergoing THA have bilateral coxofemoral disease, unilateral treatment appears to provide adequate function with proportionately greater weight bearing on the implanted limb after surgery relative to preoperative values (3, 18, 51, 76). However, this may lead to increased loading and earlier mechanical failure of unilateral implants. Post-mortem retrieval studies demonstrated that bilateral implants were significantly more biomechanically stable and had a lower incidence of aseptic loosening than unilateral implants (40, 51). It appears that load sharing between two operated legs results in less wear of individual components and offers greater resistance to aseptic loosening.
Although our radiographic scores of the two implant groups were significantly different, this finding most likely reflects the inherent differences in the radiographic appearance of a particular system of fixation. In particular, the difference in percentage of canal fill by the prosthesis (question #1 of the radiographic score) may arise due to the lack of bone cement in BFX systems where the implant must therefore fill a greater proportion of the femoral canal in order to ensure initial stability. The lack of correlation between these radiographic scores for implant system with client score indicates that early postoperative radiographic assessments are unreliable long-term predictors of functional outcome. Other canine THA studies also report radiographic assessment to be invariably inaccurate in predicting implant stability (3, 40, 50, 51, 77). However, certain radiographic findings, such as stem retroversion (version angles < −6°), cement mantle cracks, radioluencies at either the bone-cement or cement-metal interfaces, stem subsidence, eccentric implant positioning, contact of the distal stem tip with the endosteum and voids in the cement mantle have been associated with loosening (3, 18, 50, 51, 77). Widening periprosthetic radiolucent zones indicate loosening and necessitate serial radiographs and close monitoring in order to avoid implant failure (3). The lack of predictive value of radiographs in both this study and the veterinary literature generally reflects the relatively early time frame in which these films are usually taken thus limiting their usefulness to later highlight interface problems.

Our finding on radiographic analysis that incomplete canal fill with PMMA around the CFX prosthesis was associated with better functional outcome, suggested that complete cement filling to the cortex may not be favourable in canine cemented THA patients. However, this observation runs contrary to the current recommendation for CFX implantation that cement mantles should be greater than 2 mm in thickness, based on previous observations that cement mantles of less than 1 mm thickness, implant malposition and stem tip contact with the endosteum have been associated with implant instability (77). Also, incomplete cement mantles in human THA negatively impact load distribution and are associated with aseptic loosening (50, 51). The failure of cement to fill the intramedullary canal may have resulted from either incomplete reaming or inadequate pressurisation of the cement during cement placement. Excessive reaming and cement pressurisation in the canine femora has been shown to be detrimental to bone blood flow leading to ischaemia and areas of cortical necrosis (78, 79). Hence it is possible that incomplete reaming may preserve some cortical vasculature.

Questions with little variability in their responses fail to differentiate outcomes between groups. Some of the questions were less relevant due to the restricted routine permitted during the early postoperative care of THA patients (such as restricted exercise, thus invalidating questions #9 and #12, for example). Hence questions that are correlated but that provide minimally variable responses (such as questions #5 and #6) will be omitted from future questionnaires.

The limitations of this study include the relatively small size of the study cohort, a relatively short-term follow-up for both clinical and radiographic assessments, and the retrospective nature of the study precluding assessment of objective parameters of functional outcome after THA (such as thigh circumference, goniometry, pain on palpation and force plate and kinematic data). The models of statistical analyses utilized in this study assumed a linear progression of deterioration with time, which may not necessarily represent what is occurring clinically. Although the current study did not demonstrate any significant differences between CFX and BFX THA systems, longer term follow-up studies are warranted in order to investigate the true results of longer term functional and radiographic outcomes of these two THA designs. The paucity of long-term follow-up clinical and radiographic examinations of canine THA patients impedes the detection of early signs of aseptic loosening. Aseptic loosening is likely to progress asymptptomatically until failure ultimately results in clinical signs that are obvious to the client and veterinarian (sudden lameness and non weight bearing). It could be said that although some owners may detect a gradual deterioration in function over time, it becomes inappropriately attributed as part of the ‘natural ageing process’ and often goes unreported to their veterinarian thereby lowering detection of the true incidence of aseptic loosening in our canine THA patients.

Since radiographic failure precedes clinical failure, early radiographic evidence of loosening will provide the earliest indications for surgical intervention. Revision surgery may provide a good prognosis in early cases of aseptic loosening, before excessive osteolysis has removed surrounding bone stock (50). In chronically loose implants that are detected much later, the degree of osteolysis prevents revision THA (42). Aseptic loosening rates increase with time and may be observed radiographically (49, 50, 80, 81). As such, more frequent clinical and radiographic monitoring (such as annual radiography) is recommended in order to provide earlier detection of interface deterioration and implant loosening (18, 46, 50, 80).

**Conclusion**

There were neither any significant differences in outcomes between the CFX and BFX in terms of owner-perceived functional outcomes in this relatively short term study, nor were short-term postoperative radiographs predictive of longer term functional outcome. The patients that underwent bilateral THA, or THA associated with complications, functioned as well as unilateral or THA associated with complications, functioned as well as unilateral or uncomplicated THA, respectively. To the authors’ knowledge, this is the first report to attempt a direct comparison between cemented and uncemented THA in clinical canine patients. However, further prospective investigations that incorporate longer term clinical and radiographic follow-up, cases performed beyond the surgeons’ ‘learning curve’, and objective measures of clinical outcome assessment are required. It is only with standardized follow-up times that direct comparisons can be made in order to fully evaluate the outcomes between CFX and BFX systems. The clinical outcome scoring system has been modified and will
be further tested as an instrument to monitor and assess clinical outcomes between surgical types and institutions in prospective studies.

References

45. Skurla CP, Pihlar GE, Frankel DJ et al. Assessing the dog as a model for human total hip replace...
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