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Zurich Cementless Total Hip Replacement: Retrospective Evaluation of 2nd Generation Implants in 60 Dogs

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Objective—To evaluate the results of application, and identify complications, of the 2nd generation of Zurich Cementless Total Hip Replacement (ZCTHR).
Study Design—Case series.
Animals—Client-owned dogs ($n = 60$) that had ZCTHR ($n = 65$).
Methods—Dogs with ZCTHR (2001–2003) with a minimum follow-up ≥ 6 months were evaluated. Data included signalment, cup position, longest follow-up, complications, management of complications and outcome.
Results—Mean follow-up was 22.68 months. Eleven cases (17%) had postoperative complications: femoral fracture ($n = 1$; 1.5%), prosthesis luxation (7; 11%), cup loosening (2; 3%), and implant failure (1; 1.5%); 9 cases were successfully revised. Explantation of implants was performed in 1 case because of infection, and 1 dog was euthanatized after reluxation.
Conclusions—ZCTHR can restore function in dogs affected by disabling diseases of the coxofemoral joint. The press-fit fixation of the cup allowed for corrections in cases of incorrect positioning. Cases with aseptic loosening were revised successfully by impacting larger cups. Newer stems of this generation are shot peening treated to increase their resistance to breakage. In our cases, infection is a disastrous event, leading to implant removal. After resolution of complications, a successful final outcome was achieved in 97% of THR.
Clinical Relevance—ZCTHR offers a reliable alternative for treating dogs with disabling diseases of the hip joints.

INTRODUCTION

TOTAL HIP replacement (THR) is an accepted method of treatment for dogs with disabling diseases of the hip joints. Hip dysplasia, coxarthrosis, coxofemoral luxation, and intra-articular fractures are some indications for canine THR.[1–5] Cemented and cementless THR systems are clinically used.[1,5–10] A cementless THR, Zurich Cementless Total Hip Replacement (ZCTHR; Kyon Inc., Zurich, Switzerland), was developed at the University of Zurich in the late 1990s. The most important characteristic of this prosthesis is anchorage of the stem to the medial cortex of the femur with locking screws. As a result, avoidance of the coupling effect of the medial and lateral femoral cortices, and reduced stress shielding in the proximomedial femoral cortex, is achieved.[11–13] Initial fixation of the cup is obtained by press fit. The porous design of the cup and its elasticity supposedly allow for fluid convection and long-term fixation by bone ingrowth (Appendix A).[3,11,13] Similar flexible press-fit cups have been successfully used in human surgery for many years.[14,15]

Various generations of models have been developed. The 2nd generation was launched in 2001, to address problems related to luxations, to increase the press fit of the cup, and to reinforce the stem. Modifications performed to the cup were flattening of the polar region of the cup, adding 3 parallel ridges to the periphery of the

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shell, extension of the polyethylene liner over the equator to lateralize its center of motion and to provide 200° of head coverage, adding a plasma coat to the shell, and changing the shell to pure titanium instead of titanium alloy.[3,11,16,17] Stem failure at the peg base was a reported complication of the 1st generation ZCTHR.[16,17] The most important modification to the stem of 2nd generation was a redesign of the radius of curvature at the peg base to reduce stress risers and implant failure at this point. A reduction in the complication rate was reported with use of this generation.[16,17] From 2002 on, and in response to nonreported breakage of stems of this generation, shot peening treatment was applied. This process consists in impacting a surface with round glass, metal, or ceramic particles with force sufficient to produce plastic deformation. This deformation induces compressive stresses in the surface that increases resistance to breakage up to 40%.[18,19]

Frequently reported clinical complications of cemented THR are: septic or aseptic loosening, luxations, femoral fracture, pulmonary embolism, intramedullary infarction, and sciatic neuropraxia.[5,20–24]

Our purpose was to evaluate use of, and to identify complications of the ZCTHR in the first 100 consecutive cases operated on with 2nd generation of implants. Our hypothesis was that ZCTHR would provide long-term satisfactory limb function with an acceptable rate of complications.

MATERIALS AND METHODS

Inclusion Criteria

Medical records of the first 100 consecutive cases (April 2001–September 2003) with 2nd generation ZCTHR were reviewed. Telephone contact with owners who did not return for re-evaluation was attempted. Only those dogs that had clinical and radiographic evaluation with $\geq$ 6 months follow-up were included in this study.

All surgery was performed by the same surgeon (P.M.M.), using a standard surgical technique.[25] As reported previously,[3] the central screw of the cup does not compensate for an inaccurate press-fit of the cup and was used only in a very few cases at the beginning of this study.[3,25] In dogs with thin sclerotic femoral cortices, or in very young giant breeds, 2 bicortical screws were used to increase the initial fixation of the stem.[25]

Data Retrieved

Information obtained from medical records and radiographs included: breed, gender, body weight, date of surgery, indication for THR, operated side, surgical time, angles lateral opening (ALO) and of inclination (AI) of the cup, and longest clinical and radiographic follow-up. Complications (intra- and postoperative), management of complications, and outcome were recorded.

ALO and AI

Immediate postoperative lateral, and ventrodorsal or oblique ventrodorsal radiographs of the pelvis were used to evaluate complete insertion of the cup, caudal and cranial contact between implant and bone, and to determine ALO and AI of the acetabular component (Fig 1).

ALO was defined as the angle between the dorsal plane of the pelvis and the plane of the ellipse formed by the inner margin of the titanium ring, with an optimum ALO of 45°.[2,25,26] Measurements were performed with standard THR transparencies (Kyon Inc., Zurich, Switzerland) superimposed on laterolateral radiographs. These templates with ellipses of different sizes allow for measurement of the ALO for all implants with an accuracy limited to the nearest 10°.

AI was also determined from the laterolateral radiograph. The long axis of the ellipse used to evaluate the lateral opening was extended caudally. A 2nd line was drawn from the mid point of the ilium to the ischial tuberosity, defining the long axis of the pelvis. The angle between these 2 lines was defined as the AI of the acetabular component. AI was determined by the anatomy of the dog by impacting the cup flat with the

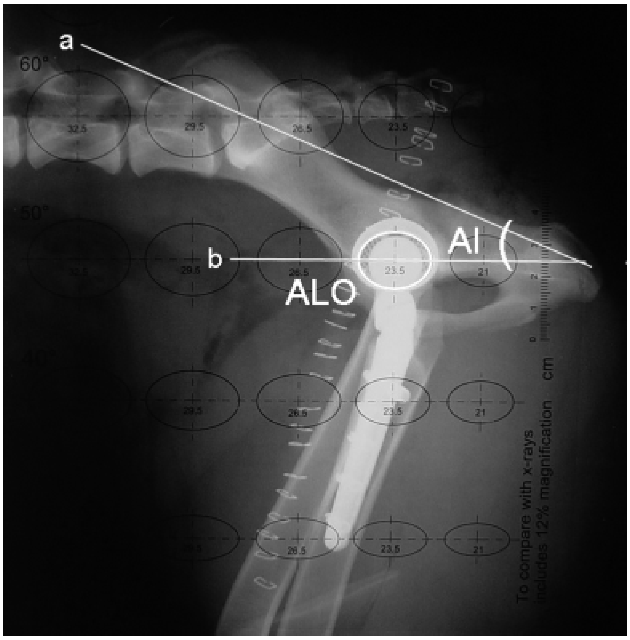

Fig 1. The angle of lateral opening (ALO) of this Zurich Cementless Total Hip Replacement (ZCTHR) is evaluated in laterolateral radiographs, with the help of commercially available transparencies superimposed along the ellipse formed by the inner margin of the titanium ring. The angle of inclination (AI) is defined as the angle formed by a line drawn from the center of the ilial tuberosity to the ischium (a), and a line drawn along the long axis of the ellipse used to evaluate the lateral opening (b).

caudal acetabular lip.[17,25] The cranial lip of the acetabulum was not taken into consideration to plan for the acetabular version, because of osteophytes typically present in this area in severely osteoarthritic dogs. The stem was placed with ~ 10° more femoral anteversion of the head and neck than the caudal inclination given to the cup.[25]

The position of the femoral component relative to the medial cortex of the femur and the insertion of the screws were evaluated from flex-leg ventrodorsal radiographs of the pelvis, and later from a postoperative oblique view of the femur (Fig 2). To take this projection, the dog was positioned in lateral recumbency with the operated hip lying on the table. The upper leg was abducted and the pelvis tilted dorsally to avoid superimposition with the operated THR. The operated leg was abducted and externally rotated, under fluoroscopic control, until the X-ray beam was perpendicular to the screws of the stem, and the radiograph was taken. Version of the stem was not evaluated.

Clinical Evaluation

Clinical variables retrieved from the latest follow-up examination were presence of pain on manipulation of the hip joint, range of motion, muscle mass compared with the contralateral leg, and lameness. These variables were evaluated using a previously reported scale[5]; THR function was graded as excellent, good, fair, poor, or failed (Appendix B).

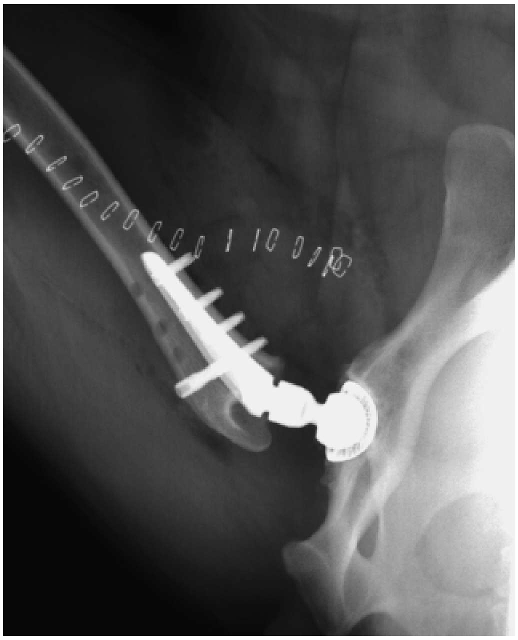

Fig 2. Postoperative oblique radiographic projection of femur and pelvis. The X-ray beam is directed perpendicular to the screws of the stem. Contact between stem and medial femoral cortex, full insertion of screws, and full introduction of the acetabular component with craniocaudal contact are assessed in this radiograph.

Radiographic Assessment

The latest follow-up radiographs were evaluated and compared with immediate postoperative films. At least 2 radiographic projections of each ZCTHR were available. The acetabular component was assessed on lateral and ventrodorsal projections of the pelvis. The stem was evaluated on lateral projections of the pelvis, and extended hip radiographs, frog-legged projections, and/or oblique projections of the femur.

Radiographs were assessed for signs of implant failure, migration, or change in position, prosthesis luxation, signs of bone remodeling secondary to nondetected bone fractures or to infection, and for radiolucent zones between implants and bone. For cases with positive radiolucent zones, radiographs were compared with earlier radiographs to determine progression of lucency. Radiolucent zones were classified as either focal or complete. Cup loosening was defined as the presence of a complete uneven radiolucent zone around the acetabular component with or without signs of implant migration. Bone ingrowth cup fixation was characterized by the absence of radiolucent zones around the cup, or when only focal zones of radiolucency were detected, and no movement of the cup was observed (Fig A1).

Bone ingrowth stem fixation was characterized by no gap increase between stem and bone with time, no signs of radiolucent zones between screws and bone, and no detectable migration of the implants (Fig A1). Stem instability was characterized by the presence of a radiolucent zone around the screws and the bone, a progressive increase in the gap between stem and bone, presence of irregular new bone formation along the medial aspect of the proximal metaphysis of the femur, and thinning of the cortex in that area in follow-up examinations.

RESULTS

From the first 100 consecutive cases operated on with the 2nd generation ZCTHR, complete data with follow-up ≥ 6 months was retrieved from 65 THRs in 60 dogs.

Signalment

Eighteen breeds were represented, with a mean (± SD) body weight of 32.78 ± 9.77 kg (range, 18–64 kg). There were 33 males (7 castrated) and 32 females (20 neutered). Mean age at surgery was 3.80 ± 2.43 years (range, 7 months–8.2 years). Breeds included were mixed breeds (n = 15), Labrador Retriever (12), German Shepherd (11), Golden Retriever (7), Bernese Mountain Dog (4), Border Collies (2), Pit Bull (2), Rottweiler (2), and 1 each of Belgian Shepherd, Doberman, Hovawart, Leonberger, Flat-Coated Retriever, Greater Swiss Mountain Dog, Irish Setter, Magyar Vizla, Newfoundland, Riesenschnauzer.

Surgical Results

Reasons for surgery were hip dysplasia and secondary coxarthrosis (59), failure of conservative and/or surgical management of traumatic coxofemoral luxation (5), and an old Salter–Harris fracture of the proximal femoral physis (1). Mean surgical time was 101 minutes (range, 57–150 minutes). The left coxofemoral joint was replaced in 38 cases and the right hip in 27 cases.

ALO and AI

The acetabular component was impacted with a mean AI of $24.17 \pm 8.53^\circ$ (range, 5–50°) and mean ALO of $45.14 \pm 9.12^\circ$ (range, 20–60°). The cup was completely impacted in all cases, and good contact was achieved between bone and cup in the cranial and caudal aspects of the acetabulum. Contact between the medial femoral cortex and the stem were interpreted as acceptable in all cases and all stem screws were fully inserted.

Complications

In 1 dog, a femoral fissure was created during reaming. To prevent complete fracture of the bone, 3 cerclage wires were placed around the proximal femur.

Postoperative complications occurred in 11 dogs (11 ZCTHR). One dog had a long oblique femoral fracture 1 week after surgery; the fracture extended from the 4th screw hole to the midfemoral diaphysis (Fig 3). The fracture was stabilized with a 3.5 mm broad dynamic compression plate (DCP; Synthes Inc., Solothurn, Switzerland) with 3 screws in the greater trochanter and 5 screws in the distal femoral diaphysis. Additionally, 5 cerclage wires were added and the prosthesis was left in place. The fracture healed uneventfully.

Seven dogs had prosthesis luxation (5 ventral, 2 dorsal). The first 5 luxations occurred in a caudoventral direction during manipulation of the dogs under general anesthesia. In 4 cases, luxation occurred during the ventrodorsal postoperative radiographic examination with the hip joints held in flexion and adduction (Fig 4). The 5th case developed aspiration pneumonia immediately after surgery and the prosthesis luxated during a diagnostic bronchial lavage 5 days later. Dogs that had luxation during radiographic examination were revised while anesthetized. In 3 cases and in the dog that had the luxation 5 days postoperatively, the cup ALO was between 20° and 30° (Fig 5) and the AI between 20° and 30°. The cups were removed and impacted again with an ALO between 45° and 55° in revision surgery; the AI was not modified. To remove the impacted cup, the plug covering the central hole of the cup and the screw were removed, the tip of a Hohmann retractor was placed in

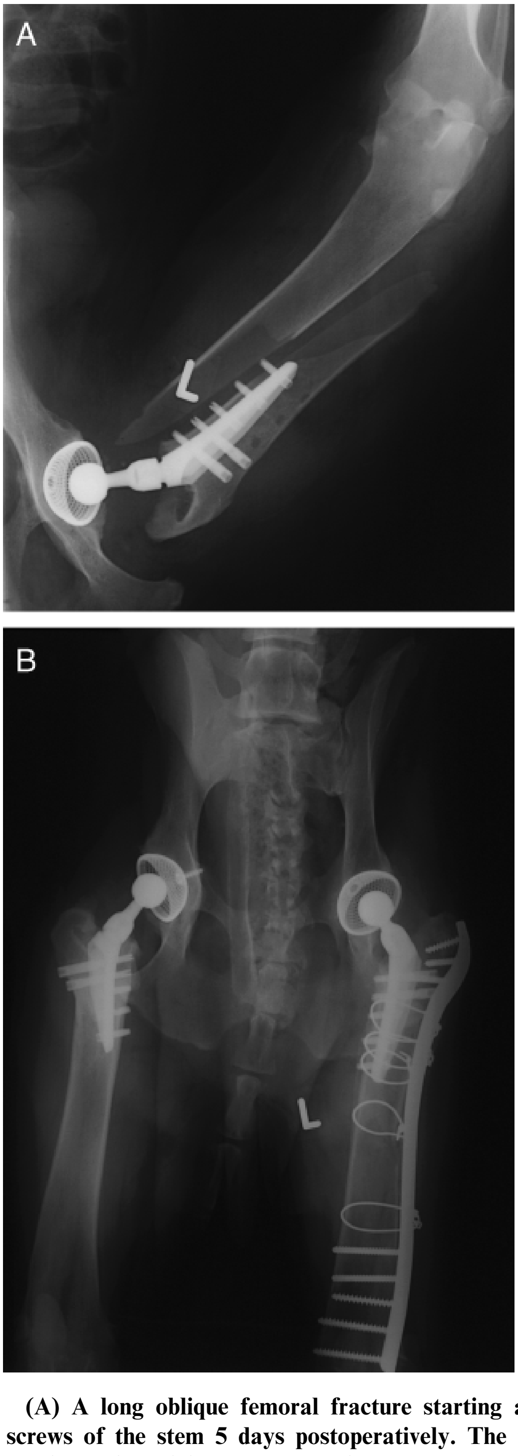

Fig 3. (A) A long oblique femoral fracture starting at the distal screws of the stem 5 days postoperatively. The femur presents thin cortices. (B) Follow-up radiograph 7 months after fixation is shown. Anatomical reduction was provided with a 3.5 mm broad dynamic compression plate. The screws were fixed to the greater trochanter and to the distal femoral area. Five full cerclage wires were applied to reinforce fixation. A total hip replacement (THR) was performed in the right hip 14 months previously. Both THRs were stable and functioning well.

Fig 4. Similar positioning of the leg during postoperative radiographs led to caudoventral luxation of the prosthesis at the beginning of the study. The extremity was held in strong adduction and outward rotation of the hip to get the screws parallel to the radiographic plate. The positioning was improved with abduction of the hip joint, as shown in Fig 2 and no postoperative luxation reoccurred. Luxation of the prosthesis in the original position was also dependent on closed angle of lateral opening (ALO) of the cup insertion.

the polar hole of the acetabular component, and the cup was dislodged by leveling the retractor. After short reaming and repositioning of a cup, a screw of the measured length was inserted, and a polyethylene plug was impacted again covering the head of the screw. The position of the cup in the 5th case was considered adequate, but some laxity was detected in the reduced prosthesis. The head/neck unit was replaced with a longer one during revision surgery, and no changes in the position of implants occurred.

During revision surgery in the dog that had aspiration pneumonia, and because of the suspicion of infection, the wound was thoroughly lavaged, and an ingress–egress drain was added. Two weeks later, the infection could not be controlled, so the prosthesis was removed and continuous lavage performed for 2 more weeks through the ingress–egress drainage. *Escherichia coli* was cultured from the surgical wound and from the bronchial lavage.

Fig 5. Luxation of a cementless total hip replacement (THR). Note the closed angle of lateral opening of the cup. In this case, the THR luxated in a caudoventral direction during manipulation under general anesthesia, and later migrated dorsally.

Antibiotics selected based on susceptibility testing were administered (amoxicillin–clavulanic acid) for 1 month. Two-and-a-half months after explantation, after complete blood work, clinical, radiographic, and negative bacteriologic evaluation, a new ZCTHR was implanted. A 200 mg Garamycin® sponge (Essex Chemie AG, Luzern, Switzerland) was placed in the surgical wound before closure.

Bacterial culture from the surgical wound was negative. Four months later, the dog had lameness in the operated leg and pain on manipulation. Loosening of the acetabular and femoral components were detected in radiographs. The prosthesis was removed leaving the dog with an excision arthroplasty.

Two dogs had later luxations of the THR, one 2 weeks postoperatively and the second 2 months postoperatively. Cup ALO was ~ 60° in both dogs. In 1 dog, the cup was impacted with ~ 35° of caudal inclination, and in the second, ~ 15°. During revision surgery, reaming of the acetabulum was performed, and new cups of the same size were impacted deeper with an ALO of between 40° and 45° and AI of 20° in 1 dog and 35° in the other dog. This last dog had a new luxation of the THR 2 weeks later and the owner declined further treatment and euthanatized the dog.

Acetabular cup loosening occurred in 2 cases. Loosening was evident 10 months after surgery in 1 dog admitted for chronic lameness on the operated leg. On radiographic examination, the cup was medially displaced and caudally rotated, and the head and neck unit was dislodged from the stem. On revision surgery, the acetabulum was reamed to the next larger cup size, the bone defect was filled in with granulated tricalcium phosphate, and a new cup impacted. The last postoperative radiographic examination was performed 3 years later and the dog was walking without lameness (Fig 6). The 2nd dog was admitted 6 months after surgery, lame in the operated leg with pain on hip manipulation. An irregular radiolucent area was detected around the cup on radiographs. Deeper reaming was performed during revision surgery, until a bleeding bed was obtained, and a new cup of the same size was impacted. No complications occurred until 34 months later when the dog was admitted for lameness in the operated leg. The acetabular component was loose. Because this was the largest available cup, a custom cup, 36 mm diameter without polyethylene, was impacted and additionally fixed with 4 selftapping 2.4 titanium screws to the acetabular bone, and a standard 32 mm cup was impacted inside the larger one. No bacteria were isolated from cultures taken during surgery.

One dog had stem failure through the most proximal hole 5 years after surgery. During revision surgery, a window was created on the lateral cortex of the proximal femur,[27] but more proximally. The stem was removed and replaced with a new one of the same size, and fixed to the femur using the same holes as before. The 2 most proximal screws were bicortical. The femoral window was cerclaged with 1 polydioxanone and buttressed with a locking compression plate (LCP; Synthes Inc.). Two locking screws were inserted in the greater trochanter and 2 in the femoral diaphysis, distal to the femoral stem (Fig 7).

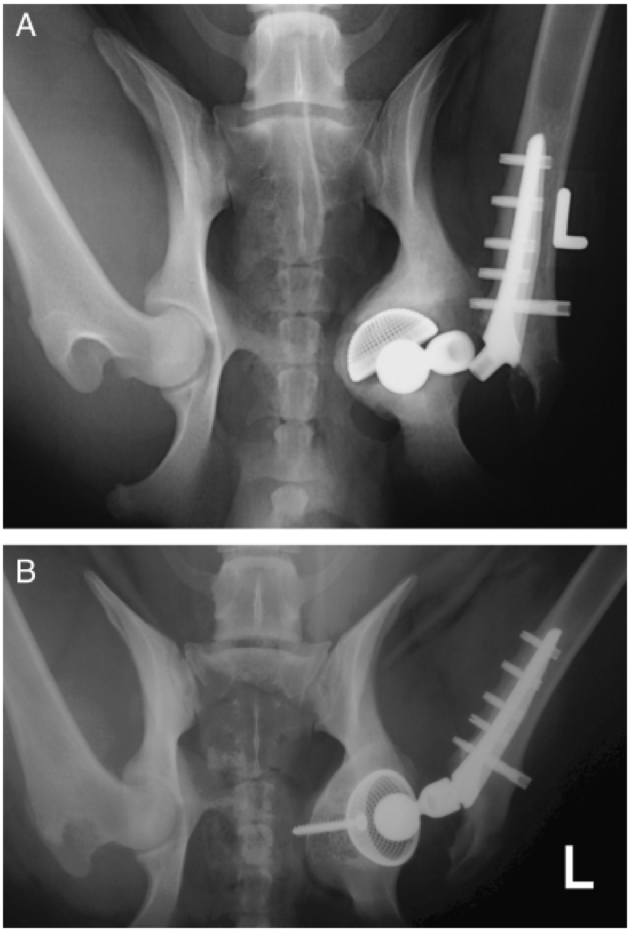

Fig 6. (A) Ventrodorsal frog-legged radiograph 10 months after total hip replacement (THR). The cup is displaced caudal and medial, and the head and neck unit is luxated and dislodged from the stem. (B) Follow-up radiograph 3 years after revision, showing stable acetabular and femoral implants. On revision surgery, the acetabulum was reamed again and a larger cup was impacted. The defect was filled in with granulated tricalcium phosphate.

Outcome at Last Follow-up

Mean follow-up was 22.68 ± 16.75 months (range, 6–68 months). Of 65 ZCTHR, 60 were considered to have an excellent clinical outcome, 3 a good outcome, and 2 as failed. Radiographs of 63 ZCTHR were evaluated. Focal radiolucent zones were observed in the acetabular component of 23 cases and none of the THR had a complete radiolucent zone around the cup or stem. No other complications were detected. Findings compatible with bone ingrowth fixation were observed for all acetabular and femoral implants (Appendix A). Smooth bone thickening along the medial femoral cortex and distal to the stem was observed in 53 THR (Fig 8).

DISCUSSION

ZCTHR can restore function in dogs affected by disabling diseases of the coxofemoral joint. Sixty-three of 65 cases (97%) had a good or excellent final outcome, although 11 dogs (17%) needed one or more revision surgeries.

Of 100 operated dogs, completed follow-up (including radiographs) of ≥ 6 months was available for 65 dogs. Follow-up was shorter in 2 dogs (1 euthanatized dog, 1 dog that had infection and explantation). Of the 35 remaining dogs, some died before this study, some owners had moved out of the country, and some did not want their dogs re-examined. Patient signalment and indications for surgery were similar to other studies.[2,6,26]

Complications

Intraoperative complications were limited to a femoral fissure during femoral stem insertion in a 6-year-old German Shepherd that had end-stage degenerative joint disease (DJD) of the affected hip and had contralateral THR 3 years earlier. Over-reaming of the femoral canal

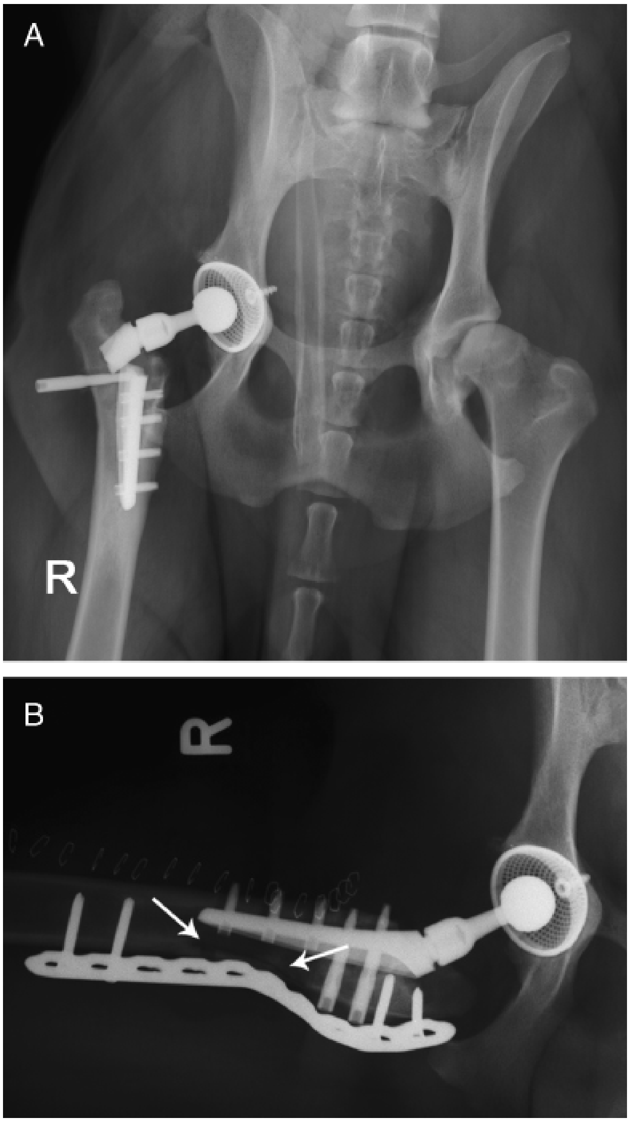

Fig 7. (A) Ventrodorsal radiograph 5 years after total hip replacement (THR). Rupture of the stem at the level of the most proximal screw is observed with lucency around the stem at the level of the 3 most proximal screws. (B) Open leg projection immediately after revision surgery. A window was open in the lateral femoral cortex to facilitate removal of the stem (arrows), and a new stem was positioned using the same screw holes. The stability of the stem was augmented by placing 2 bi-cortical screws proximally. The window was buttressed with a 3.5 mm locking compression plate fixed with 4 locking screws. Three of the locking screws engage only the *cis*-cortex.

led to the creation of the fissure during stem insertion. Three full cerclage wires were used to prevent fissure propagation. In later cases, not included in this study, and to avoid contact between full cerclage wires and screws, the use of full cerclage wires has been replaced for locking plates applied in buttress function and anchored in the trochanteric and in the distal area of the femur.

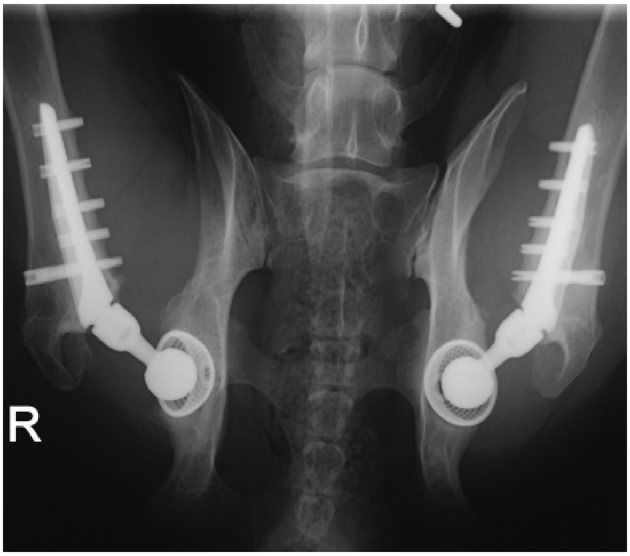

Fig 8. Ventrodorsal frog-legged radiograph 12 (right total hip replacement [THR]) and 14 (left THR) months after surgery. Increased thickening of the medial femoral cortices along the screws is shown. The gap observed between the distal part of both stems and the medial cortices of the femurs is because of placement of the stems in incomplete contact with the cortices during surgery. It did not increase in following examinations, and had no clinical significance.

A 7-year-old Bernese Mountain dog with radiographically thin and sclerotic femoral cortices had an oblique femoral fracture 1 week after surgery without observed trauma. The fracture was oblique and started from the 2nd most distal screw extending distally and ending in the midfemoral diaphysis. This is a well-reported complication after THR in dogs, and appears to be more common in old animals because of nonuse of the leg or other pathologic conditions.[23] Successful ZCTHR of the contralateral hip 3 years earlier may have contributed to reduced limb use affecting bone quality predisposing to fracture. This single femoral fracture compares similarly with fractures occurring with cemented THR systems.[22,23]

Femoral cortical bone loss is a reported complication of stable and unstable cemented THR, making revision surgery more difficult.[28,29] No femoral cortical thinning was observed on long-term follow-up. This is likely a consequence of additional physiologic load on the medial cortex[11,13] and reduced stress shielding created by this fixation.[11–13] Indeed, increased cortical thickening was observed along the medial femoral cortex and distal to the stem in most cases (Fig 8). This bone remodeling and apposition may prevent occurrence of femoral fractures in the long-term that occur with cemented THR because of cortical thinning (Appendix A).[23]

Luxation

Luxations occurred in 7 dogs. Many factors seemingly contribute to luxation[26]: correct positioning for postoperative radiographs, correct surgical positioning of the acetabular component, corresponding adequate anteversion of the stem, and the use of the correct length of head and neck unit to obtain enough periarticular muscular tension.[30] Breed, body conformation, and an increased range of motion are some factors that may also be relevant in the incidence of luxations.[2,30] Impingement between the acetabular component and femoral head during motion results in levering of the femoral head and subsequent prosthesis luxation.[2,26,30] All of these factors may be more relevant in younger dogs with less marked signs of DJD and more range of motion of the hip joints.[11] No reluxation occurred after revision surgery in 6 of 7 cases, so the cause of luxation was likely addressed. Given that radiographs did not allow evaluation of the angle of version of the femoral component, the cause of luxation is inconclusive.

Prosthesis luxations occur in dorsal and ventral directions.[2,30] One difference from other studies was that more ventral luxations occurred in our study.[2,26,31] All ventral luxations occurred during limb manipulation under general anesthesia and, in 4, during the postoperative ventrodorsal radiographic examination with the hip joint in flexion and adduction, similar to a previous study.[30] In 4 dogs, the acetabular components had an ALO $<30^\circ$, which appears to be too closed and may predispose to luxation.[25,26] These dogs, except for 1 with infection, were revised by changing ALO during the same anesthetic period; no reluxation occurred. Nelson et al reported ventral luxation in St. Bernard dogs with ALO $<30^\circ$.[30] Other breeds of dogs in that study had ventral luxations with normally open cups, suggesting that ALO is not the only causative factor of ventral luxation.[30] In fact, 2 other dogs in our series had the acetabular component impacted with 30° ALO without any complication.

Positioning of implants was judged as being correct in a 5th dog, but not enough tissue tension was achieved with the selected head and neck unit. Joint laxity may predispose dogs to luxation.[26] This dog was successfully revised, replacing the neck with a longer one.

Retroversion of the stem was reported as being a cause of ventral luxation.[30] We speculate that by providing adequate anteversion to the femoral component, to match the retroversion given to the cup, the risk of caudal and/or ventral luxations would be reduced. Unfortunately, our radiographs did not allow evaluation of stem version.

Muscle relaxation and repair of the arthrotomy during anesthesia could also be factors contributing to luxation. A measure taken to reduce risk of immediate postoperative ventral luxation was to eliminate the ventrodorsal radiographic examination with the operated hip in adduction. Instead, a more abducted projection of the femur is used, which avoids luxation and provides more information about the positioning of the stem relative to the medial femoral cortex, and allows for evaluation of screw insertion.

Dorsal luxation occurred in 2 dogs with acetabular components impacted with $\sim 60^\circ$ ALO, which has been suggested to increase risk of luxation[26]; however, many other dogs in our study had cups in such an open position, suggesting that other factors also contribute to luxation. Both dogs were revised, 1 successfully and 1 had reluxation 2 weeks later and the owner declined further surgery. The cup in this dog was impacted in revision surgery with a more closed ALO than before, but also much caudal AI was given ($\sim 35^\circ$); we speculate that this was the cause of a possible caudal luxation.

Even when luxations occurred without known cause, in most cases it was related to implant malpositioning during surgery, which can be controlled by the surgeon.[26] Intraoperative manipulation of the implants should be performed to evaluate the stability of the prostheses and to make required changes to prevent luxation. If too much laxity is present during manipulation, the head and neck unit should be changed for a longer one.

Component Loosening

Aseptic loosening of the femoral and/or acetabular component is a common complication of THR.[3,22,29,32–35] Loosening occurred in the acetabular component of 2 dogs, 6 and 10 months after surgery, and in the 1st dog again at 34 months after revision surgery. Bacteriologic samples taken in both cases during revision surgery were negative. Both dogs were lame and had pain on hip manipulation. In a previous study, 11.8% of dogs were lame after ZCTHR and were more likely to have acetabular component–bone interface lucency[3]; however, only dogs presented for reevaluation, or because of lameness were included. Unfortunately not all operated dogs were evaluated, nor was the total number of operated dogs provided leading to speculation that lucency was overrepresented in that study. Skurla and James reported in a necropsy study of 38 cemented THR that only 4 specimens had both components firmly implanted and both components were loose in 14 cases.[34] Because our dogs were alive, definitive assessment of aseptic loosening cannot be provided.

In humans, a 2-stage procedure is a standard technique to treat infected THR.[36–39] The current recommendation for infection after THR in dogs is explantation.[27] Trying to salvage the THR in our case, a 2-stage procedure was performed, and ultimately failed. More cases are needed before definitive conclusions can be made.

Implant stresses are higher in the ZCTHR stem compared with cemented stems, reaching a maximum in the neck region of the implant, with a second peak at the level of the most proximal screw.[12] In response to breakage of the stem at the peg–stem interface in the 1st generation ZCTHR, redesign of the radius of curvature at the peg base eliminated stress concentration in that area[16,17] and no failure in this area has been reported with 2nd generation stems. In response to sporadic, and unreported, breakage of stems distal to this area after 2002, all stems are shoot-peened, causing plastic deformation in the stem surface and increasing resistance of implants to breakage.[18,19] The broken stem in our series was placed in 2001, and therefore not shot peened. Longer follow-ups are needed to ensure that late implant breakage does not occur.

Complication Rates

Previously reported complication rates ranged between 6.3% and 20.3%.[5,22,30,40,41] Luxation in cemented and cementless systems is the most frequently reported complication, with rates from 1.1% to 11.8%.[10,22,26,30] We report a complication rate of 17% and a luxation rate of 11%. The high luxation rate in our cases presumably reflects technical errors during surgery and postoperative radiographic positioning, and therefore its incidence should be reduced with increased surgeon experience. Dogs not readmitted to our clinic for final follow-up examination were excluded from study. Because most of these dogs were assessed clinically and radiographically by referring veterinarians, and luxation is an early complication after THR, we can assume that luxation rate is overrepresented in our study.

The diameter of the heads used during this study was 16 mm. Recently, 19 mm diameter heads were developed to be used with the 2 larger cup sizes. These heads have increased the range of motion by 15°, and therefore should contribute to reduced incidence of luxation.

Revision surgery failed in 2 of 11 dogs (18.1%) comparing favorably with previous studies, with explantation rates after complications ranging from 50% to 54%.[5,22] Olmstead reported satisfactory resolution of $\sim 60\%$ of the complications.[40] We failed to solve luxation in 2 of 7 THR (28.5%). Dyce et al reported complications in 4 of 12 (33.3%) cases after revision surgery for luxation.[26] A study including cemented and cementless THR reported failure to solve ventral luxations in 7 of 13 cases (53%).[30]

In our cases, instrumentation and implants are adequate to treat medium to large size dogs. Even when no complications occurred in smaller size dogs, we found actual size of implants and instruments as being too large to treat dogs $< \sim 20\,\text{kg}$. Smaller implants and instruments should be developed to treat dogs of smaller size.

In conclusion, implantation of ZCTHR proves to be a reproducible, acceptable surgical technique to treat disabling diseases of the hip joint in medium to large size of dogs, providing immediate and definitive anchorage. The complication rate was high in our study (17%): most of them being THR luxations (11%). Increased surgeon experience should help to reduce technical surgical errors and therefore the rate of complications. After the resolution of complications, a successful outcome was achieved in 97% of the THR at an average of 2 years postoperatively, similar to previous reported rates of 91–96%.[5,7,8,40]

REFERENCES

1. Schulz KS: Application of arthroplasty principles to canine cemented total hip replacement. Vet Surg 29:578–593, 2000
2. Preston CA, Schulz KS, Vasseur PB: Total hip arthroplasty in nine canine hind limb amputees: a retrospective study. Vet Surg 28:341–347, 1999
3. Hanson SP, Peck JN, Berry CR, et al: Radiographic evaluation of the Zurich cementless total hip acetabular component. Vet Surg 35:550–558, 2006
4. Pooya HA, Schulz KS, Wisner ER, et al: Short-term evaluation of dorsal acetabular augmentation in 10 canine total hip replacements. Vet Surg 32:142–152, 2003
5. Massat BJ, Vasseur PB: Clinical and radiographic results of total hip arthroplasty in dogs: 96 cases (1986–1992). J Am Vet Med Assoc 205:448–454, 1994
6. Marcellin-Little DJ, DeYoung BA, Doyens DH, et al: Canine uncemented porous-coated anatomic total hip arthroplasty: results of a long-term prospective evaluation of 50 consecutive cases. Vet Surg 28:10–20, 1999
7. Olmstead ML: Canine cemented total hip replacements: state of the art. J Small Anim Pract 36:395–399, 1995
8. Olmstead ML, Hohn RB, Turner TM: A five-year study of 221 total hip replacements in the dog. J Am Vet Med Assoc 183:191–194, 1983
9. Marcellin-Little DJ: Development and principles of application of the canine BFX® cementless hip system. Proceedings of 14th Annual American College of Veterinary Surgeons Forum, Denver CO, 2004, pp 294–296.
10. Olmstead ML: The canine cemented modular total hip prosthesis. J Am Anim Hosp Assoc 31:109–124, 1995
11. Tepic S: Development and mechanical basis for Kyon THR. Proceedings of 14th Annual American College of Veterinary Surgeons Forum, Denver CO, 2004, pp 289–291.
12. Shahar R, Banks-Sills L, Eliasy R: Mechanics of the canine femur with two types of hip replacement stems – finite element analysis. Vet Comp Orthop Traumatol 16:145–152, 2003
13. Montavon P, Tepic S: Clinical application of Zurich Cementless canine total hip prosthesis. Proceedings of 1st World Orthopaedic Veterinary Congress, Munich, Germany, 2002, p 150.
14. Elke R, Berli B, Wagner A, et al: Acetabular revision in total hip replacement with a press-fit cup. J Bone Joint Surg Br 85:1114–1119, 2003

15. Morscher E, Berli B, Jockers W, et al: Rationale of a flexible press fit cup in total hip replacement. 5-year followup in 280 procedures. Clin Orthop Relat Res 42–50, 1997
16. Peck JN: Five years clinical results using the Zurich Cementless (Kyon) total hip replacement: 150 cases. Proceedings of 14th Annual American College of Veterinary Surgeons Forum, Denver CO, 2004, pp 292–293.
17. Boudrieau R: Clinical evolution of the Zurich Cementless Hip System. Proceedings of 13th Annual American College of Veterinary Surgeons Forum, Washington, DC, 2003, pp 569–573.
18. Starker M, Frohling M, Hirsch T: Effect of bending on shot peened and polished osteosynthesis plates. Biomed Tech (Berl) 36:56–59, 1991
19. Starker M, Starker P: Methods for increasing fatigue strength of osteosynthesis plates. Z Orthop Ihre Grenzgeb 121:142–145, 1983
20. Sebestyen P, Marcellin-Little DJ, DeYoung BA: Femoral medullary infarction secondary to canine total hip arthroplasty. Vet Surg 29:227–236, 2000
21. Palmisano MP, Dyce J, Olmstead ML: Extraosseous cement granuloma associated with total hip replacement in 6 dogs. Vet Surg 32:80–90, 2003
22. Bergh MS, Gilley RS, Shofer FS, et al: Complications and radiographic findings following cemented total hip replacement: a retrospective evaluation of 97 dogs. Vet Comp Orthop Traumatol 19:172–179, 2006
23. Liska WD: Femur fractures associated with canine total hip replacement. Vet Surg 33:164–172, 2004
24. Liska WD, Poteet BA: Pulmonary embolism associated with canine total hip replacement. Vet Surg 32:178–186, 2003
25. Montavon P, Tepic S: Surgical Technique: Zurich Cementless Total Hip Course, University of Zurich, Switzerland, 2001
26. Dyce J, Wisner ER, Wang Q, et al: Evaluation of risk factors for luxation after total hip replacement in dogs. Vet Surg 29:524–532, 2000
27. Dyce J, Olmstead ML: Removal of infected canine cemented total hip prostheses using a femoral window technique. Vet Surg 31:552–560, 2002
28. Bergh MS, Muir P, Markel MD, et al: Femoral bone adaptation to stable long-term cemented total hip arthroplasty in dogs. Vet Surg 33:214–220, 2004
29. Bergh MS, Muir P, Markel MD, et al: Femoral bone adaptation to unstable long-term cemented total hip arthroplasty in dogs. Vet Surg 33:238–245, 2004
30. Nelson LL, Dyce J, Shott S: Risk factors for ventral luxation in canine total hip replacement. Vet Surg 36:644–653, 2007
31. Cross AR, Newell SM, Chambers JN, et al: Acetabular component orientation as an indicator of implant luxation in cemented total hip arthroplasty. Vet Surg 29:517–523, 2000
32. Ota J, Cook JL, Lewis DD, et al: Short-term aseptic loosening of the femoral component in canine total hip replacement: effects of cementing technique on cement mantle grade. Vet Surg 34:345–352, 2005
33. El-Warrak AO, Olmstead ML, von Rechenberg B, et al: A review of aseptic loosening in total hip arthroplasty. Vet Comp Orthop Traumatol 14:115–124, 2001
34. Skurla CP, James SP: Postmortem retrieved canine THR: femoral and acetabular component interaction. Biomed Sci Instrum 40:255–260, 2004
35. Skurla CP, Pluhar GE, Frankel DJ, et al: Assessing the dog as a model for human total hip replacement. Analysis of 38 canine cemented femoral components retrieved at postmortem. J Bone Joint Surg Br 87:120–127, 2005
36. Fitzgerald RH Jr.: Infected total hip arthroplasty: diagnosis and treatment. J Am Acad Orthop Surg 3:249–262, 1995
37. Takahira N, Itoman M, Higashi K, et al: Treatment outcome of two-stage revision total hip arthroplasty for infected hip arthroplasty using antibiotic-impregnated cement spacer. J Orthop Sci 8:26–31, 2003
38. Mitchell PA, Masri BA, Garbuz DS, et al: Cementless revision for infection following total hip arthroplasty. Instr Course Lect 52:323–330, 2003
39. Lai KA, Shen WJ, Yang CY, et al: Two-stage cementless revision THR after infection. 5 recurrences in 40 cases followed 2.5–7 years. Acta Orthop Scand 67:325–328, 1996
40. Olmstead ML: Total hip replacement. Vet Clin North Am Small Anim Pract 17:943–955, 1987
41. Dyce J, Wisner ER, Schrader SC, et al: Radiographic evaluation of acetabular component position in dogs. Vet Surg 30:28–39, 2001

Appendix A. Examination of a ground section of a 6-year-old Labrador male, 5 weeks and 4 days after implantation of a Zurich Cementless Total Hip Replacement (ZCTHR) system

Lymphangiosarcoma was detected at that time, and the owner chose euthanasia and allowed the clinic to retrieve the implants for examination (Fig A1). (A) Ground section made trough the acetabulum (arrowhead) and one hole of the titanium shell of the cup (curved arrow) showing new bone ingrowth in the hole (arrow). (B) Ground section made trough the third screw of the stem reveals good quality of the cortical bone around the screw (curved arrow), presence of cancellous bone between stem and cortex (arrow), and new periosteal bone apposition (arrowhead). Images by Melinda Harman MSc, The BioMotion Foundation, West Palm Beach, FL.

Appendix B. Grading scale for postoperative clinical evaluation of hip function after ZCTHR

- *Excellent*: No pain on manipulation of the hip joint, normal range of motion, muscle mass similar or greater than in the other leg, no clinically detectable lameness.
- *Good*: No pain on manipulation of the hip joint, reduced range of motion, mainly in extension, muscle

mass similar or greater than in the contralateral leg, clinically normal gait.

- *Fair*: Moderate pain during manipulation of the hip joint, reduced range of motion, moderate muscular atrophy, intermittent to persistent lameness.
- *Poor*: Pain easily detected during manipulation, range of motion severely reduced, substantial muscular atrophy, and constant to no weight bearing lameness.
- *Failed THR*: The implants were removed or the animal euthanatized because of the failure of the ZCTHR.

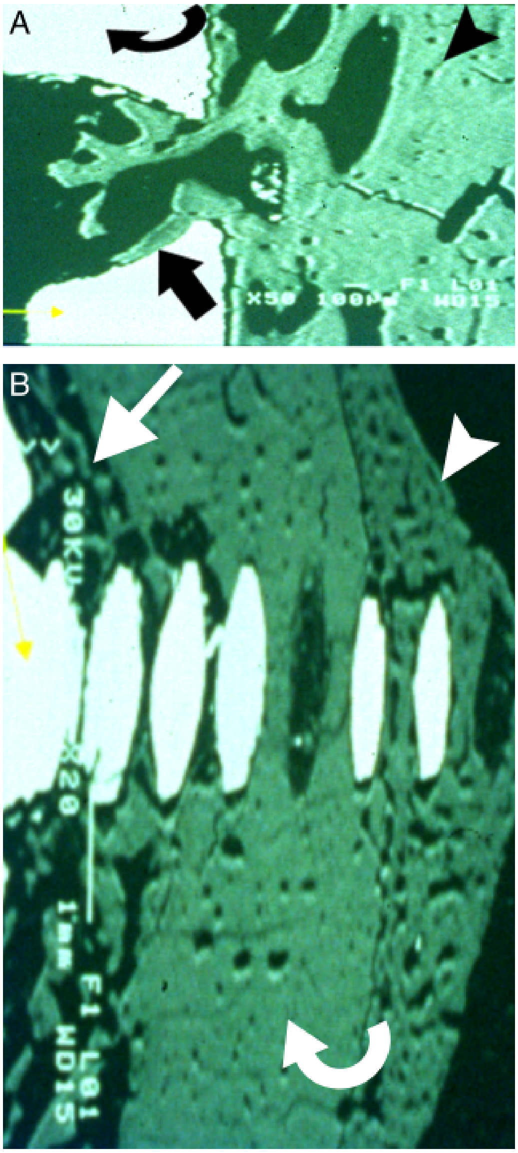

Fig A1. (A) Ground section through one hole of the titanium shell of the acetabular cup. (B) Ground section though a screw of the stem.