Use of a revision cup for treatment of Zurich cementless acetabular cup loosening

Surgical technique and clinical application in 31 cases

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Total hip replacement, cementless, revision, acetabular, cup loosening

Summary
Loosening of the acetabular cup is one of the most common complications following total hip replacement and has an incidence rate of 1.8% to 36.8%. The objective of this study was to describe the surgical technique for the application of a cementless acetabular component specifically designed for treatment of cup loosening and preliminary clinical experience. The Kyon revision cup is composed of two components; the first is a perforated titanium outer shell with holes for 2.4 mm titanium screws, which is impacted into the acetabulum after removal of the loose cup and reaming of the acetabulum. It is secured with a variable number of screws. The second component is an inner plain titanium cup with an ultra-high-molecular-weight polyethylene insert, which is impacted into the outer shell to obtain press-fit stability. This revision cup was used in 31 dogs with cup loosening and a minimum follow-up period of six months. There were four intra-operative complications and two postoperative complications. The main intra-operative complication was difficulty inserting the inner cup into the outer shell. Postoperative complications included craniodorsal hip luxation in one dog, which was successfully managed, and cup loosening in another dog, which required explantation of the prosthesis. The main advantage of the revision cup appears to be increased implant stability afforded by screw fixation. Our initial clinical results in 31 dogs were promising; all but one dog had a successful clinical outcome.

Introduction
Total hip replacement (THR) is a well-established procedure for the treatment of disabling disorders of the coxofemoral joint. Several THR systems, both cemented and cementless, have been developed and clinically tested over the last four decades (1-9). The success rate of THR has increased over the years because of improvement in implant design and application technique. However, seven to 22% of canine cases incur complications, the most common of which are luxation, infection, periprosthetic fracture, septic or aseptic loosening of the implants, and implant failure (1-17). Other less frequently encountered complications include sciatic neurapraxia and pulmonary embolism (1-19).

Loosening of a cementless acetabular component is commonly the result of infection (septic loosening), lack of initial stability with subsequent failure of osteointegration (early aseptic loosening), or osteolysis induced by polyethylene wear debris (late aseptic loosening) (20). The incidence of cementless cup loosening was reported to range from 1.8% to 36.8% in seven studies (6, 10-15). Cup loosening after Kyon THR had an incidence of 3%, 3.7%, and 2.5% in three different studies; the latter study also reported cup breakage with subsequent loosening in 1.6% of cases (6, 10, 11).

Treatment options for loosening of the acetabular component include explantation or implant revision. Revision of a loose cementless cup can be achieved with cemented or cementless implants (4, 21, 22). Implantation of a new cementless cup can be particularly difficult when bone defects or poor bone quality prevent optimal press-fit of the implant. A successful acetabular revision with a cementless cup must provide intimate contact between the acetabular implant and the host bone and a stable mechanical construct that minimizes micromotion and allows bone ingrowth into the cementless acetabular component. Supplemental fixation with multiple screws to minimize micromotion and to promote bone ingrowth is advised in all human THR revisions (23, 24). In human medicine, many implants have been developed for cup revision in patients with severe bone defects (23-28). However, to our knowledge, the use of comparable prosthetics has not been described in veterinary orthopaedics.
In April 2010 a special press-fit cementless revision cup\textsuperscript{a} with additional screw fixation was introduced to provide better implant stability in dogs with poor acetabular bone quality. The purpose of this retrospective study was to describe the surgical technique for the use of this revision cup and the results of preliminary clinical application in 31 cases.

\section*{Materials and methods}

The medical records from a single referral practice (Clinica Veterinaria Vezzoni) were reviewed to identify dogs that had undergone surgical revision of THR because of cementless acetabular cup loosening using a cementless revision cup between April 2010 and April 2012. The inclusion criterion for this study was that dogs had a minimum clinical and radiographic postoperative follow-up period of six months.

\section*{Preoperative clinical assessment}

Information obtained from the medical records included: date of presentation for cup loosening, date of revision surgery, date of first surgery, sex, breed, age, body weight, clinical signs used to evaluate degree of lameness, muscle atrophy, signs of pain on coxofemoral manipulation, and limb affected. A video recording was made of each patient while walking immediately prior to revision surgery.

Lameness was assessed subjectively at a walk and trot and graded from 1 to 5 using the following scale: 1 = no lameness; 2 = mild intermittent weight-bearing lameness; 3 = persistent moderate weight-bearing lameness; 4 = persistent severe weight-bearing lameness, with or without intermittent non-weight bearing; and 5 = persistent non-weight-bearing lameness \textsuperscript{(29)}. Signs of pain on manipulation of the hip joint and muscle atrophy were assessed subjectively.

\section*{Radiographic evaluation}

Radiographic evaluation was done while the dog was under deep sedation or general anaesthesia. A minimum of three radiographic views of the pelvis were obtained: a ventrodorsal view with the legs extended, an oblique view of the pelvis with the x-ray beam tangential to the equator of the acetabular cup, and an oblique view of the femur with slight external rotation so that the radiographic beam was perpendicular to the screws of the stem. Fluoroscopy was used to ensure appropriate positioning in the latter two radiographic views. The acetabular component was assessed using the hip-extended and oblique views of the pelvis, while the stem was evaluated on the ventrodorsal view with the hip extended and the oblique view of the femur.

Radiographs were assessed for signs of radioluency between implants and bone, cup breakage, migration, and change in position of the implants. In dogs with positive radiolucent zones, radiographs were compared with earlier radiographs to determine progression of lucency. Radiolucent zones were classified as focal or complete. Cup loosening was defined as the presence of a complete radiolucent zone around the acetabular component with or without signs of implant migration. Bone ingrowth in osteointegrated cups was considered adequate when no radiolucent zones around the cup or only focal zones of radiolucenty were detected and no signs of movement of the cup were apparent \textsuperscript{(6)}. Cup breakage was diagnosed when metallic irregularities in the cup profile were detected.

\section*{Implant design}

The outer diameters of available revision cups were 23.5 mm, 26.5 mm, 29.5 mm, and 32.5 mm. The cup was composed of two components: The first was a perforated titanium outer shell with holes for placement of 2.4 mm titanium screws with flat cruciform heads, and a superficial plasma spray coating to promote bone ingrowth. The second component was an inner plain titanium cup with an ultra-high molecular-weight polyethylene insert, which was impacted into the outer shell to obtain a snap fit coupling with residual taper locking press-fit.

The revision cups used in this study were first-generation and second-generation because some relevant modifications in the implant design were introduced in May 2011. The first-generation revision cup was modified from the standard flat pole Kyon cementless cup\textsuperscript{b} by simply drilling 13 holes for the 2.4 mm screws and countersinking the heads through the outer shell so that the screw heads did not interfere with the inner cup. This cup had a 0.2 mm gap between the shell and inner cup, which was also present in the standard Kyon cup. The thickness of the outer shell was 0.8 mm and that of the inner titanium cup was 0.6 mm. In the second-generation revision cup, the outer shell was modified to allow sufficient space for the heads of the 2.4 mm screws. The outer shell thickness was gradually increased from 0.8 mm at the opening (equator) of the shell to 1.7 mm at the bottom (pole) of the shell, changing the flat pole design into a true hemispherical design, without changing the outer diameter of the equator of the shell. The number of screw holes was reduced from 13 to six. In addition, the gap between the shell and the cup was increased from 0.3 mm at the opening of the shell to 0.6 mm at the bottom so that after insertion, the screw heads had about 0.5 mm clearance from the inner cup. Another minor modification was that the revision shell had an additional cylindrical section, approximately 0.5 mm in height, at the opening of the outer shell to allow for proper seating of the inner shell before impaction (Figure 1 A, B). These modifications did not require the use of new reamers, since the outer diameter at the equator did not change from the first to second generation implants.

\section*{Surgical technique}

All surgical procedures were carried out by the same board certified surgeon (AV). Dogs were premedicated with morphine (0.15 mg/kg IM) and acepromazine (0.02 mg/kg IM). Anaesthesia was induced with propofol (2-4 mg/kg IV) and maintained with isoflurane after endotracheal intubation. Analgesia was provided by a target

\textsuperscript{a} Kyon AG Veterinary Surgical Products, Zurich, Switzerland

\textsuperscript{b} For personal or educational use only. No other uses without permission. All rights reserved.
Screws were inserted perpendicular to the inner surface of the outer shell to avoid interference between the screw heads and the inner cup, thus permitting complete seating of the inner cup. For optimal bone purchase the screws were inserted in the cranial, dorsal and caudal holes of the cup, but not in the central and ventral areas because of inadequate cortical width of the medial acetabular wall. After confirming that all screws were tight, the inner cup was inserted with the appropriate impactor in a coaxial direction relative to the outer shell. An insertion angle that deviated from the coaxial direction did not allow optimal seating of the inner cup and carried the risk of subsequent instability and avulsion. Correct insertion of the inner cup was confirmed when the rims of the two components were flush.

A head-neck unit of appropriate length was connected to the stem to ensure appropriate soft tissue tension, and the prosthesis was reduced. After insertion of a gentamicin-impregnated collagen sponge into the joint capsule, closure of the layers was achieved in a routine fashion (Figure 2).

**Aftercare**

Amoxicillin with clavulanic acid\(^c\) (20 mg/kg orally BID) was administered for one week postoperatively, but the treatment was modified in cases in which the results of the intraoperative culture indicated that the isolated pathogen was not sensitive to amoxicillin and clavulanic acid. Meloxicam\(^d\) (0.1 mg/kg orally) was administered once daily for one week and then on alternate days for another two weeks. The owners were advised to keep their dog in the house for four weeks, after which time leash walking was allowed for another two months.

**Postoperative radiographic examination**

A ventrodorsal frog-leg radiographic view, a lateral view of the pelvis with superim...
position of the iliac wings and ischial tuberosities, and an oblique view of the pelvis with the x-ray beam tangential to the equator of the acetabular cup were obtained immediately after surgery. Further views were taken when deemed necessary.

Seating of the inner cup in the outer cup was evaluated on the oblique radiographic view of the pelvis; placement was considered optimal when the equators of the two cups were in the same plane. Cup positioning was measured on the lateral view of the pelvis as previously described (6-31). For measurement of the angle of lateral opening (ALO), an ellipse was drawn outlining the projection of the acetabular cup and its major and minor axes were identified. The angle was calculated using the formula, $\text{ALO} = \sin^{-1} (\text{minor axis/major axis})$. The coronal retroversion angle (CR) of the acetabular cup was measured as follows: a line representing the pelvic axis was drawn from the centre of the iliac wing to the ischiatic tuberosity, and a second line was drawn passing through the long axis of the ellipse of the acetabular cup; the angle between these two lines was measured and represented the coronal retroversion angle (6, 31, 32).

**Follow-up examinations**

Follow-up examinations were carried out at one, three, six and 12 months after surgery and then once every year. At each examination, hip joint range-of-motion and signs of pain or discomfort during manipulation of the hip joint were recorded. In addition, video recordings of the dog walking away from and towards the camera, as well as from the side, were made for
criterion while one dog was excluded because the follow-up period was shorter than six months.

The mean age of the dogs at the time of revision surgery was 62 months (range 10.5 to 157 months) and the median body-weight was 28.5 kg (range 15 to 48.5 kg). Breeds included German Shepherd Dog (n = 6), Labrador Retriever (n = 5), English Setter (n = 4), Rottweiler (n = 3), Golden Retriever (n = 3), Samoyed (n = 2), Border Collie (n = 2), Brittany Spaniel (n = 2), Boxer (n = 1), Italian Pointer (n = 1), Hovawart (n = 1), and Newfoundland (n = 1). There were 20 male and 11 female dogs.

Surgery was performed on 19 right hip joints and 12 left hip joints. The mean interval between initial surgery and revision surgery was 31.4 months (median 18 months, range 1.5 to 73 months). Five dogs had early cup loosening (within 6 months of initial surgery) and 26 dogs had late cup loosening (more than 6 months postoperatively). In 21 cases primary THR surgery was performed in the same veterinary clinic, while 10 cases were referred after THR had been performed elsewhere. All dogs were presented because of the complaint of persistent lameness in the affected limb, which varied in degree from grade 3 to grade 5 (median 4), and all showed signs of pain when the affected hip joint was manipulated. In all dogs, a complete radiolucent line was evident around the acetabular cup on preoperative radiographs.

In 15/31 dogs, the cup loosening was septic, and isolated bacteria included *Burkholderia cepacia* (n = 8), methicillin-resistant *Staphylococcus pseudointermedius* (n = 2), *Streptococcus canis* (n = 1), *Serratia marcescens* (n = 1), *Enterococcus faecalis* (n = 1), *Neisseria canis* (n = 1) and *Rickettsia conori* (n = 1). In the remaining 16/31 dogs, the cup loosening was aseptic. Four of these cases were related to polyethylene wear, which was confirmed macroscopically in all cases; cytology of the fibrous tissue underlying the loose cup showed predominance of vacuolate macrophages in all of these four cases. Histopathological examination of the tissue underlying the acetabular cup and the joint capsule was performed in three cases (numbers 5, 11, 13) and confirmed the suspected diagnosis. In the remaining five cases, cup loosening...

comparison with preoperative and other follow-up evaluations.

At each re-evaluation, a ventrodorsal radiographic view with limbs in the extended position and an oblique view of the pelvis with the x-ray beam tangential to the equator of the acetabular cup were taken. The latter projection was obtained under fluoroscopic guidance to ensure appropriate positioning. The acetabular component was assessed using both radiographic views of the pelvis. Further views were taken when deemed necessary.

The longest follow-up of each dog included assessment of the general clinical status of the dog and problems relating to the locomotor system. The radiographic findings were compared with those obtained immediately after revision surgery, and changes that had occurred since the operation were recorded. All views were carefully checked for radiolucent zones around the prosthesis, bone remodelling or sclerosis, implant failure or implant migration. Cup loosening was defined as the presence of a complete radiolucent zone around the acetabular component with or without signs of implant migration. The absence of radiolucent zones around the cup, occurrence of radiolucency limited to focal zones, and absence of cup movement were taken as evidence of bone ingrowth into osteointegrated cups (6, 33) (Figure 3).

Results

From April 2010 to April 2012, 32 dogs (Appendix Table 1 – available online at www.vcot-online.com) underwent revision surgery using Kyon revision cups because of cementless cup loosening after THR. Thirty-one of the dogs met the inclusion criterion while one dog was excluded because the follow-up period was shorter than six months.
was related to breakage of the titanium shell of the acetabular cup. The degree of bone loss radiographically evident varied but was generally subjectively assessed as greater when the joint was not infected and cup loosening was related to polyethylene wear or cup breakage (Figure 4). The size of the failing implants was 21.5 mm (n = 9), 23.5 mm (n = 9), 26.5 mm (n = 10), or 29.5 mm (n = 3). In 23 cases, first-generation revision cups were used, and second-generation revision cups were used in the remaining eight dogs. The number of screws used for fixation of the cup ranged from two to seven (median 5). The average number of screws used was 5.4 with first-generation cups and 3.4 with second-generation cups. The size of the revision cup was 23.5 mm (n = 9), 26.5 mm (n = 15), and 29.5 mm (n = 7). In 12 dogs, the size of the revision cup was the same as the initial cup, in 16 dogs the revision cup was one size larger, and in three dogs it was two sizes larger. The cup angle of lateral opening (ALO) varied from 38° to 53° (mean 46.1°) and the angle of coronal retroversion (CR) ranged from eight degrees to 35° (mean 18.3°).

Intraoperative complications occurred in four dogs (12.9%). In two dogs (numbers 7, 26) one of the screws was inserted eccentrically and its head impinged upon the inner cup, which precluded its full insertion. Filing of the screw head with a high speed bur allowed full insertion of the inner cup. Copious lavage and high negative pressure aspiration were performed during filing of screw head in order to eliminate as many metallic particles as possible. In five dogs (numbers 5, 6, 8, 16, 18), the inner cup was inserted with an angular eccentricity relative to the outer shell. In three dogs (numbers 5, 16, 18) a slight degree of angulation between the inner and outer cups was noticed intra-operatively and on postoperative radiographic images. However, this was considered to be tolerable, and until the end of the study, cup stability was not affected. However in the two other dogs (numbers 6 and 8), the degree of angular eccentricity between the outer shell and the inner cup was considered intolerably high, and the inner cup was immediately dislodged and re-impacted to achieve proper positioning.

Postoperative complications occurred in two dogs; one of these (number 24), a young Labrador Retriever with very lax hips, suffered a craniodorsal hip luxation after a fall on a slippery floor three weeks after surgery, which was revised successfully using a longer head and neck unit. The second postoperative complication (number 19) consisted of lack of integration with a complete thin radiolucent line with sclerosis of the surrounding acetabular bone indicative of cup loosening, and a complete radiolucent line around the femoral stem in an English Setter, occurring after attempted revision of initial cup loosening, which was associated with Streptococcus canis infection (Figure 5). In this dog, secondary cup and stem septic loosening occurred, which required explantation of the prosthesis. Removal of the inner cup was achieved by using a custom-made sliding hammer extractor anchored to a hole drilled in the polyethylene liner. The press-fit insertion of the inner cup is very tight, making removal difficult and these special instruments were required for this.

The mean follow-up time was 13.6 months (range 6 to 30 months). At the final follow-up examination, all but one dog were sound, free of signs of pain on manipulation of the hip, without reduction in range-of-motion, and had complete limb function. Radiographic evaluation showed osteointegration of the revised acetabular cup in 30/31 dogs without radiolucent lines around the cup and without sclerosis or periosteal reaction of the acetabular bone. One dog (number 19) had persistent grade 3 lameness at the six-month follow-up due to cup and stem loosening.

Discussion

This report describes the use of a special cementless revision cup designed to manage cases of cup loosening after THR; a successful outcome was achieved in 30 of 31 dogs.
Macroscopic movement at the bone-cup interface of the loose cup was evident during revision surgery in all dogs. In nine dogs (numbers 3, 4, 5, 11, 12, 13, 16, 23, 30), there were cavitory defects characterized by fibrous tissue. In all of these cases loosening was suspected to be related to wear debris. In three cases polyethylene wear was demonstrated by histological examination, and in the fourth case gross wear was evident. In the cases with cup breakage, titanium debris was found around the cup suggesting a role in bone resorption and cup loosening (20).

We encountered two postoperative complications. The postoperative luxation was not directly related to the revision surgery and the problem was corrected successfully by increasing the neck length of the implant. The other postoperative complication, represented by failure of osteointegration and secondary cup loosening, was resolved by explantation of the prosthesis.

In our experience, correct insertion of the inner cup is critical but also very difficult. It is important that the impactor be placed in an exact coaxial position relative to the outer shell. Correction of suboptimal position of the inner cup is difficult or even impossible, and the only solution may be removal and re-impaction of the inner cup.

We noticed that with some first-generation cups, tightening of the screws created a slight deformation of the rim of the shell, which complicated insertion of the inner cup. This problem seems to have been resolved in the second-generation cups because the thickness of the outer shell had been increased, which rendered it more resistant to deformation.

The two cases of screw impingement that hampered correct cup insertion were successfully managed by filing the screw head. This problem might also have been solved by removing the screws followed by reinsertion at a different angle. However, because bone quality was poor and screw purchase after reinsertion questionable, we decided instead to file the screw heads with a high speed bur, which made correct cup insertion possible.

Second-generation revision cups allow the insertion of a maximum of six screws compared with 13 screws in first-generation revision cups. The reason for this change was to avoid weakening of the outer shell and the risk of breakage, although breakage did not occur in any of our cases. The number and positioning of screws necessary to confer optimal stability of the cup has been investigated in several studies in human patients. It seems that the number of screws may not be the major determinant of cup stability; it has been shown that two or three screws are sufficient for implant stability (34-36). It appears that increasing the number of screws enhances stability only if the screws are inserted in an optimal direction without eccentricity. An angular eccentricity greater than 15° or an offset eccentricity results in a significant decrease in cup stability (37). We found it particularly useful to drill the screw holes in the deep acetabulum with a 1.6 mm Kirschner wire to avoid angular eccentricity. The direction of the wire could be easily changed in order to be coaxial with respect to the hole, bending the wire without risk of breakage, which may occur with a drill bit. While 2.4 mm screws require drilling with a 1.8 mm drill bit, a smaller diameter Kirschner wire was used because of greater elasticity and bending properties. In the dog with secondary cup and stem septic loosening, explanation of the prosthesis was required. Removal of the inner cup was achieved by using a custom-made sliding hammer extractor anchored to a hole drilled in the polyethylene liner. The press-fit insertion of the inner cup is very tight thus making removal difficult and therefore special instruments were required for this.

Fifteen dogs required revision surgery because of cup loosening associated with bacterial infection. We were surprised that in all but one dog, the infection could be controlled, and we believe that the increase in implant stability combined with the use of slow-release gentamicin-impregnated collagen sponges contributed to the success rate in the treatment of septic cup loosening (38).

Conclusion

The results of using a cementless revision cup with screw fixation for the treatment of cup loosening after THR were encouraging, mainly because of increased stability of the implant. We hope that further improvements made to the implants will facilitate the insertion of the inner cup. To critically evaluate the improvement afforded by screw fixation, this revision cup should be compared with the standard cup for revision of cup loosening. Moreover, the promising results achieved using this revision cup have prompted us to use it in other cases with poor acetabular bone quality, such as chronic luxation with cancellation of acetabular bone precluding a good press-fit. The efficacy of the revision cups for this indication requires further investigation.

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Conflict of interest

None declared.

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