The use of a linear versus curvilinear oscillating saw blade for femoral head and neck excision surgery in cats

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OBJECTIVE
To determine the effects of using either a linear or curvilinear oscillating, battery-powered saw blade on the extent of bone resection, bone fissure or fragmentation, soft tissue trauma, and surgical time for femoral head and neck excision (FHNE) in feline cadavers.

ANIMALS
18 feline cadavers.

METHODS
Paired feline cadaveric femora were randomly assigned to either a 10 mm linear or 12 mm curvilinear blade for FHNE by 2 surgical residents. CT of each femur pre- and postoperatively were used to create 3D reconstructions of each femur. The residual remaining or excessively resected bone volume at the ostectomy site was compared to an “ideal” ostectomy line made by a board-certified surgeon on preoperative CTs.

RESULTS
There were no significant differences in residual or excessive bone resection by a saw blade (P = .84), between surgeons (P = .65), or in surgery time (P = .39). When compared to the “ideal” ostectomy, the linear saw blade removed slightly less bone compared to the curvilinear blade, but was not statistically significant (P = .82). No fissures or fractures were noted; however, the curvilinear blade removed the entire lesser trochanter in 1 cadaver and the linear blade partially removed the greater trochanter in 1 femur and 2 lesser trochanters in 2 femora.

CLINICAL RELEVANCE
The use of a curvilinear blade may be a viable option for performing FHNE in cats. In vivo studies are warranted to determine its efficacy in clinical cases where FHNE is performed and the incidence of complications postoperatively.

Keywords: FHNE, feline, curvilinear blade, linear blade

Femoral head and neck excision (FHNE) is a commonly performed salvage procedure in cats for the management of severe or end-stage coxofemoral joint disease. Indications include chronic or nonreducible coxofemoral luxations, acetabular fractures, aseptic necrosis of the femoral head, capital physeal fractures, femoral neck fractures, femoral neck metaphyseal osteopathy, and severe degenerative joint disease. The goal of FHNE is the formation of a pain-free pseudoarthrosis resulting in a functional limb although, some gait abnormalities such as shorter stride length, reluctance to jump or play, severe lameness, and decreased range of motion may be appreciated. The overall outcome after FHNE is good in 38% of animals, satisfactory in 20%, and poor in 42%. Based on long-term follow-up in dogs, residual functional gait deficits have been reported to persist up to 4 years postoperatively.

The medium- to long-term functional outcome in 18 cats after FHNE has been previously reported as excellent in 71% and good in 29% based upon an owner-completed questionnaire; however, most cats took 1 to 2 months postoperatively to resume normal activity. Gait analysis of 17 cats that had undergone FHNE at least 1 year prior had decreased peak vertical force and vertical impulse compared to controls with normal coxofemoral joints and 13/17 out of these cats showed reduced range of motion and pain.
on flexion and extension of the hip joint. A cited reason for poor outcome in small animals may be inadequate excision of the caudal aspect of the femoral neck resulting in bone-on-bone contact of the femur with the acetabular rim causing pain, morbidity, and signs of lameness. Additional factors that may contribute to a less than satisfactory outcome include excessive trauma to the surrounding musculature, femoral fissure formation—either through the greater trochanter or through the femoral shaft, and spur formation at the residual femoral neck.

Various instruments have been reported for use in FHNE including a sagittal bone saw, an osteotome and mallet, Gigli wire, and double-action bone cutters. Angulation of the saw blade caudomedial to the femoral neck has been suggested to improve cut accuracy; however, residual bone remaining or excessive removal of bone continues to be reported despite these methods.

The curvilinear saw blade is most commonly used in the tibial plateau leveling osteotomy (TPLO) and CORA-based leveling osteotomy (CBLO). Its use has also been reported in other procedures such as mandibular rim excision and partial mandibulectomy. To the authors’ knowledge, no studies have determined the efficacy of using a curvilinear blade to resect the femoral head and neck in small animals for a FHNE arthroplasty. The authors postulate that a curvilinear saw blade may safely improve cut accuracy by capturing the entirety of the femoral neck to reduce bone-on-bone contact between the femur and acetabulum post-FHNE.

The objective of this study was to determine the effects of using either a linear or curvilinear oscillating, battery-powered saw blade on the extent of bone resection, bone fissure or fragmentation, soft tissue trauma, and surgical time for FHNE in feline cadavers. We hypothesized that the use of the curvilinear blade would lead to improved ostectomy excision, fewer femoral fissures, less damage to the lesser trochanter, and reduced surgical time compared to a linear saw blade.

Methods

Specimen selection

Twenty adult feline cadavers were obtained through the Sydney School of Veterinary Sciences, Animal Donation Program. All the cats were euthanized for reasons unrelated to this study. The cats weighed between 2.53 kg to 6.40 kg (mean = 3.80 kg). Breeds included 1 exotic short-hair, 1 Tonkinese, 12 domestic short-hair, 2 domestic long-hair, 2 Burmese, and 2 Ragdoll cats. There were 11 female and 9 male cats. Exclusion criteria included cats that were juvenile with open growth plates, evidence of previous coxofemoral or pelvic surgery, and trauma or neoplasia of the pelvic limbs, lower spine, or pelvis.

Computed tomography

All the cadavers were defrosted overnight at room temperature (24°C) before the procedure and pre- and postoperative CT scans. Cadavers were placed in a foam trough and positioned in dorsal recumbency. Both pelvic limbs were extended caudally with the stifles oriented perpendicular to the table to maintain rotational alignment. The thoracic limbs were secured in a neutral position. The limbs were maintained in this position using adhesive tape. CT scans of the pelvis and femora were performed using a 128-slice helical scanner (General Electric 128-slice Computed Tomography scanner, Revolution EVO Gen 3; General Electric Company) and images were acquired as a volume with 200 mA, 120 kVp, 1.25 mm slice thickness, 0.9 mm interval, 0.53 helical pitch, 512 X 512 matrix and 1 second rotation time. The same settings were used pre- and postoperatively. Two cadavers were excluded: 1 with a femoral head fracture, and another with a preexisting FHNE.

Image analysis

3D reconstruction of each femur was performed pre- and postoperatively using a commercially available program (Advanced Workstation, General Electric Company). Each femur was isolated and the total femur volume (cm³) was recorded. A board-certified surgeon (WB) analyzed the preoperative CT images and drew an “ideal” FHNE ostectomy line from the medial aspect of the greater trochanter to just proximal to the lesser trochanter (Figure 1), which was used as a guide by the surgeons intraoperatively. The ideal femur volume removed was determined by excluding the femoral bone volume distal to this ostectomy line.

Postoperatively, the femora were scanned using the same CT settings as previously described and 3D reconstructed to record the postoperative CT femur volume. The actual femur volume removed was determined by subtracting the postoperative CT femur volume from the total femur volume determined on the preoperative CT images. The difference between what was removed and the ideal bone to be removed was calculated by subtracting the actual...
femoral volume removed from the ideal femoral volume to be removed and is reported as the calculated difference in volume.

The volume of any bone remaining proximal to the ostectomy line was expressed as a positive value and any excess removed bone was expressed as a negative value. The board-certified surgeon was blinded as to which blade was used per femur and which surgeon performed the procedure.

Ostectomy

Two surgical residents (M.P. and J.M.), experienced with FHNE, performed the procedures in this study. Each cadaver was operated upon by 1 surgeon randomly assigned to it and each blade type was assigned randomly to either the left or right side of the cadaver, therefore, each cadaver had 1 side with a linear blade FHNE and the other with a curvilinear blade FHNE (http://www.randomizer.org). The order in which the surgery was performed for each cadaver was also randomized for each surgeon. The surgical protocol was standardized using a previously described technique for a FHNE2,15,16 and followed by each surgeon to eliminate variations in technique that may have affected the outcome and surgery time. Saw blade sizes were 10 mm and 12 mm for the linear and curvilinear blades, respectively. These sizes were chosen as the blade lengths approximately fit the ideal ostectomy line length made on the 3D CT images. No augmentations to the ostectomies were performed to assess the different blades’ tendencies to cut the bone and leave rough edges or bone fragments. Previous reports have found that more bone fragments and jagged edges develop when using an osteotome and mallet compared to a battery-powered, linear saw blade.11

The cadavers were placed in lateral recumbency with the randomly assigned coxofemoral joint to be operated on most dorsal. A standard craniodorsal approach was made to the coxofemoral joint15 with the linear skin incision made from just above the greater trochanter and extending to the distal third of the femur. The tensor fascia lata was incised and the incision was extended dorsally and ventrally to allow exposure of the vastus lateralis and gluteal muscles. The superficial and middle gluteal muscles were retracted dorsally and a partial tenotomy of the deep gluteal muscle was made in the ventral half of the tendon. The joint capsule was incised to expose the femoral head and neck via a T-shaped incision and a Hatt spoon was used to excise the ligamentum flavum from the femoral head and neck. The origin of the vastus lateralis was gently elevated using a periosteal elevator to expose the femoral neck to maximize exposure. The coxofemoral joint was externally rotated so that the patella was translated perpendicular to the animal’s spine.2 A battery-powered oscillating saw (Colibri II, DePuy Synthes; Johnson and Johnson MedTech) attached to either a size 12 mm curvilinear or a 10 mm linear blade (Figure 2) was used to create the ostectomy from the medial surface of the greater trochanter and lateral extent of the trochanteric fossa to just proximal to the lesser trochanter. Each ostectomy was directed caudomedially to the femoral neck.2,15 A standard closure was performed using monofilament, absorbable suture to close the remaining joint capsule, the vastus lateralis, and the deep gluteal tenotomy separately in interrupted cruciate suture pattern. The tensor fascia lata and fascia of the biceps femoris as well as the subcutaneous tissue and skin were closed in a simple continuous suture pattern. After ostectomy and closure, the coxofemoral joint and hind limb were manipulated by the surgeon in a full range of motion including flexion, extension, and abduction/adduction to assess for crepitus. The bone edge was palpated for ostotomy smoothness, excess femoral neck, or fragmentation by the surgeon. All femora were assessed on CT imaging for the presence of bone fragments and ostectomy edge for protrusions or fissures and recorded as present or absent by the blinded board-certified surgeon. Bone raps or rongeurs were not used, nor was there any augmentation of the ostectomy or femur after the cut and removal of the head and neck. The time from incision to completion of closure of the skin was also recorded.

Statistical analysis

All statistical tests were calculated using GraphPad Prism 9.0 (GraphPad Software, Dotmatics). Results were analyzed using the Dallal-Wilkinson-Lilliefors (Kolmogorov-Smirnov test) and the data was found to be normally distributed. A P value of < .05 was considered significant. Two-way ANOVA was performed to analyze residual bone volume between saw blades and surgeons and surgery time and surgeons, respectively. Brown-Forsythe and Welch ANOVA were performed to analyze the difference between total residual bone volume by each blade. Mann-Whitney U test was used to compare between patient weights and saw blade type.

Results

The calculated difference in volume, whether in excess or residual, was divided by the respective entire femur volume to standardize bone resected between differing-sized cadavers. There was no significant difference in the amount of residual femoral neck that was removed by either blade ($P = .84$) or between
surgeons \((P = .65)\) (Figure 3). There was no statistical difference in the amount of femoral neck removed between the preoperative 3D ideal ostectomy (linear \(0.92 \pm 0.14 \text{ cm}^3\); curvilinear \(0.95 \pm 0.22 \text{ cm}^3\)) vs the actual bone removed (linear \(0.85 \pm 0.4 \text{ cm}^3\); curvilinear \(0.93 \pm 0.45 \text{ cm}^3\)) \((p = 0.82)\) (Figure 4). There was no significant difference in the saw blades (linear: \(13.55 \pm 3.80 \text{ minutes}\) vs curvilinear: \(13.28 \pm 3.26 \text{ minutes}\)) used or surgeon on the length of time to complete the surgery \((P = .67)\). Cadaver body weight did not affect the calculated difference in volume by either blade or surgeon \((P = .88)\). No impingement of coxofemoral range of motion with palpably smooth osteotomies was appreciated in all femora of both saw blade groups by the surgeons performing the procedures. No significant difference in the presence of sharp edges, jagged edges, protrusions, or bone fragments was present in either the blade used or the surgeon. Four femora in total had excessive bone removed from the greater or lesser trochanter—the curvilinear blade removed the entire lesser trochanter in 1 cadaver and the linear blade partially removed 1 greater trochanter and 2 lesser trochanters either partially or completely (Figure 5).

**Discussion**

This ex vivo study failed to find a significant difference between saw blades in residual bone volume left in the proximal femur after FHNE and, therefore, rejects our hypothesis. The procedure using either blade took approximately the same amount of time to complete. While the FHNE arthroplasty is a common salvage procedure used in dogs and cats with coxofemoral joint disease, complications and poor outcomes occur in as many as 50% or more of animals.\(^2\)\(^–\)\(^5\) The most common cause of poor outcome has been suggested to be due to bone-on-bone contact between the femoral ostectomy site and acetabulum as it causes ongoing pain and interrupts the formation of pseudoarthrosis.\(^5\)\(^–\)\(^11\) Patients with chronic disease may also have a delayed return to function and will need more intensive physiotherapy postoperatively compared to those with acute disease or trauma.\(^6\)\(^7\)\(^17\) The effect of using a
curvilinear saw for FHNE may improve postoperative function despite removing similar amounts of bone if the cut results in reduced bone-on-bone contact due to the curvature of the acetabulum and a curved residual proximal femur during weight-bearing. Soft tissue augmentation such as the biceps femoris muscle flap\(^8,9,18\) or deep gluteal muscle interposition\(^1\) has been proposed to provide a barrier between the ostectomy site and acetabulum to prevent bone-on-bone contact. However, inadequate excision of the femoral neck still resulted in pain, lameness and poor outcomes in some animals despite the applied augmentation.\(^1\) The inability of previously mentioned techniques to improve outcome in dogs and cats emphasizes the importance of removal of the entirety of the femoral neck when performing a FHNE.\(^8,12,15,20\) rather than soft tissue interposition. Whether removal of the femoral neck using a curvilinear blade would improve weight-bearing postoperatively is unknown, however, based on the current study results, this warrants further investigation.

There was an increased rate of occurrence of bony fragments and fissures when using an ostectomy and mallet compared with a linear saw in a previous study;\(^11\) however, we found that neither blade in this study resulted in fissures or bony fragments to the femora. On average, 1 surgeon tended to remove too much bone and the other removed too little regardless of what blade was used. This is likely a normal variation between surgeons but shows that both blades are viable options for performing FHNE, with no significant differences between the surgeons.

The greater trochanter is important for the insertion of the gluteal muscles and the lesser trochanter serves as the insertion point for the iliopsoas muscle.\(^7,8,17,21\) Removal of the lesser trochanter of the femur with loss of the insertion of the iliopsoas muscle insertion may also contribute to a poorer outcome due to reduced pseudoarthrosis stability\(^7,17\) and limb shortening due to femoral translocation dorsal to the acetabulum when weight bearing.\(^4,7,17\) The clinical significance of excess bone removal from the femur after FHNE remains unclear. However, these could potentially cause additional trauma at the periosteum or surrounding soft tissue structures causing pain or altering the biomechanics of the pseudoarthrosis.\(^7,8,11\)

Although not significant statistically, there were 3 femora in this ex vivo study using the linear blade where either the greater or lesser trochanter was partly or totally removed and only 1 femur was affected using the curvilinear blade. Clinically, the curvilinear blade may provide a safer technique for preserving these structures and the surgeons reported fewer instances where the blade slid off the bone into adjacent soft tissue using the curvilinear blade.

The base of the femoral neck is curved where it meets the proximal femur diaphysis and the curvilinear blade more closely mimics this anatomy, potentially resulting in more complete femoral neck resection. However, femoral neck bone volume in cats is small and differences may not have been detected in this study. The surgeons subjectively found it easier to preplace the ends of the curvilinear blade at the 2 landmarks (medial to greater trochanter to proximal lesser trochanter) and stay within the proposed ostectomy site. This is supported by how closely matched the average bone removed by the curvilinear saw (0.95 ± 0.22 cm\(^3\) ideal; actually (0.93 ± 0.45 cm\(^3\)) was compared to the linear saw (0.92 ± 0.14 cm\(^3\) ideal; linear 0.85 ± 0.4 cm\(^3\) actual), even if this difference was not statistically apparent. It may be clinically significant that 3 cadavers sustained excessive bone removal which affected muscular insertions with the linear blade, whereas there was only 1 cadaver affected with the curvilinear blade.

Limitations of this study include its ex vivo design with the procedures performed on feline cadavers, small sample and surgeon size of the study, limited cadaver size and species, as well as the use of only CT to document postoperative outcomes. The clinical effects of the techniques are unknown; however, inadequate femoral neck resection may cause more periarthritic trauma and may interfere with pseudoarthrosis formation, as well as gluteal and iliopsoas muscle function.\(^11\) Another limitation was that the procedures were also performed on healthy coxofemoral joints and we did not evaluate cadavers with degenerative joint disease or pathology where FHNE is most often used. Pathology may include osteophytes, enthesophytes, bone sclerosis, and joint fibrosis that make bony landmarks more difficult to locate. Local soft tissues may be thickened with chronicity or disrupted with acute trauma and these changes have the potential to lead to inaccurate saw placement, angulation, and irregular ostectomy site resection. Care should also be taken when performing this procedure in patients with chronic disuse atrophy as the bone may be osteopenic predisposing to fracture when performing the ostectomy.\(^6\) The authors recognize that procedures were performed by surgical residents rather than board-certified surgeons though this is to reflect that this procedure is more likely to be performed in general practice rather than referral practice.

In conclusion, the use of a curvilinear blade may be considered a viable option for performing FHNE in cats. A prospective, randomized controlled clinical trial with owners blinded to saw blade used and postoperative gait analysis may be warranted to investigate the technique further. The indications for salvage FHNE and any comorbidities would need to be standardized in the inclusion criteria in any prospective study to minimize confounding factors of the varying disease conditions on saw blade choice. Prospective clinical trials understandably remain a challenge; however, they provide the most evidence for or against a technique. Further investigation of the biomechanical axis in cadavers loaded on a materials testing machine may also elucidate more of the effects of a curvilinear proximal femur bone edge on the acetabulum during load bearing.

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Disclosures

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