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Limb-Sparing Surgery in a Dog with Osteosarcoma of the Proximal Femur

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Objective—To report successful limb-sparing surgery in a dog with a proximal femoral osteosarcoma (OSA) using a composite allograft–prosthetic technique.
Study Design—Case report.
Animal—Client-owned dog.
Methods—A stage IIB OSA of the proximal aspect of the femur was resected in accordance with oncologic and limb-sparing principles. The osseous defect was reconstructed with a proximal femoral allograft and cemented, long-stemmed femoral prosthesis. Soft tissue reconstruction was achieved by suturing host tendons to their respective allogeneic tendons on the allograft. Coxofemoral joint function was preserved using standard total hip arthroplasty techniques.
Results—Limb-sparing surgery of the proximal aspect of the femur using a composite allograft–prosthetic technique resulted in excellent limb function. Postoperative complications included aseptic loosening of the femoral composite graft and allograft nonunion, which required revision, traumatic implant luxation, and local tumor recurrence. Limb function was excellent after surgical stabilization of the allograft nonunion but deteriorated after implant luxation 270 days postlimb-sparing surgery. Pulmonary and skeletal metastases were diagnosed and local tumor recurrence suspected 596 and 650 days postoperatively, respectively. The dog was euthanatized 688 days after limb-sparing surgery as a result of progressive local and metastatic disease.
Conclusions and Clinical Relevance—Limb-sparing surgery for dogs with primary bone tumors of the proximal aspect of the femur is feasible with good functional results.

Key words: osteosarcoma, limb-sparing surgery, femur allograft, total hip arthroplasty, nonunion, aseptic loosening, dog.

INTRODUCTION

A 9-YEAR-OLD, neutered male, Golden Retriever was admitted with a 2-week history of right pelvic limb lameness. The lameness was acute in onset with no known inciting cause. Radiographs of the right femur and whole-body nuclear bone scintigraphy were performed before referral. A primary bone tumor was suspected based on radiographic changes, including a mixed pattern of bone lysis and increased production, and a localized increase in radionuclide uptake in the proximal aspect of the right femur. Palpation of a mass in the proximal aspect of the right femur elicited a painful response. The only abnormality detected on hematology, serum biochemistry, and urinalysis was mild anemia (hematocrit 36%; reference interval, 43–58%). Radiographs of the right femur revealed a primarily lytic lesion extending from the proximal femoral diaphysis into the

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femoral neck (Fig 1A). There was no evidence of metastatic disease on three-view thoracic radiographs. A bone biopsy was not performed. The owners were offered a variety of different palliative and curative-intent management options to treat the suspected primary bone tumor and elected to proceed with limb-sparing surgery.

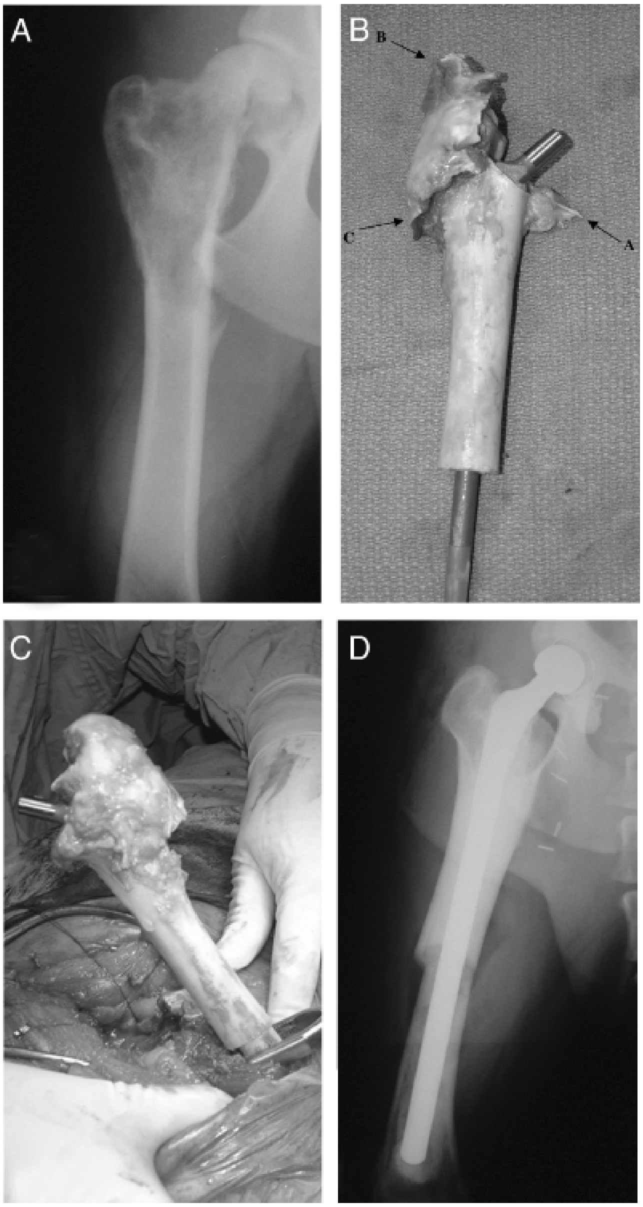

Fig 1. (A) Preoperative craniocaudal radiograph of the right femur. A mixed osteolytic-proliferative pattern is seen in the proximal femur, greater trochanter, and femoral neck. (B) An intraoperative image of the long-stemmed, noncollared femoral prosthesis inserted into the proximal femoral allograft. Note the allogeneic tendons of insertion used for soft tissue reconstruction (arrows; A, iliopsoas; B, gluteals; C, vastus lateralis). (C) An intraoperative image of the cemented allograft–prosthetic composite in situ. (D) Immediate postoperative craniocaudal radiograph showing adequate position and alignment of the allograft, femoral stem, and total hip arthroplasty.

Surgery

The dog was anesthetized and a lateral approach to the right femur and coxofemoral joint performed. The tendons of insertion of the superficial gluteal, middle gluteal, deep gluteal, vastus lateralis, internal and external obturator, gemilli, and iliopsoas muscles were tagged with 0 polypropylene and divided 1 cm distant to the mass in the proximal aspect of the femur. The coxofemoral joint capsule was incised and the femoral head was disarticulated. A femoral osteotomy was performed 3 cm distal to the distal margins of the tumor, as determined by limb radiographs, scintigraphy, and gross intraoperative evaluation.[1–5] A radiograph of the resected specimen confirmed the presence of radiographically normal bone at the osteotomy site. The femoral mass, ligament of the femoral head, and bone marrow from the intramedullary canal opposite the osteotomy site were fixed in 10% formalin and submitted for histopathologic examination. The osteotomy site and tendons of insertion on the proximal femur were individually inked for further evaluation of surgical margins.

The acetabulum was reamed and a 25 mm polyethylene cup (Biomedtrix, Inc., Allendale, NJ) was cemented into the right acetabulum using cephazolin-impregnated polymethylmethacrylate (PMMA; 1 g cephazolin to 40 g PMMA; Surgical Simplex P, Stryker Orthopaedics, Mahway, NJ) mixed in a vacuum system and injected while in the working phase. A fresh-frozen femoral allograft from our institutional bone bank, consisting of the entire femur and proximal tendinous insertions, was thawed in a solution of isotonic saline and gentamicin at room temperature. A mid-diaphyseal osteotomy of the femoral allograft was performed so that the proximal segment fitted into the defect resulting from resection of the tumor. The allogeneic femoral head was ostectomized proximal to the calcar. A custom-designed, extra long, noncollared femoral stem (#7 collarless titanium alloy stem, 180 mm length; Stryker Orthopaedics, Mahway, NJ) was first cemented into the femoral allograft (Fig 1B) and then the allograft–prosthetic composite was inserted into the distal femur with cephazolin-impregnated PMMA (Fig 1C).The PMMA was mixed in a vacuum and injected under pressure using 3rd generation cementing techniques. The allograft and host femoral bone were aligned using the caudal rough faces as a landmark. A + 0 mm femoral head (Biomedtrix, Inc., Allendale, NJ) was impacted on to the stem and the coxofemoral joint reduced. The divided tendons of the superficial, middle, and deep gluteal muscles, vastus lateralis, internal and external obturator, gemilli, and iliopsoas muscles were sutured to their corresponding allogeneic tendinous insertions using 0 polypropylene in either a 3-loop pulley or locking loop suture pattern. A closed-suction drain was inserted adjacent the surgery site. Muscle, subcutaneous tissue, and skin were closed routinely. Good positioning of the femoral stem and alignment of the femoral allograft, host bone, and stem were observed on postoperative radiographs (Fig 1D).

Postoperative Care

Postoperative analgesia consisted of continuous rate infusion of fentanyl for 24 hours, fentanyl transdermal patch and oral morphine for 3 days, and oral carprofen for 10 days. Oral cephalexin was administered for 4 weeks after the last chemotherapy treatment and exercise was restricted to short, leashed walks for 4 weeks. The closed-suction drain was removed 17 hours after surgery. Lameness progressively improved from toe-touching the day after surgery to full weight bearing without visible lameness 5 weeks postoperatively.

Chemotherapy

Localized stage IIB OSA, without extension into the ligament of the femoral head, was diagnosed after histopathologic examination of the bone sample. Surgical resection was considered complete with no evidence of tumor in the bone marrow, distal osteotomy site, ligament of the femoral head, or tendinous insertions on the proximal femur. Starting 4 weeks after surgery, the dog was treated with an alternating protocol of carboplatin (300 mg/m^2) and doxorubicin (30 mg/m^2) every 3 weeks for 8 treatments followed by 4 further administrations of doxorubicin every 3 weeks.

Outcome

An acute onset of right pelvic limb lameness and mid-femoral pain was diagnosed at 140 days. Mild periosteal reaction adjacent to the allograft–host bone interface and rotation of the femoral allograft–prosthetic composite relative to the distal femur was observed in lateromedial but not craniocaudal radiographic projections, indicating aseptic loosening of the composite stem in the cement mantle in the distal femur. A lateral approach to the femur was performed and the allograft and distal femur were aligned and stabilized with a 7-hole broad 3.5 mm limited-contact dynamic compression plate. The dog was discharged the day after surgery with instructions to restrict exercise for a minimum of 4 weeks, continue oral antibiotics, and complete the chemotherapy course.

The pelvic limb lameness associated with the composite instability resolved within 7 days and the dog continued to progress without complications until 9 months postoperatively when an acute craniodorsal hip luxation was diagnosed after a traumatic incident. Radiographs of the right femur showed good alignment of the allograft–prosthetic composite within the femur and no evidence of implant instability or radiolucency around the femoral stem or PMMA. Closed reduction of the hip was successfully performed under general anesthesia. Hip reduction was maintained with an Ehmer sling for 14 days. A grade 4/5 right pelvic limb lameness was noted after removal of the Ehmer sling. There was no clinical or radiographic evidence of hip luxation or implant instability. Limb function improved over 6 months with conservative management but mild lameness persisted and function did not return to pre-luxation levels.

The dog was readmitted 20 months after limb-sparing surgery with a 6-week history of progressive right pelvic limb lameness. There was a mild normocytic, normochromic anemia (hematocrit 39%) but no abnormalities on serum biochemical analysis. Right femoral radiographs revealed the distal tip of the femoral stem contacting the cranial cortex of the distal femur with associated periosteal remodeling. A 3.0×4.5 cm lesion was identified in the right hemithorax on three-view thoracic radiographs. Pulmonary metastasis was suspected but primary pulmonary neoplasia or a non-neoplastic lesion could not be excluded. Increased radionuclide uptake in the right 6th rib and xyphoid process after whole-body nuclear bone scintigraphy was also consistent with metastatic disease. Micromotion of the composite implant was considered the most likely cause of the pelvic limb lameness but surgical revision of the femoral stem loosening and malalignment was not pursued because of suspected metastatic disease to the lungs and skeleton.

The dog was reassessed 6 weeks later. The right pelvic limb lameness had progressed to nonweight bearing and the size of the pulmonary mass had not changed on repeated thoracic radiographs. A 2nd revision of the allograft–prosthetic composite was planned because of the deterioration in limb function, however, 14 days later (and 650 days after limb-sparing surgery), a 10% reduction in body weight and severe atrophy of the right pelvic limb muscles were noted. The dog had a nonweight bearing right pelvic limb lameness with proprioceptive deficits when toe-touching. A large, firm soft tissue mass encompassed the right coxofemoral joint and limited extension and abduction of the limb. Neurologic examination revealed questionable deep pain sensation and absence of both patellar and withdrawal reflexes. Reevaluation of limb radiographs taken 8 weeks earlier showed a mass in the proximal thigh region displacing normal fascial planes. Hemipelvectomy was considered but the owners declined further surgical intervention. The dog was euthanatized due to progressive pain and systemic illness

688 days after limb-sparing surgery. A necropsy was not performed.

DISCUSSION

OSA is the most common primary bone tumor of the appendicular skeleton in dogs.[1,2] Curative-intent treatment for dogs with appendicular OSA involves surgical ablation of the local bone tumor and postoperative chemotherapy to minimize the risk of metastatic disease.[1,2] Surgical options for the management of the local tumor include limb amputation and limb-sparing surgery.[1,2] In dogs, the distal radius is the most amenable site for reconstructive limb-sparing surgery as arthrodesis of the carpal joint is well tolerated.[1,2,6–8] Reconstruction of other sites with cortical allografts and concurrent arthrodesis is associated with a high complication rate and poor postoperative limb function.[1,2,9] However, novel limb-sparing techniques are being investigated for tumors in nonradial sites, such as distraction osteogenesis using circular fixators, and vascularized, irradiated, pasteurized, or autoclaved autografts.[1,2,7,10–14]

A number of different surgical techniques have been reported for limb-salvage in humans with either failed total hip arthroplasties or tumors of the proximal aspect of the femur, including endoprostheses, composite allograft–prostheses, and massive osteoarticular allografts.[15–31] The preoperative planning of these cases is essential for a successful outcome. Advanced imaging is recommended to determine the extent of local tumor involvement and the margins necessary to achieve complete resection of the tumor.[15] In the present case, the local tumor was evaluated with regional radiographs and nuclear scintigraphy. Survey radiographs and nuclear scintigraphy overestimate the degree of neoplastic bone involvement by up to 30% and, as a result, provide a good indication of the bone margins necessary for complete tumor resection.[3–5] However, soft tissue involvement cannot be reliably evaluated using these imaging techniques. Extension of the tumor into the coxofemoral joint should be suspected if there is evidence of radiographic or scintigraphic changes in the femoral head.[15] Magnetic resonance imaging (MRI) is a more sensitive indicator of soft tissue involvement and intrapelvic extension of the tumor.[15] Local tumor recurrence was suspected in the dog described in this report and a preoperative MRI may have permitted a more accurate determination of the degree of soft tissue involvement and the amount of both bone and soft tissue required to achieve complete resection of the tumor.

If a biopsy is to be performed, careful planning is required to minimize the impact of the biopsy tract on curative-intent limb-sparing surgery. The biopsy tract should be distal to the planned incision site, distant to neurovascular structures, and course through muscles and other anatomic structures that are either expendable or involved in the tumor.[15] Based on our experience in musculoskeletal oncology, we usually only recommend a preoperative biopsy when the history, signalment, clinical findings, and tumor location are not typical for a dog with a primary bone tumor.[2] A biopsy was not performed in this dog because signalment and clinical presentation were characteristic of a primary bone tumor and not typical for either metastatic neoplasia or fungal osteomyelitis, and the surgical management and willingness of the owner to proceed with treatment would not have been changed by knowledge of the tumor type. Intraoperative cytology, from either fine-needle aspirates[32] or impression smear, or frozen-section histopathology could have been considered to confirm the diagnosis and differentiate from other diseases with a similar radiographic appearance before proceeding with limb-sparing surgery.

Surgical resection of bone tumors during limb-sparing surgery is standard regardless of anatomic location: wide resection of the tumor and all contiguous tissue should be performed based on preoperative imaging findings and gross intraoperative evaluation. In most dogs, limb-sparing surgery involves reconstruction of the bony defect with an allograft and arthrodesis of the adjacent joint.[1,2] Coxofemoral arthrodesis is described in humans but orthopedic function is suboptimal and surgical techniques that preserve joint function are preferred.[15] Osteoarticular allografts are occasionally used for reconstruction of the proximal aspect of the femur and preservation of coxofemoral joint function, however, this was not considered a viable option in this dog because of the high rate of early complications reported in humans (i.e., subchondral bone collapse, allograft fracture, and allograft–host bone nonunion) and the necessity of restricting postoperative activity until healing of the allograft–host bone interface.[15,16,18,29,31] An endoprosthesis is the most commonly used method for reconstructing the proximal aspect of the femur as the implant provides immediate stability, postoperative recovery is rapid, and success is not completely dependent on bone healing.[15,25–30]

We used a composite technique because the combination of both an allograft and prosthesis provided the advantages of both an osteoarticular allograft and endoprosthesis while minimizing the disadvantages of both implant types.[15–31] In this dog, a proximal femoral allograft and cemented, long-stemmed femoral prosthesis were used to reconstruct the proximal femur, while coxofemoral joint function was preserved with a total hip arthroplasty. An important additional consideration in limb-sparing surgery of the proximal femur is reconstruction of soft tissue structures to preserve normal hip joint biomechanics.[15,22] Similar to an osteoarticular allograft, the use of a proximal femoral allograft facilitates soft tissue reconstruction as the tendons of insertion of the gluteal muscles, internal hip rotators, vastus lateralis, and iliopsoas muscles can be preserved on the allograft to permit suturing of these allogeneic tendons to their respective host tendons.[15–17,19,22–26] The immediate strength of this reconstruction and the long-term complication rate can be improved by supplementing tendon sutures with a vascularized autogenous onlay graft.[33] Other advantages of the composite technique are provision of immediate stability, and postoperative function is not dependent on healing of the allograft.[15–30]

Complications after composite allograft–prosthesis reconstruction of the proximal femur in humans are similar to both osteoarticular allografts and endoprostheses, although the incidence and severity of these complications are often reduced. Complications in the dog we describe included implant failure as a result of aseptic loosening of the femoral components and allograft nonunion, hip luxation, and local tumor recurrence with distant metastasis. Allograft nonunion is a relatively common occurrence in canine limb-sparing surgery.[1,2] The clinical impact of nonunion is usually minimal as the allograft–host bone interface is rigidly stabilized and protected with a dynamic compression plate.[1,2] In this dog, however, the allograft–host bone interface was only stabilized by the cemented femoral stem. A step-cut, rather than a transverse osteotomy, at the allograft–host bone junction increases torsional stability and improves allograft–bone healing but is more difficult to perform.[34] A transverse cut was performed in this dog because of the diameter mismatch between the allograft and host femur. The loss of rotational stability contributed to aseptic loosening of the stem-cement interface. In humans, the incidence of aseptic loosening after endoprosthesis or composite allograft–endoprosthesis reconstruction of the proximal femur is 8–21% on the femoral side, 14–45% on the acetabular side, and 5–57% overall.[15–30] Furthermore, the most commonly reported cause of aseptic loosening of femoral components in human and canine total hip arthroplasties is rotational instability.[35–38] In future cases, as recommended by other authors,[15,17,34] the allograft–host bone interface should be further stabilized with a step-cut osteotomy and bone plate using plate-rod principles.[34,39,40]

Implant luxation is the most common short-term complication in canine total hip arthroplasties and proximal femoral limb-sparing surgery in humans.[15–30,41–43] The reported incidence in humans after proximal femoral reconstruction with either an endoprosthesis or composite technique is up to 22%.[15–30] The most common cause of implant luxation after proximal femoral reconstruction is loss of abductor muscle function and strength.[15–30] The incidence of implant luxation is lower with composite limb-sparing techniques because use of allografts with attached tendons allows reconstruction of the abductor muscle mechanism and preservation of both strength and function.[15–24] Implant luxation is usually an acute, nontraumatic postoperative complication.[41–43] In contrast, the dog described herein was diagnosed with implant luxation after a traumatic event 270 days postoperatively. Furthermore, closed reduction of the hip was successful in maintaining long-term stability. Hence, because of the late onset, association with trauma, and success of conservative management, there is reasonable evidence to suggest that implant luxation may not have been a direct surgical complication in this dog.

Local tumor recurrence is a recognized complication of limb-sparing surgery in both dogs and humans.[6–9, 15–30] Local tumor recurrence was suspected in our dog because of radiographic evidence of a soft-tissue density adjacent the allograft. In dogs with OSA of the distal aspect of the radius treated with various limb-sparing techniques, the reported rate of local tumor recurrence is 10–28%.[6–9] The rate of local recurrence is significantly reduced by inserting cisplatin-impregnated open-cell polylactic acid biodegradable implants (OPLA™-Pt, Kensey Nash Corporation, Exton, PA) into the surgical wound bed.[44,45] However, OPLA-Pt was not used in this dog because the polymer material cannot be fixed with sutures and migration of these implants distant to the allograft was likely because of the size of the surgical field. In humans, the incidence of local tumor recurrence after proximal femoral limb-sparing surgery is $<10\%$.[15–31] Interestingly, as in the present case, the vast majority of recurrences occur in soft tissue adjacent to the surgical site.[29] The high rate of local tumor recurrence in soft tissue highlights the importance of using imaging modalities preoperatively, such as MRI, to assess neoplastic extension of primary bone tumors into adjacent soft tissue.

We described limb-sparing surgery in a dog with a proximal femoral OSA using a composite allograft–prosthesis technique. Limb function was good to excellent after surgery. Complications included allograft instability because of aseptic loosening and allograft nonunion that required revision surgery, and possibly implant luxation. Tumor control was good with a disease-free interval of 688 days, although local tumor recurrence was suspected.

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