FEMORAL REMODELING FOLLOWING STABLE LONG-TERM CEMENTED TOTAL HIP ARTHROPLASTY IN DOGS

INTRODUCTION: Total hip arthroplasty (THA) is an accepted procedure to treat intractable pain and severe arthritis in the coxofemoral joint of human and canine patients. Despite short-term success, complications due to aseptic loosening often require revision surgery. As the demand for THA in younger and more active patients increases, the need for long-term success becomes apparent.

Femoral remodeling has been implicated in implant loosening and subsequent failure. To date, both mechanical and biological events have been suggested as mechanisms leading to bone remodeling. The presence of the implant within the femur may shield the femur from normal loading forces, resulting in altered bone structure. Surgical techniques, including medullary reaming during prosthetic implantation, alter femoral blood supply and may affect bone remodeling. Generation of particulate debris by the articulation of reaming during prosthetic implantation, alter femoral blood supply and may affect bone remodeling. Subsequent femoral adaptation to the implant may lead to an extensive decrease in bone mass of the proximal femur, complicating revision surgeries.

We hypothesized that femoral bone remodeling is a dynamic process that continues to occur in response to long-term stable THA. The specific purpose of this study was to quantify the degree and location of bone remodeling in the canine femur following long-term THA in clinical cases, by measuring cortical bone area (B.Ar), medullary area (Ma.Ar), cortical porosity (Vd.Ar), and bone activation frequency (Ac.F). Because canine bone architecture and biological response to stress are similar to human bone, comparisons can be made between species.

METHODS: Hips of 12 dogs (mean age ± SEM 10.53 ± .88 years, mean weight ± SEM 31.64 ± 1.27 kg) that previously received unilateral cemented THA were included in this study. Length of implant duration ranged from 1.67 to 7.17 years (mean 4.33 ± .61 years). The animals were donated to a hip retrieval program after death due to causes unrelated to THA. All implants were grossly stable at time of retrieval. The femurs were fixed in 70% ethanol, embedded in polymethylmethacrylate, and transversely sliced and ground to approximately 100µm sections at three levels. Measurements were taken at three levels, four quadrants and two to three areas within each femur. Level 1 was immediately distal to the collar of the implant, level 2 was 3 cm proximal to the distal tip of the implant, and level 3 was 2 cm distal to the implant. Level placement was determined through radiographs. The contralateral unimplanted femurs were cut at the same location as implanted femurs. Sections were surface stained with a 1% aqueous Toluidine blue stain.

Bone morphology was analyzed through digital images captured with microscopes, a color camera (Sony, Model DXC-390), and a frame grabber (Scion Inc.). B.Ar and Ma.Ar were measured from images of each complete section captured with a stereoscopic microscope (Nikon, Model SMZ-10) at .66X magnification. Vd.Ar, and Ac.F. were measured from consecutive images from periosteum to endosteum in each quadrant (cranial, caudal, medial, lateral) at 90° intervals to each other, which were captured with a light microscope at 10X magnification. All measurements were obtained with an image analysis program (Scion, Inc.).

Mixed procedure of SAS was used to analyze data at split-plot analyses to accommodate the nested nature of the design. When p-values for the t-test were <0.05, comparisons were considered significant. Dog age, weight, and implant duration were included in the analyses as covariates and a backward elimination process was used to remove insignificant covariates. Because variables were not normally distributed, data were log transformed before analysis. Data are reported as mean ± maximum standard error.

RESULTS: The mean B.Ar. for implanted femurs (1.08 ± .05 cm²) was significantly greater than the mean B.Ar for non-implanted femurs (.92 ± .05 cm²). When implanted and non-implanted femurs were compared at corresponding levels, B.Ar was greater at level 2 (1.13 ± .05 cm² vs .87 ± .06 cm²) and level 3 (1.16 ± .06 cm² vs .94 ± .05 cm²) in implanted femurs. Dog weight was positively correlated with B.Ar. Within implanted femurs, B.Ar was greater at level 2 (1.13 ± .05 cm²) and level 3 (1.16 ± .06 cm²) when compared to level 1 (.95 ± .06 cm²). There was no significant difference between levels 2 and 3 within implanted femurs. There was no significant difference in B.Ar between levels within non-implanted femurs. Ma.Ar was not significantly different between implanted and non-implanted femurs. The mean Vd.Ar. for implanted femurs (7.10 ± .54 %) was significantly greater than the mean Vd.Ar. for non-implanted femurs (5.19 ± .46 %) (Figure 1). When implanted femurs were compared to unimplanted femurs at corresponding levels, cortical Vd.Ar was significantly greater at level 1 (7.88 ± .77 %) and level 2 (7.79 ± .77 %) in implanted femurs when compared to the non-implanted femurs (4.92 ± .57 % and 5.73 ± .65 %, respectively). When Vd.Ar. was compared within implanted femurs at each level, level 1 (7.88 ± .77 %) and level 2 (7.79 ± .77 %) had significantly greater Vd.Ar than level 3 (5.73 ± .59 %). Within non-implanted femurs, there was no significant difference in Vd.Ar between any level. Ac.F was decreased in the periosteal area of the quadrilateral in level 2 of implanted femurs (4.48 ± 1.03 #/mm/yr) when compared to non-implanted femurs (14.16 ± 3.15 #/mm/yr). At level 3, Ac.F was decreased in the periosteal area of the quadrilateral of implanted femurs (4.29 ± 1.00 #/mm/yr), when compared to the same level and region of non-implanted femurs (8.93 ± 2.06 #/mm/yr). Ac.F was negatively correlated with dog age.

DISCUSSION: Previously, short-term changes in porosity, vascularity and bone formation have been documented following canine THA, and some studies have suggested that the changes in Vd.Ar return to a state of homeostasis six months after initial implantation. The results of this study do not support a state of homeostasis and demonstrate significant differences in femoral bone architecture and geometry found in implanted femurs many years post-THA. Increases in Vd.Ar were observed proximally (in levels 1 and 2), and increases in B.Ar were observed distally (in levels 2 and 3), in implanted femurs when compared to unimplanted femurs. Increased Vd.Ar without increased B.Ar at level 1 indicates a loss of bone mass immediately distal to the collar of the implant. At level 3, B.Ar was increased, while Vd.Ar was not significantly different, compared to the same level in unimplanted femurs, resulting in an increase in bone mass distal to the implant. These findings suggest that femoral remodeling is a continuous dynamic process, and support the mechanical phenomenon of stress-shielding, whereby physiologic load bypasses the portion of the femur occupied by the implant and is redistributed distal to the implant tip.