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Christopher, Scott A ; Kim, Stanley E ; Roe, Simon ; Pozzi, Antonio

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Short Communication

Biomechanical evaluation of adjunctive cerclage wire fixation for prevention of periprosthetic femur fractures using cementless press-fit total hip replacement.

Scott A. Christopher[a], Stanley E. Kim[a], Simon Roe[b], Antonio Pozzi[a]*

[a] Comparative Orthopaedics Biomechanics Laboratory, College of Veterinary Medicine, University of Florida, Gainesville, FL
[b] Randall B. Terry Companion Animal Veterinary Medical Center, College of Veterinary Medicine, North Carolina State University
* Corresponding author

Email Addresses:
Scott A. Christopher: sachristopher@ufl.edu
Stanley E. Kim: stankim@ufl.edu
Simon Roe: simon_roe@ncsu.edu
Antonio Pozzi: antonio.pozzi@uzh.ch

Abstract

Periprosthetic femoral fractures are a common complication associated with cementless press-fit total hip arthroplasty. The use of prophylactic cerclage wire fixation has been advocated to reduce this complication. The objective of this study was to evaluate whether a double loop cerclage wire, used as adjunctive fixation, increases the peak torsional load to failure in femora implanted with press-fit cementless stems. Peak torsional load to failure was compared between femora without adjunctive fixation and femora receiving a 1 mm double loop cerclage wire placed proximally to the lesser trochanter. Femora treated with adjunctive cerclage wire fixation failed at 20% greater peak torque ($P = 0.0001$). In conclusion, a double loop cerclage wire may aid in the prevention of periprosthetic fractures associated with press-fit cementless femoral stems.

Keywords: total hip arthroplasty, cerclage, press fit, periprosthetic fracture

The BioMedtrix Biologic Fixation (BFX) total hip replacement (THR) system is a commonly used system for cementless press-fit THR in dogs (Marcellin-Little et al., 1999). Excellent outcomes have been reported for this system, with high client satisfaction and full return to function in most cases (Lascelles et al., 2010). One complication of BFX THR includes periprosthetic femoral fracture (Ganz et al., 2010) with a reported prevalence of 5% (Hunt and Preston, 2009). Postoperative femoral fractures are typically spiral, extending from the base of the femoral neck distally, suggesting that the most likely mechanism may be a combination of axial and torsional loads (Ganz et al., 2010; Jasty et al., 1992; Jasty et al., 1994). Prophylactic cerclage wire has been advocated for preventing periprosthetic fractures in dogs (Ganz et al., 2010). The goal of this study was to biomechanically evaluate the prophylactic use of double loop cerclage wire as adjunctive fixation for BFX THR.

This study was approved by the institutional animal care and use committee (#20138104, September 2013). Paired femora without evidence of pathology were collected from 10 mature dogs, euthanized for unrelated reasons. After taking orthogonal radiographs of the femur, the canal flare index, defined as the ratio between width of the medullary canal at the lesser trochanter and at the narrowest point of the isthmus (the region where the canal narrows distal to the proximal femoral metaphysis), was measured using the craniocaudal radiographic views (DeYoung et al., 1993). Femora with a canal flare index < 1.8 (stovepipe morphology) were excluded (Ganz et al., 2010). Only femora that fitted a size 8 BFX stems (Biomedtrix, LLC) were selected.

Femora were prepared and stems were inserted as previously described (McCulloch et al., 2012). Paired femora were randomly assigned to either the treatment group (with adjunctive cerclage wire) or the control group (without cerclage wire). For the treatment group, one double-loop cerclage wire of 1 mm (selected based on previous recommendations (McCulloch et al., 2010) was applied proximal to the lesser trochanter. Mean cranial canal fill was calculated on craniocaudal images by averaging the canal fill at the smooth/porous junction (proximal third) of the BFX stem, 5 mm proximal to the distal tip of the implant, and midway between these two points; mean lateral canal fill was measured in the lateral projections 5 mm above the distal tip of the implant in the lateral projection (DeYoung et al., 1993).

The distal end of the femur was potted (3M Bondo, 3M Corp) using a custom jig and fixed to the base of a servohydraulic materials testing machine (MTS 858 Mini Bionix II) equipped with an axial-torsional load cell. Specimens were mounted in the MTS and a custom made jig was attached to the actuator of the MTS (Pozzi et al., 2013). After biomechanical preconditioning, specimens were loaded to 300 N of axial compression and 0.5 Nm of torsional load for 2 seconds, then loaded to failure under a constant axial load of 300 N and internal rotation of the femur applied at a rate of 10°/s. Load at failure was defined as the load at which the fracture was first initiated and was associated with a sudden decrease in load and torque. High definition digital video camera was used to record fracture propagation. Fractures were classified using the Vancouver classification scheme (Brady et al., 2000).

For data analysis, a Shapiro-Wilk test was used to evaluate the normality of distribution. Canal flare index, canal fill, and peak torque load to failure were compared between the treatment and control group using paired t-tests (Prism, GraphPad Software, Inc.) $P < 0.05$ was considered significant. Slow motion and frame-by-frame video analysis was used to characterize the location and initiation site of the periprosthetic fracture.

Canal flare index and mean cranial and lateral canal fill was not significantly different between the treatment and control groups. Cerclage wire application resulted in a significant increase in peak torque at failure of 19.6%±1.2%.

All control femora failed with a similar fracture configuration, consistent with a Vancouver class B_2 fracture (Fig 1A). Femora with cerclage wire fixation fractured by one of three distinct manners: One femur fractured through the region at the base of the femoral neck resulting in cerclage wire failure and a loose femoral stem (class B_2); 2 femora failed with a spiral fracture extending below the stem into the diaphysis, (class C); the remaining 7 femora resulted in fractures originating as a small non-displaced fissure in region at the base of the femoral neck propagating distally resulting in a fracture with a well-fixed femoral stem (class B_1) (Fig. 1B).

This study showed that a double loop cerclage wire placed proximally to the lesser trochanter significantly increased the resistance to periprosthetic fractures in femora implanted with BFX under combined axial and torsional loads. Based on these results, prophylactic cerclage wire may reduce the likelihood of periprosthetic femoral fractures associated with BFX *in vivo*. This is in accordance with results of both clinical and mechanical studies investigating the benefit of cerclage wire application in conjunction with BFX (Ganz et al., 2010; McCulloch et al., 2012).

The fracture configurations observed in this study were consistent with previous reports of periprosthetic fractures (Ganz et al., 2010). As expected, a single cerclage wire limited fissure widening proximally, but had no protective effect distally. Therefore, multiple cerclage wires may be a better choice in dogs at high risk of fractures because of the ability to control fracture propagation distal to the lesser trochanter as suggested by previous human studies (Fishkin et al. 1999).

One limitation of this study may have been the variability associated with femoral preparation and implant application. However, this variation is considered insignificant because digital templating of stem size was performed by two experienced surgeons (SK and AP), surgical procedures were performed by a single surgeon (SK), and mean cranial and lateral canal fill was not significantly different between treatment and control groups.

In conclusion, application of prophylactic cerclage wire should be considered at the time of stem implantation in dogs with a proximal femoral morphology suitable for BFX but at risk of periprosthetic fractures.

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Conflict of Interest Statement

None of the authors of this paper has a financial relationship with other people or organizations that could inappropriately influence or bias the content of the paper. Antonio Pozzi is an instructor for THR Biomedtrix courses.

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Table 1

Mean ± SD for the treatment (with adjunctive cerclage wire) and control groups and corresponding P-values (treatment vs. control) for the parameters canal flare index, mean cranial canal fill (measured on craniocaudal radiographs), lateral canal fill (measured on lateral radiographs) and peak torque at failure.

	Treatment	**Control**	**P-value**
Canal flare index	2.09 ± 0.167	2.10 ± 0.155	0.39
Mean cranial canal fill	75.2 ± 6.67%	75.7 ± 5.8%	0.44
Mean lateral canal fill	65.4 ± 6.28%,	65.76 ± 6.83%	0.69
Peak torque at failure	22.71 ± 2.41 Nm	18.98 ± 2.91Nm	0.0001

Figure legends

Figure 1: Paired specimen representative of the typical fracture patterns noted in implanted femora with and without cerclage wire. In the untreated femur (A) the stem subsided (black arrows) and caused a Vancouver B_2 fracture: a fissure line originated from the base of the femoral neck and propagated distally resulting in an unstable femoral stem. In the contralateral femur with a double cerclage wire applied proximally to the lesser trochanter, a small non-displaced fissure at the base of the femoral neck with a well-fixed femoral stem can be noted (class B_1).