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Original Article

The Effect of Prophylactic Cerclage Wires in Primary Total Hip Arthroplasty: A Biomechanical Study

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ABSTRACT

Background: Despite literature to support the use of various cerclage techniques to address intraoperative femoral fractures in total hip arthroplasty, there are limited data to support prophylactic cerclage wiring of the femur during cementless implant placement. This study aims to evaluate the effect of prophylactic calcar cerclage wires on the biomechanical parameters required to produce periprosthetic femoral fractures and on the morphology of these fracture patterns in stable cementless femoral implants.

Methods: Ten pairs of matched fresh frozen cadaveric femurs were implanted with anatomic tapered cementless implants with or without the addition of 2 monofilament calcar wires. Specimens were axially loaded and externally rotated to failure. Initial torsional stiffness, rotation and energy to failure, and torque at failure were measured. Statistical significance was set at $P < .05$. Fracture patterns were classified according to a well-known classification system.

Results: Wired specimens required significantly more rotation ($P = .039$) and energy to failure ($P = .048$). No significant difference was detected in initial torsional stiffness ($P = .63$) or torque at failure ($P = .10$). All unwired samples developed a Vancouver B2 fracture pattern. Seven of the 8 wired specimens also developed a Vancouver B2 fracture pattern, while the eighth wired specimen developed a Vancouver B1 fracture pattern.

Conclusion: Prophylactic cerclage wire placement increases the rotation and energy to failure in well-fixed press-fit femoral implants. The increase in torsional energy needed for failure may reduce the risk of early periprosthetic fracture. Further studies are needed to evaluate cost vs benefit and long-term outcomes of prophylactic wiring. Based on the results of our study, consideration of prophylactic wiring should be addressed on a case-to-case basis.

Obtaining initial mechanical stability of cementless femoral implants during total hip arthroplasty (THA) is necessary to reduce micromotion so that bony fixation can reliably occur [1,2]. A well-known complication during the placement of cementless femoral implants is intraoperative fracture. The incidence of intraoperative fractures has been noted to be between 1.5% and 27.8% [2-5]. These fractures most commonly occur during femoral preparation [6] as the surgeon attempts to attain optimal initial stability [2,4,5,7-9].

Unidentified insertional fractures may propagate [10] and may compromise initial mechanical stability, which adversely affects bony ingrowth, resulting in early loosening [6,10]. Implant survivorship has not been shown to be affected when these fractures are identified and appropriately addressed [3,4,6,11]. Intraoperative femoral fractures tend to occur around the calcar and current treatment algorithms employ the use of cerclage techniques [6,7,10,12,13]. Cerclage wiring reduces fracture propagation by increasing the resistance to hoop stresses [5]. A single cerclage wire can provide stem stability at 890 N of load in the presence of a fracture [10]. However, the effect of cerclage wires in improving the resistance to fracture occurrence or propagation from torsional load has not been previously investigated.

Prophylactic use of 2-mm cerclage cables around the calcar has been proposed from a biomechanical analysis demonstrating an increase in hoop stress resistance [5]. Additionally, there have been

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clinical reports of prophylactically using cerclage cables in cases with significant hip dysplasia while implanting the Mallory-Head porous femoral implant [4]. This technique was employed to not only prevent visible fracture propagation, but also to minimize the impact of unrecognized fractures.

Concerns with routine application of prophylactic cerclage cables include the risk of neurovascular injury, increased operative time, and increased cost [3]. There is limited literature exploring whether there is a benefit of cerclage constructs beyond preventing the propagation of known and unknown hoop stress fractures. The purpose of this study is to determine whether the application of cerclage wires around the calcar affects the biomechanical parameters required to produce periprosthetic femoral fractures and/or alters the fracture patterns that occur around apparently stable cementless femoral implants.

Methods

Ten pairs of matched cadaveric femurs were obtained from 7 male and 3 female donors (age range 47-88, mean 70.2 years). The femurs had no evidence of bony lesions, malignancy, or metabolic bone disease. Femoral neck bone density was measured using dual-energy X-ray absorptiometry using the Hologic QDR-4500A (Hologic, Inc, Waltham, MA). Bone mineral density ranged from 0.53 to 1.39 g/cm^2 and did not reveal a significant difference ($P = .46$) between specimens of the test (cerclage wire) (0.79 ± 0.25 g/cm^2) and control (no cerclage wire) (0.77 ± 0.22 g/cm^2) groups. Anteroposterior radiographs were obtained from each specimen. Imaging was performed with specimens internally rotated at 15°, with the X-ray tube positioned 100 cm from the focal plane of the cassette. Each femur was templated from these radiographs with a 15-mm femoral neck cut at 20% magnification using TraumaCad software (Voyant Health, Westchester, IL). Specimens were stored at −20°C in airtight bags until testing at which time they were thawed at room temperature and cleared of all soft tissues.

A femoral neck osteotomy was created proximal to the lesser trochanter according to the preoperative template following manufacturer recommendations [14]. Matched specimens were then prepared in one of the 2 ways, alternating right and left between unwired and wired specimens. The unwired specimens were sequentially broached in anatomic version with the femoral neck until manual axial and rotational testing through the broach handle, as would typically be done intraoperatively, indicated sufficient stability. Afterward, rotational stability at 6.8 Nm (60 in-lb) of torque was confirmed using a torque wrench applied through the broach handle. The final broach was then removed and replaced with the correspondingly sized FDA-approved (FDA reference K110807) anatomic tapered femoral stem (ABGTMII; Stryker, Inc, Mahwah, NJ). Specimens that sustained visible fractures from insertion were removed from the study. All wired specimens were first prepared by placing two 1.0-mm diameter monofilament wires (18-gauge, Ethicon DS18; Johnson and Johnson, Somerville, NJ) just proximal to the lesser trochanter. Attention during wire placement ensured that wires were not crossed and were laid evenly on the calcar. The wires were tightened to 1.0 Nm (9 in-lb) using a custom attachment on a calibrated microtorque screwdriver (MT50AFH; Mountz, San Jose, CA), cut to approximately 1.7 cm and laid against the femur as would be done in surgery. The remaining femoral preparation for the femoral implant was identical to that of the unwired group.

A transverse osteotomy 30 cm distal from the apex of the greater trochanter was completed to remove the distal femur. The distal end of the remaining specimen was then fixed in a 45-mm long section of 2-inch polyvinyl chloride piping with two 3.2-mm (1/8 inch) diameter transfixing pins and the polyvinyl chloride pipe was filled with polymethylmethacrylate which was then allowed to cure completely.

Tests were performed using a biaxial servohydraulic testing machine (Model 1321; Instron Corporation, Canton, MA) retrofitted with MTS TestStar II digital controller (MTS Corporation, Eden Prairie, MN). Specimens were mounted at a 25° adduction angle such that the center of rotation of the assembly passed through the proximal end of the prosthetic neck, approximating the center of the femoral head (Fig. 1). The specimens were axially loaded to 500 N. The distal aspect of each femur was then externally rotated at 90°/s to failure [15]. Initial torsional stiffness from 5 to 40 Nm of torque, rotation and energy to failure, and torque at failure were analyzed via paired t-tests. Statistical significance was set at $P < .05$.

Fracture patterns were described and classified at the time of failure according to the Vancouver classification [16] which is the most widely accepted classification scheme for periprosthetic femur fractures and focuses on fracture location, implant stability, and available bone stock to guide treatment. Using these 3 factors, fractures are broken down into Vancouver A, B, or C. Vancouver A fractures occur around the greater or lesser trochanter and conservative measures are usually the mainstay of treatment. Fractures that occur around the implant itself are Vancouver B fractures and vary differently in treatment. Vancouver B1 fractures have a well-fixed implant and excellent bone stock and are typically managed with open reduction internal fixation with or without supplemental cortical strut allografts. Vancouver B2 fractures have a loose implant with excellent bone stock. These are the most common fracture patterns and are managed with revision THA with a long-stem prosthesis. Vancouver B3 fractures are those with a loose implant and poor bone stock and require revision THA with bone stock augmentation. Vancouver C fractures occur below the level of the implant and are treated with open reduction internal fixation.

Results

All the unwired specimens and 7 of the 8 wired specimens developed a Vancouver B2 periprosthetic femur fracture pattern (Fig. 2). All the Vancouver B2 periprosthetic femur fracture patterns contained at least one fracture line from the calcar into the metadiaphyseal region. The eighth wired specimen developed a Vancouver B1-like periprosthetic fracture pattern. This was considered a B1-like pattern because the fracture occurred at the

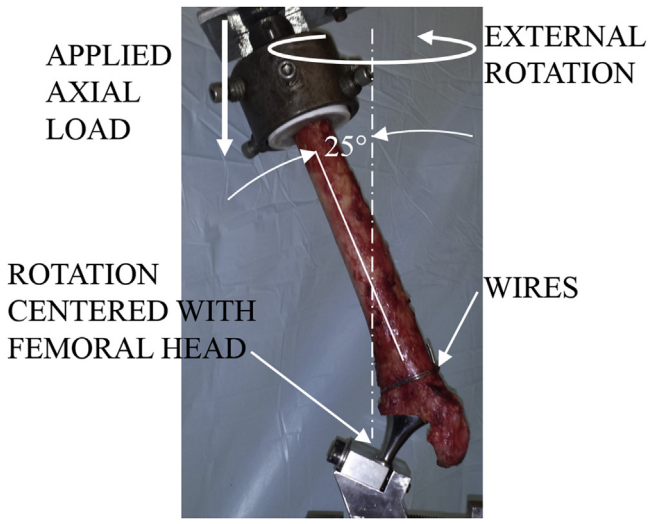

Fig. 1. Typical femur (right, wired) in 25° of adduction to the direction of axial loading with the axis of rotation aligned to the estimated center of femoral head.