The Journal of Arthroplasty Vol. 26 No. 2 2011

The Addition of a Hydroxyapatite Coating Changes the Immediate Postoperative Stability of a Plasma-Sprayed Femoral Stem

Amos Race, PhD,* Christopher D. Heffernan, BEng,† and Peter F. Sharkey, MD‡

Abstract: Nonbiologic and mechanical effects of hydroxyapatite coatings have received little evaluation. Hydroxyapatite coatings give porous metal the appearance of decreased roughness. We hypothesized that this apparent decrease in surface roughness would result in diminished initial implant stability. We measured the initial stability of titanium plasma sprayed press-fit femoral stems with and without HA. Stems were implanted into cadaver and synthetic femora and subjected to aggressive stair-climbing loads. Migrations (retroversion and subsidence) and cyclic motions were recorded. Hydroxyapatite coating significantly reduced retroversion (P = .0007) and cyclic subsidence (P = .0086). Scanning electron microscopy imaging revealed that HA coating appeared to have reduced roughness on a millimeter scale but increased roughness on a micrometer scale. We concluded that HA coating improves initial stability through mechanical means, before biological action. **Keywords:** hip, femoral stem, HA, stability, micromotion.

The use of hydroxyapatite (HA) coatings on uncemented joint replacement implants is controversial. Proponents of HA reference cell and animal studies, which reveal that coatings accelerate and enhance osteogenic adhesion [1,2]. Those who do not support HA cite clinical studies demonstrating little or no improvement in surgical results [3-5]. To the authors' knowledge, nonbiologic and mechanical effects of HA coatings have received little evaluation. We considered the possibility that mechanical factors might help explain the apparent contradictions in the HA coating literature. HA coatings give a rough metal substrate the gross appearance and feel of decreased surface roughness. We hypothesized that this apparent decrease in surface roughness would result in diminished initial implant stability and potentially result in a higher risk of bone osteointegration failure.

*From the *Department of Orthopedic Surgery, SUNY Upstate Medical University, Syracuse, New York; †Stryker Orthopaedics, Mahwah, New Jersey; and ‡Rothman Institute, Philadelphia, Pennsylvania.*

Submitted August 17, 2009; accepted February 9, 2010.

Benefits or funds were received in partial or total support of the research material described in this article. These benefits or support were received from the following sources: Stryker Orthopaedics.

Reprint requests: Amos Race, PhD, SUNY Upstate Medical University (ihp 3217), 750 E Adams St, Syracuse, NY 13210.

0883-5403/2602-0020$36.00/0

doi:10.1016/j.arth.2010.02.004

Methods

This study tested the effects of the HA coatings applied to a commercial plasma-sprayed β-titanium alloy stem (Accolade TMZF, Stryker Orthopaedics, Mahwah, NJ). Stems with the standard plasma-sprayed titanium coating overlaid with plasma-sprayed HA (standard) were compared with identical stems without HA (non-HA). Sections of each stem surface type were imaged using scanning electron microscopy and surface roughness measurements (Ra) taken using a Mitutoyo Surfpak QC-4050 (Mitutoyo America Corporation, Aurora, Ill). Stems of each finish were implanted into a homogenous set of synthetic femora and into paired cadaver femora. The motion of the implanted stems was recorded under short-cycle stair-climbing load, using a system that has been described previously [6].

Micromotion Measurement

Before implantation, all stems were drilled and tapped to accept a custom micromotion measurement target fixed via a USF10-32 set screw. The attachment point was on the posterior side of the implant, halfway between the stem's distal tip and neck. The 3-ball micromotion target was monitored by an array of 6 displacement transducers that were fixed to the cortex by 3 pointed screws, which were coplanar with the target (Fig. 1). Thus, stem micromotion was measured relative to the cortex in the same transverse plane as the target [6]. The system measured translations to 1 μm and rotations to 0.001°.

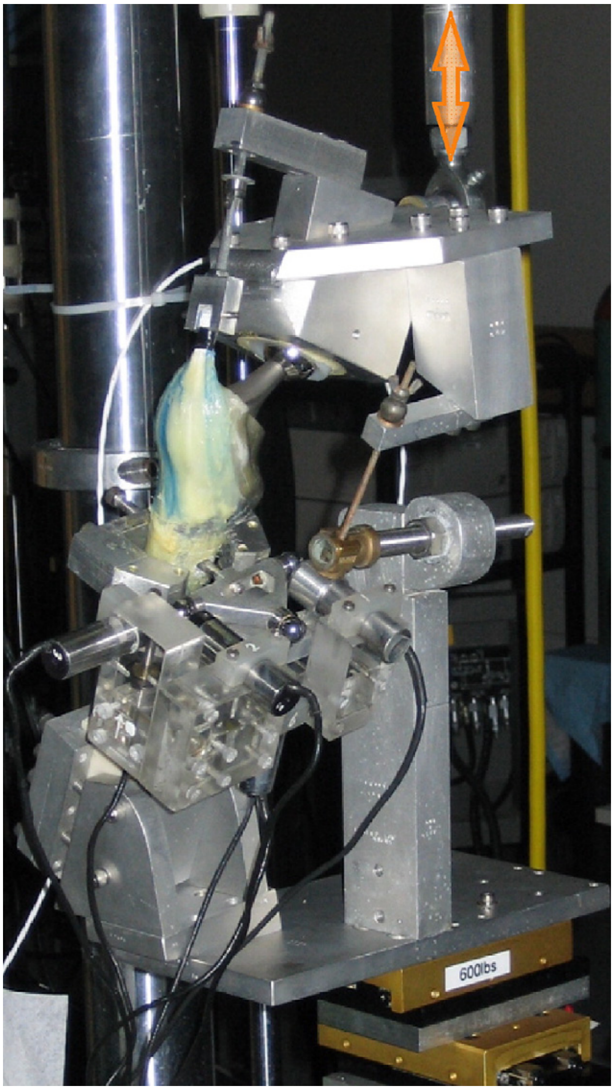

Fig. 1. Synthetic femur in the custom stair-climbing fixture. Load was applied to the femoral head via an acetabular cup. The greater trochanter was loaded via a strap to simulate the forces of the abductor muscles. The abductor loading strap was a high-stiffness woven plastic tape that was frayed and fixed with acrylic-based adhesive. Stem motion was monitored by an array of 6 displacement transducers (LVDT) bearing on a 3-ball target fixed to the stem via a portal in the cortex. The LVDT array was fixed using 3 setscrews in the same transverse plane as the target. For the sawbones, the area around the micromotion measurement portal and the contact points of the clamp for the LVDT array was reinforced with glass fiber and acrylic-based adhesive.

Cadaveric Specimen Preparation

Three fresh frozen pairs of femora were obtained from the Anatomical Gift Program of SUNY Upstate Medical University. Before selection for this study, the femora were screened for gross bone pathology by analyzing plain x-rays. Femora were stripped of all soft tissue and then prepared by an experienced total joint surgeon, after the normal clinical protocol for the Accolade TMZF Femoral Hip System. Each femoral pair was then implanted with a randomly assigned control/treatment pair of stems of an appropriate size. The distal thirds of the femora were then removed, and the remaining stem/femur constructs were potted in polymethylmethacrylate. Consistency of potting across pairs was ensured by a jig that held the femoral head. Postimplantation, A-P and M-L view plain radiographs were taken to check stem position (see Fig. 2). To fit a micromotion measurement target to the stem, 9.5-mm-diameter holes were drilled through the posterior femoral cortex, aligned with the previously machined holes in the stem (Fig. 1) [6]. During preparation and testing, care was taken to prevent the femora from dehydrating.

Synthetic Femora Preparation

Ten “sawbones” (3rd Generation Large Composite Femur, Pacific Research Laboratories Inc., Vashon, Wash) were prepared in a similar manner to the cadaver specimens. Because the synthetic femora were identical, neck resections could be performed identically, reducing variability. The cuts were made using a band-saw fitted with a jig designed to reproduce a standard neck

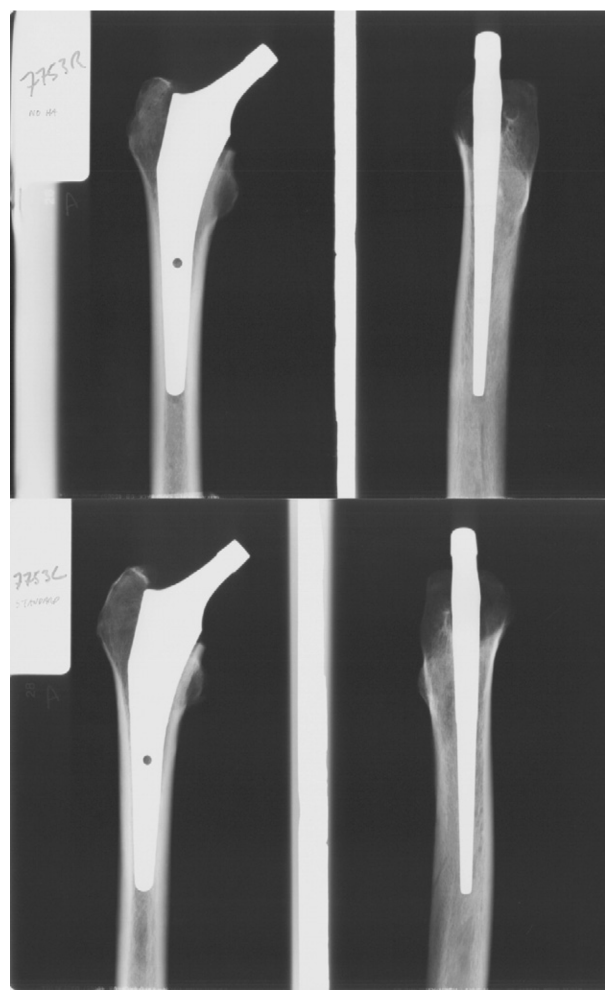

Fig. 2. Typical matched pair of femora implanted with (top) a non-HA stem and (bottom) a standard stem.