Failure Mechanisms of Bi-cruciate Retaining TKAs

+[1]Salehi, A; [1]Walker, B; [2]Ries, M; [3]Jerry, G
+[1]Smith and Nephew Orthopaedics, Inc, Memphis, Tennessee, [2]Tiburon, CA, [3] Port Huron, MI

INTRODUCTION: Bi-cruciate retaining (BCR) total knee implants maintain both anterior and posterior cruciate ligaments resulting in more normal knee kinematics. However, BCR implants were used in the past and abandoned because of high failure rates. The most common causes of failure in BCR implants have been aseptic loosening and bearing related problems. They are 2.2 times more likely to fail compared with posterior cruciate retaining implants [1]. Retaining the ACL may also lead to poor quality of implantation due to preservation of the ligament being technically more difficult [2]. The purpose of this study was to analyze clinically failed bi-cruciate retaining TKA implants to identify the shortcomings of the early designs which may minimize the failure risk for newer BCR designs using modern designing tools, improved materials, and fixation techniques.

METHODS: Twenty retrieved BCR knee implants (BioPro, Port Huron, MI, and Goemedic, Howmedica, Rutherford, NJ) were obtained and evaluated for mode of failure. With the exception of two polyethylene inserts, all were sterilized with gamma irradiation in air. The time in vivo ranged from 6 to 20 years. Optical microscopy, scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy (FT-IR) were performed to identify the failure mechanisms of the retrieved implants.

RESULTS: Mechanical failure of the tibial component occurred in all cases. There were 4 modes of failure, namely a) implant fracture, b) tibial insert disassociation, c) UHMWPE wear and d) tibial tray loosening. Two out of sixteen titanium trays fractured anteriorly, as shown in Figure 1. The SEM analysis indicated the fatigue fracture initiated from the anterior region of the ACL cut out from the baseplate. One out of two all polyethylene tibial implants fractured obliquely through the mid-section of the bridge. One out of two polyethylene inserts supported by CoCr tibial trays fractured through the anterior screw hole (Figure 2). Two out of sixteen BioPro inserts were disassociated anteriorly. Four inserts showed wear patterns consistent with malrotation insert resulting in peripheral bowing of the posterior part of the insert which likely contributed to dissociation. Seven out of eighteen tibial trays showed signs of burnishing on the porous coated surfaces, consistent with loosening.

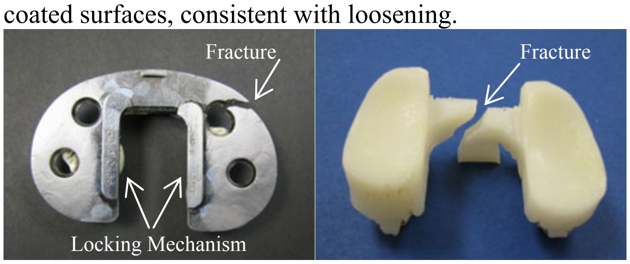

Figure 1. Fractured Ti-6Al-4V tibial tray and all polyethylene tibial implant

The oxidation index of the gamma-air sterilized polyethylene insert was examined using FT-IR. The peak oxidation index value recorded was 4.2. For reference, the oxidation index for a 6 year old cross-linked polyethylene (10 Mrad) and 10 year old virgin polyethylene inserts both sterilized by ethylene oxide technique was measured to be less than 0.02.

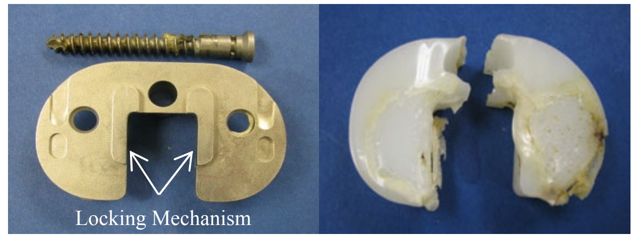

Figure 2. CoCr tibial tray with its corresponding polyethylene insert, fractured through the screw hole in the bridge

DISCUSSION: Our findings indicate that tibial component fracture and dissociation are common failure mechanisms of BCR TKA which is consistent with previous clinical reports. The anterior baseplate fracture is likely related to the lack of central baseplate material needed to accommodate the ACL bony insertion which results in high shear and bending stresses on the implant. Dissociation appeared to be related to the use of a central insert locking mechanism. The mechanical integrity of the insert attachment to the locking mechanism was disrupted as the posterior plateaus of the insert bowed outward from the center of the baseplate. In the past, delamination was also commonly observed since most of the UHMWPE implants were sterilized by gamma irradiation in atmospheric environment and stored in air. Today, the oxidation issue for conventional and highly cross-linked polyethylene is minimized or eliminated through the choice of sterilization technique and post annealing process, respectively. Evidence of loosening of the cementless porous ingrowth surface seen in this study is consistent with the less favorable results of cementless compared to cemented TKA. Failure mechanisms of BCR tibial components are consistent with the implant design features (inadequate anterior bridge strength and central longitudinal locking mechanism), material properties (gamma irradiated in air UHMWPE and porous coated either titanium or cast cobalt chrome alloys), and fixation methods used in the past. However these failure mechanisms rarely occur with currently available anterior cruciate sacrificing designs suggesting the mechanical problems with BCR designs may be addressed using modern design tools, implant materials, and fixation methods.

REFERENCES: 1. Stiehl et al., International Orthopaedics, 2006, 264**,** 2. Jenny et al, Arch Orthop Trauma Surg, 1998, 118 p 145-148**.**