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Analysis of wear asymmetry in a series of 94 retrieved polyethylene tibial bearings

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Abstract

Knee joint kinematics is the focus of a significant amount of experimental study for the purpose of knee prosthesis design and for testing the wear of current and prospective bearing materials. This study reports the wear assessment of a series of 94 explanted tibial bearings of various designs and manufacturers and focuses on the extent to which clinical wear is symmetric in the medial–lateral aspect, or is indicative of a systematic asymmetry that would be informative to the design and testing of knee prostheses or surgical practice. Wear assessment of the series of retrievals indicates that, statistically, there was more clinical wear on the medial side. Patterns of wear varied greatly among individual knees; a majority showed very similar extents of wear on the medial and lateral sides, however there were cases with significantly more wear on one condylar articulation than the other. Evidence of edge loading, whereby the femoral component articulates at the margin of the tibial bearing, was common. It was seen most frequently in the central zone of the medial condylar area, and, like the overall wear, edge loading was significantly more frequent on the medial side of bearings. Total bearing wear was seen to generally increase with time over the 208 months of in vivo duration covered by the retrievals in the study. The medial–lateral asymmetry of the wear does not appear to be significantly dependent on duration, however.

Keywords: Knee arthroplasty; Polyethylene wear; Retrievals; Wear; Wear pattern

1. Introduction

Knee joint kinematics is the focus of significant experimental study for the purpose of knee prosthesis design and for testing the wear of current and prospective bearing materials. Laboratory investigations have measured the stress distribution across the bearing surface (Andriacchi, 1994; Morrison, 1970; Postak et al., 1997; Schipplein and Andriacchi, 1991) and have modeled of the stresses within polyethylene knee bearings (Bartel et al., 1986; Collier et al., 1991; Wright et al., 1989). Wear simulators have been used to study the mechanisms of polyethylene wear in tibial bearing inserts, and have focused on the contact fatigue failure mechanism that is critical in the rolling and sliding articulation of the knee (Blunn et al., 1991; Currier et al., 1998; Feehan, 1990; Kennedy et al., 2000; Walker et al., 1996). A number of recent investigations have quantified the surface area of wear and the volume of wear in knee bearings under various gait pattern inputs in knee simulators (Bell et al, 2003; Conditt et al., 2003; Harman et al., 2001; Laurent et al., 2003; Muratoglu et al., 2003). Both the American Society for Testing and Materials (ASTM, 2002) and the International Organization for Standardization (ISO, 1996) have undergone extensive studies of knee testing protocols and have issued industry standards for testing of joint arthroplasty devices. There remains significant debate regarding the appropriate simulator inputs to simulate in vivo service of knee bearings. Direct comparisons of wear in retrieved tibial bearings with simulator wear on the same bearing design for similar numbers of cycles using the ISO testing standard (Harman et al., 2001) indicated that the damage to the retrievals was significantly greater (60–90%) in both anterior–posterior extent and area in the clinical retrievals.

In vivo kinematic studies of total knee arthroplasties have been done using a range of imaging modalities, including roentgen stereophotogrammetry (Karrholm et al., 2000; Nilsson et al., 1991; O'Connor et al., 1990),

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fluoroscopy (Banks et al., 2000; Dennis et al., 1998, 2001; Hoff et al., 1998; Stiehl et al., 2000) and gait analysis systems (Alexander and Andriacchi, 2001; Cappello et al., 1997; Kelman et al., 1989; Li et al., 2003). Findings from these studies have been variable and have sometimes given conflicting indications of kinematic phenomena. Various studies have indicated the dominance of posteriomedial rollback (Lewis et al., 1994; Morra et al., 2003), posteriolateral rollback (Banks et al., 2000; Dennis et al., 2003; Most et al., 2003), anterior translation with flexion (Andriacchi et al., 2003; Banks et al., 2000; Dennis et al., 2003; Stiehl et al., 1995), and both internal and external tibial rotation (Banks et al., 2000; Bertin et al., 2002; El Nahass et al., 1991). Therefore, it is of interest to observe and document the wear characteristics of explanted knee bearings to see how the various kinematic phenomena identified in laboratory studies are manifest in wear and damage of the tibial bearings over extended time in vivo.

There have been a number of published studies on the in vivo wear measured on retrieved total knee bearings. Several of these studies have assessed wear in a large number of retrievals, but do not report on the extent to which the wear is symmetric in the medial lateral aspect (Collier et al., 1996; Engh et al., 1992; Hood et al., 1983; Landy and Walker, 1988; Rose et al., 1979). Wasielewski et al. (1994) reported detailed wear data, separated according to the medial and lateral condylar areas, on a series of 55 knees of one design with an average in vivo duration of 34 months. That study reports a very strong predominance of greater damage on the medial side. More recently, Berzins et al. (2002) reported on 69 knees of the same design as in the Wasielewski study, and for a mean in vivo duration of 61 months indicated no medial–lateral difference in damage except for the severity of pitting, which was greater on the lateral side.

The objective of the current authors' study is to extend the wear assessment of TKA bearings to include the most recent retrievals, which encompass longer in vivo duration and more recent prosthesis designs than had been available to earlier retrieval studies. A particular focus of the current study is to quantify the extent to which wear observed in clinical retrievals is symmetric in the medial–lateral aspect, or is indicative of a systematic asymmetry that would be informative to the design and testing of knee prostheses or surgical practice.

2. Materials and methods

2.1. Knee retrievals

The prostheses used in this study were a series of 94 explanted tri-compartmental knee devices received by the Dartmouth Biomedical Engineering Center during the period 1/1/00 though 11/1/02. These explanted devices were received from 31 different retrieving surgeons. Excluded from the series were LCS Meniscal Bearing knees (DePuy, Inc, Warsaw IN), which have no documented labeling of the medial and lateral bearings, and are otherwise indistinguishable. All other tri-compartmental knee devices received during this time period were included in the study, regardless of implant design, size, thickness, in vivo duration, or patient variables.

The implants included in this study were from 9 different orthopaedic device manufacturers, and included 22 different designs (Table 1). The reasons for retrieval of the devices, as reported by the retrieving surgeon, are summarized in Table 2. Due to the large number of different device designs in this series, no attempt was made to correlate wear measurement with design or manufacturer. Radiographic records were not available for this series of retrievals, and therefore the wear results are not able to be correlated with joint alignment or with bone-implant positioning.

There were 50 right knee bearings and 44 left knee bearings in the series. There were 70 cruciate retaining

Table 1
Manufacturers and models of the knee devices included in this study

Manufacturer	Model	No. of bearings
Biomet	AGC	7
	GPACII	
Dow corning Wright/	Ortholoc	1
Wright medical	UCI	1
	Pivot	1
DePuy	AMK	4
	LCS-RP	2
	Townley	1
Howmedica	PCA	7
	Duracon	3
	Kinemax	1
	Finn	1
HSS	IB	1
Intermedics	Natural	2
Johnson & Johnson	PFC	47
	Sigma	2
	Microloc	1
Smith & Nephew	Gen II	1
	Tricon	1
	Profix	1
Zimmer	MG	5
	NexGen	2
	IB	1
	Total bearings	94