Introduction
In our previous comparisons of the wear debris between the mobile bearing knees and the fixed bearing knees, [1-2] the former was found to be associated with significantly higher prevalence of osteolysis than the latter, i.e., 47% for the mobile bearing knees and 13% for the fixed-bearing knees. Mobile bearing knees were found to produce smaller particulate debris (0.58 µm) and a higher percentage of granular debris (93%), most likely due to the more conforming articular surface and the additional wear on the flat undersurface. In this study, we focused on comparing the wear characteristics between mobile and fixed bearings, and between conforming and nonconforming total knee designs.

Methods
Between 1997 and 2002, 79 failed knee prostheses were available for tibial insert wear investigation. The wear pattern and debris of the UHMWPE retrieved from four different designs of total knee prostheses were evaluated. These four designs were Low Contact Stress (LCS) rotating platform knees (DePuy, Warsaw, IN), Total Condylar knee prosthesis (Howmedica, Rutherford, NJ), Porous-Coated Anatomical knees (PCA I, Howmedica, Rutherford, NJ), and Miller/Galante knees (M/G I, Zimmer, Warsaw, IN). The reasons for revision were polyethylene insert wear, loosening, and failure of components. No knee was revised due to infection.

The wear patterns of retrieved tibial inserts were analyzed by a stereomicroscope (Leica MZ6) and a digital image analysis system (Leica IM-1000). An articulating surface wear score modified by Hood et al. [3], Blunn et al. [4], and Tanner et al. [5] was used to evaluate the polyethylene wear. Integers, 0 (none) to 3 (severe), was used to quantify the size of the worn area. The zero grade meant that the damage mode was absent from each zone. Grades 1, 2 and 3 respectively denoted the observed damage was less than 10%, 10%-50%, and over 50% of the surface area of each zone. The severity factor of the damage was assigned according to the type of damage. The severity factors included 8 integers, 0 (no wear) 1, 2, 3, 4, 5, 6 and 7 (most severe wear) respectively for burnishing, abrasion, cold flow, scratching, pitting and metal embedded, delamination, and wear through. The wear score of a wear mode in a specific zone was obtained by multiplying the amount score by the severity factor. The damage amount present was evaluated for the backside area of the insert with the same grading system as for the articular surface.

Results
Delamination was found to be the principal wear modes of all designs. Severe delamination was seen in PCA I knees with several cases of polyethylene wear through (45.5%; 10/22). Lower incidence of polyethylene wear through were observed in TC (33.3%; 2/6) and M/G I (20.5%; 8/39) knees. Abrasion and scrapping were common in LCS-r and PCA I. All cases with embedded metal debris in M/G I were correspond to the severe wear in patellar components. The scratching pattern in the zone 2 and zone 5 were quite different in conforming and nonconforming tibial inserts. LCS-r and TC showed more rolling scratch while PCA I and M/G I showed more sliding scratch.

The list of the wear scores of the four brands in this study from high to low is PCA, TC, M/G and LCS-r. Most of the wear was seen in zone 2 and zone 5 regardless of the brand. Three out of 12 (25%) LCS tibial inserts showed asymmetric wear patterns, with two showing predominant medial side wear and one showing noticeably more lateral side wear. Three of the 6 (50%) TC tibial inserts showed asymmetric wear patterns, with one of higher medial side wear, one of higher lateral side wear and one of higher wear patterns on the posterior half of the insert. Both LCS-r and TC series did not show rotational wear. For the 22 PCA I tibial inserts asymmetric wear patterns were seen in 16 (73%). For the 39 M/G I tibial inserts asymmetric wear patterns were seen in 33.

The major modes of the backside wear in LCS-r were scratching and putting. The scratching patterns showed concentric circles centered at the cylinder of the backside of the tibial insert. The major back-side wear mode in PCA I and M/G I was abrasion accompanied with some pitting. Protrusion of polyethylene into screw holes and the imprint by the marks of the metal tray were also observed in PCA I and M/G I.

Discussion
In our study, abrasion was more frequently seen in LCS-r than in other designs, while delamination occurred predominantly on both conforming and nonconforming knee prostheses. The conforming design had a higher stability at the knee joint and a lower incidence of third-body wear of implants in our study. This result concurred with our previous findings of mobile bearing knees tended to produce higher percentage of granular debris and the particulate debris was finer due to more conforming articular surface and undersurface wear. [2] PCA I and M/G I knees had very similar backside wear patterns which showed slight abrasion related to the texture of the metal tray surface. Protrusion of polyethylene into the screw holes and imprints by the marks or lettering of the metal tray were also visible the back-side of inserts, indicating creep of polyethylene, also suggesting less relative displacement between the polyethylene insert and the metal tray, explaining for the slight backside abrasion seen.

In our study, nonconforming articulating surfaces showed a higher risk of severe wear and asymmetric wear than more conforming surfaces. The spontaneous malalignment in mobile bearing designs were proven advantageous in the wear scores in this study. Care should be exercised so as not to have an excessive posterior slope cut and improper rotation of tibia during surgery, particularly for the fixed bearing knees. Finally, the third-body wear on the back-side of the polyethylene insert needs to be assessed for both fixed bearing and mobile bearing design.