Introduction
Accelerated polyethylene wear has been recognized as the most important risk factor limiting the longevity of total hip arthroplasty that employs articulation between metallic femoral head and polyethylene. Ceramic femoral heads have been developed to reduce polyethylene wear. Some reported reduced polyethylene wear with ceramic heads, while others could not find their advantages compared with metallic heads. To eliminate problems related to polyethylene wear, hip prostheses without polyethylene, such as metal-on-metal or ceramic-on-ceramic hip prostheses, have recently been developed using new technology. These new hip prostheses have been highlighted and have widely come into clinical use. Studies using hip joint simulators have shown remarkably reduced amount of wear in these hip prostheses without polyethylene compared with those employing polyethylene.

On the other hand, change in lubrication of total hip arthroplasty can alter frictional torque-force acting at the socket-fixing interface, and thus can affect fixation of the socket. However, there have been few reports, to our knowledge, comparing friction between conventional hip prostheses with polyethylene and the recently-developed hip prostheses without polyethylene. We compared friction among various hip prostheses that are currently on the market and clinically in a widespread use.

Materials and Methods
Five manufacturers kindly donated new hip prostheses to this study. Because some manufacturers want to keep their anonymity, code letters (manufacturer E, K, J, D, and S) represent manufacturers. However, all the prostheses are in a widespread use in many countries including U.S.A.

Manufacturers E, K, J, D, and S donated 3, 6, 3, 1, and 1 types of prostheses, respectively. The type of hip prosthesis was represented by symbols as manufacturer: combination of articulating femoral and acetabular materials: diameter of the femoral head” in figures. Numbers of examined hip prostheses are described in the legend of Fig. 1. Metal used in “D:M-P:22” was stainless steel, while metal used in the other prostheses was cobalt-chrome alloy.

A pendulum friction tester was used to measure the friction coefficient. Bovine serum was used as lubricant. Friction testing was carried out under two loading conditions, with the load applied to the hip prosthesis being 18 kg or 48 kg. The initial amplitude was approximately 15°. Amplitude change was recorded and the change at the amplitude of 8° was used to calculate the friction coefficient. Frictional torque-force acting at the socket-fixing interface was calculated from the measured friction coefficient and the diameter of the femoral head. Because the size of the cementless socket that was most frequently used at the time of total hip arthroplasty at our hospital was 50 mm in the outer diameter, frictional torque-force acting at the point 50 mm from the rotation center was calculated. Group differences were assessed by ANOVA, and p < 0.05 was considered significant.

Results
Friction coefficients of the hip prostheses measured under 18-kg load are shown in Fig. 1. ‘Frictional torque / resultant force’ calculated from the measured friction coefficient and the head diameter is shown in Fig. 2. Alumina-on-alumina and metal-on-metal hip prostheses had significantly higher frictional coefficients and frictional torque-forces at the socket-fixing interface, compared with other prostheses with polyethylene (except for one prosthetic head [J:M-P:28]). These hard-on-hard hip prostheses also had higher friction coefficients under 48-kg load; thus higher frictional torque-forces were anticipated at the socket-fixing interface.

Discussion
The examined alumina-on-alumina or metal-on-metal hip prostheses had higher friction coefficients under both low and high loading conditions, when compared with the hip prostheses with polyethylene. These hard-on-hard hip prostheses have a large diameter of the femoral head (e.g. 28-mm). The higher friction coefficients and the larger head diameter are considered to result in higher frictional torque-forces acting at the socket-fixing interface as shown in Fig. 2. These high frictional torque-forces may be related to socket loosening in hard-on-hard total hip arthroplasties.

Fig.1. Friction coefficient of hip prosthesis under 18-kg load.
Each type of hip prosthesis is represented by symbols as “manufacturer: combination of articulating femoral and acetabular materials: diameter of the prosthetic head.” Materials: M, metal; P, polyethylene; A, alumina; and Z, zirconia. Each bar represents the average + SD. Numbers of examined prostheses were, from left to right, 3, 3, 3, 3, 5, 3, 7, 8, 5, 5, 5, 4, and 3. Arrow: statistically significant difference (p < 0.05), from a lower value to a higher value.

Fig.2. Frictional torque / resultant force.
Determined by friction coefficient in Fig. 1 and head diameter. Symbols and numbers of prostheses, as in Fig.1.