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Research Paper

Combined effect of the body mass index and implant size on the wear of retrieved total knee prostheses

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ABSTRACT

Total Knee Arthroplasty is a well-established surgical procedure performed to relieve pain and to restore function in knee osteoarthritis. A proper choice of the implant size is mandatory in order to guarantee the success of the implant and to respect the bone stock of tibial plateau and femoral condyles. The aim of this study was to investigate the combined effect of Body Mass Index and implant size on the wear damage of retrieved knee implants, a still debated subject. To this purpose, twelve total knee prostheses of the same design (NexGen, Zimmer, Warsaw, Indiana) but with different sizes were investigated. These prostheses were all cemented fixed bearing inserts and posterior stabilised. Roughness analyses were performed on femoral components to assess surface modifications. Micro-Raman spectroscopic characterization was performed on polyethylene inserts to evaluate crystallinity changes.

A worsening of the surface and a nonhomogeneous aspect was observed in the prostheses characterized by a high ratio between preoperative Body Mass Index and implant size, which we called Φ *factor*. Delamination, a good indicator for polyethylene osteolysis, was more pronounced in the inserts having a high Φ than in those with a low Φ. Micro-Raman analyses showed more significant crystallinity changes in the prostheses of lower size, in agreement with the results previously obtained in vitro.

The findings of the present study suggested that the Φ *factor* can be considered a predictor factor of the Total Knee Arthroplasty overall performance. Potentially, it could be used as a discriminating factor to redact Total Knee Arthroplasty outcome and prevent complications.

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1. Introduction

Total Knee Arthroplasty (TKA) is a well-established surgical procedure for pain and functional impairment in knee osteoarthritis (Falez, 2014; Wylde et al., 2007). Overweight and obese people are an ever-worsening problem in the modern society. The incidence of obesity has increased in recent decades, acquiring epidemic proportions in developed countries. The index commonly used to classify underweight, overweight and obesity in adults is the Body Mass Index (BMI). According to the International Classification (Avenell et al., 2004), the classes are defined as follows: normal, 18–24.9 kg/m^2; overweight, 25–29.9 kg/m^2; obese, more than 30 kg/m^2. Even if the links between overweight and obesity and a range of other serious diseases (diabetes, heart disease, cancer, etc.) are clearly understood, more recently epidemiological studies have shown a strong association between increased BMI and the risk of developing osteoarthritis in hip and knee joint at an earlier age (Changulani et al., 2008; Cooper et al., 1998; Bourne et al., 2007; Sturmer et al., 2000). Poor clinical outcomes with more frequent complications were observed in obese patients when undergoing total joint arthroplasty comparing with those who have a low BMI (Winiarsky et al., 1998). In contrast, a recent study has found that post-operative complication rates were not significantly high for morbidly obese patients (Napier et al., 2014). Although the tribological behaviour of a TKA is strongly influenced by the implant design (McEwen et al., 2005; Battaglia et al., 2014; Affatato et al., 2013), a proper choice of the implant size is mandatory in order to guarantee the success of the implant and to respect the bone stock of tibial plateau and femoral condyles. The knee is characterized by a complex morphometric relation and, nowadays, there are no studies about the combined effect of patient weight and knee size on wear. In fact, the patient weight does not simply reflect the knee size; it is not surprising to observe patients with the same weight but very different knee sizes (Battaglia et al., 2014; Glave et al., 2014; Cimmino et al., 2013).

Retrieval analysis of failed total knee prostheses is essential to investigate the wear mechanism leading to osteolysis and, thus, loosening of the implant. Polyethylene wear is frequently cited by orthopaedic surgeons as the cause of failure and revision of knee arthroplasty devices. A certain damage to the articulating surface could cause further damage to the UHWMPE tibial bearing surface, which is softer. So then, an increased wear particle production could be generated, leading to osteolysis and prosthesis failure (Siddique et al., 2003).

While some studies have evidenced the greatest damage accumulated in the first year of implant (Scholes et al., 2013), it is still unknown if all the different implant sizes behave in the same manner and reflect the mean behaviour.

Moreover, UHMWPE exhibits the so-called cross-shear effect and its wear cannot be simply predictable by Archard's equation (Battaglia et al., 2014; Archard and Hirst, 1956; Mazzucco and Spector, 2003).

In fact, polyethylene wear may need complex wear prediction equation such as the algorithm proposed recently by Strickland et al. (2012), taking into account also the contact area. So then, an analysis on UHMWPE inserts could be an advantage over the understanding of wear debris production, leading to osteolysis. However, the samples analysed in these studies are usually different in prosthesis type, design, stabilization and fixation. A study on this non-homogeneous cohort could lead to erroneous data interpretation, since wear may be significantly affected by the above mentioned factors. In fact, based on different tribological behaviour, it cannot be excluded a large influence of the prosthesis type, design, stabilization and fixation on the surface characteristics of the retrievals.

This study was aimed at investigating the combined effect of BMI and implant size on the wear damage of retrieved total knee prostheses. In our opinion, the identification of explants with focal damage patterns is of great importance to gain insights into the damage that occurs at the articulation between the tibial and the femoral components. In particular, on one hand, this research study may improve the understanding of the tribological behaviour of total knee prostheses. On the other hand, it may help the surgeon to select the best implant size of TKA considering patient's BMI in order to reduce complications. Furthermore, we focused our attention toward those evidences that can support the idea of a descriptive or predictive factor for TKA failure.

2. Patients and methods

In this study twelve total knee prostheses were considered; they were chosen from a large dataset available in our Institute. In particular, a set of more than 300 TKA revised at our Institute between 2005 and 2010 was taken into account. From these explanted prostheses, those failed for pain, loosening of one component (femoral or tibial), fracture of one component, and dislocation of the prosthesis were excluded. Only a representative sample group of retrieved knee prostheses was taken into account; they had the same design (NexGen, Zimmer, Warsaw, Indiana), but different sizes, and were in good explanted conditions. Moreover, from all the available explanted knees, we decided to consider only those that reflect the same desired characteristics in terms of fixation and stabilization.

The chosen prostheses were explanted from 12 patients after a mean of 3.2 years (from 1.1 to 7.4 years); there were 10 women and 2 men with a mean age of 68 years (ranging from 48 to 77 years) at implantation. These prostheses were all cemented fixed bearing inserts and posterior stabilised (the ultra-high molecular weight polyethylene meniscal component snaps or press fits into the tibial tray). Patient's details are shown in Table 1.

2.1. *Macroscopic evaluation*

Three independent observers (SA, EC, SB) carried out a qualitative assessment of the patterns of damage to the retrieved TKA. Further visual analyses were performed using a Nikon SMZ-2T (Japan) stereomicroscope on both femoral components and UHMWPE inserts, distinguishing medial and lateral compartments.