4.3 Ceramic Knee Design

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Introduction

The first ceramic knee prosthesis was implanted in 1972 by G. Langer at the Orthopedic Clinic at the University of Jena [1]. It was an alumina partial prosthesis where only the unicondylar tibial surface was replaced. This prosthesis was used in 73 cases from 1972 and 1980. Since the direct contact between ceramic and cartilage produces a limited wear, such solution is studied still today for special cases [2].

The first alumina total knee prostheses were produced in the early 80s by Kyocera Corp. in Japan (Kyoto) and were implanted by Oonishi. Throughout the years, the interest of Japanese orthopedists for ceramic prostheses has increased and today several different models are being produced (all by Kyocera Corp.).

For ceramic total knee prostheses, polyethylene has been always used as the articular liner. Even though the most critical element with respect to polyethylene, in tribological terms, is the femoral component, alumina was used also for tibial plates in the first Japanese ceramic prostheses. The primary fixation of the first ceramic knee implants was predominantly attempted without using bone cement.

Remarks on the Ceramic Knee Prostheses

It is questioned in the orthopedic community whether the use of ceramics for knee prostheses can offer real advantages with respect to traditional metal. For hip prostheses, alumina provides considerably better mechanical properties than any other material. In case of ceramic-ceramic couplings, implants can be considered everlasting from the tribological point of view, apart from the exceptionally rare fracture problem. Even if alumina is used only for the femoral head, when coupled with polyethylene, its advantageous wear behavior in comparison to metal femoral heads is statistically acknowledged. However, the articulation of hip and knee joint is very different. In case of hip prostheses, the clearance between the diameters of the ball head and the acetabular liner is in the range of 100 µm, and lubrication may be a critical issue. In particular, there is an adverse influence of gravity to the formation of the fluid film between the head and the liner. Thus, the use of ceramics is recommended because of its superior wettability with water based fluids like synovia. On the other hand, in knee prostheses the difference of curvature between the femoral component and the tibia liner is very high (especially in flexion) and the gravitational effect is such that the synovia liquid is preferably directed to the articulating interface, thus improving lubrication.

Due to the improved wettability of the ceramic, we expect lower friction in the articulating interface and consequently a lower wear rate. Furthermore, as the lubrication also decreases the shear forces in the polyethylene liner, pitting may be suppressed.
In vitro tests on ceramic prostheses

From the tribological point of view, laboratory analyses have shown that ceramic femoral components have somehow higher quality properties than CoCrMo alloy models. When comparing alumina and CoCrMo femoral components, Yasuda [3] reports a polyethylene wear rate 5 times lower when it is coupled with alumina as well as the absence of scratches due to abrasion on the ceramic surface, unlike the case of metal surface. The latter observation was also reported by Davidson [4]. However, a very important factor when evaluating polyethylene wear in vitro is the surface roughness of the femoral component. According to the tests carried out by Lancaster [5], when comparing femoral components with the same roughness, there seem to be no significant differences between ceramic and metal models. In practice, however, it is well-known that the ceramic surface finishing is usually better than the one which can be obtained on metal surfaces.

Clinical experience with ceramic prostheses

Oonishi et al. [6] reported the results of 108 patients treated surgically with alumina prostheses (both femoral and tibial) for rheumatoid arthritis and gonarthrosis with a follow-up ranging approximately from 5 to 8 years. Most of these implants were performed without acrylic cement. No pain was reported by 62% of the patients, while 26% felt moderate pain during walking. In 9 cases, for which no cement was used, aseptic mobilization occurred, and in most of cementless cases displacement of components was reported; the authors therefore concluded that fixation without cementation was not recommendable.

The same conclusion was drawn by Tateishi et al. [7]: among their 23 cases of cementless implants of KC-1 prostheses (Kyocera Corp.) for rheumatoid arthritis, 6 cases of mobilization for poor bone trophic characteristics were reported.

The importance of cementation was underlined by Koshino et al. [8] whose experience with cemented YMCK prostheses (Kyocera Corp.) in 90 cases (follow-up of 56± 20 months), still in patients suffering from rheumatoid arthritis, was considerably better, since they had a survival rate equal to 99.1% at 8 years, without periprosthetic osteolysis.

The work by Yasuda [9] is very interesting: long term results (follow-up ranging from 5 to 10 years) were compared between a ceramic prosthesis (LFA-I, Kyocera Corp.) and a metallic model (Kinemax, Howmedica). Both models were cemented and all patients followed the same post-surgery protocol. Considering 105 ceramic prostheses and 84 metal prostheses, the results are considered comparable (HSS score: 85 e 86, ROM: 112° e 113°, respectively). However, a significant difference refers to radiolucency lines (2.7% in ceramic prostheses and 10.5% in metal models). Yet it must be remembered that the polyethylene wear in prosthetic implants is not exclusively due to friction between materials, either ceramics or metal, but also, and above all, to the sterilization method used for polyethylene. In Yasuda's work no mention is made to the differences, in terms of treatment and sterilization, between the polyethylenes used for the two groups of prostheses.