MINI REVIEW

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The importance of bearing surfaces in hip replacement

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ABSTRACT

Hip replacement is a successful operation. The increase of life expectancy increased also the number of patients with hip arthritis. It also highlighted the need to produce implants that would last longer. This mini review article provides information about the important role of bearing surfaces in the longevity of hip replacements as well as their evolution over time.

Keywords: hip replacement; bearings; longevity; ceramics; polyethylene; vitamin E

Introduction

More than a century has passed since 1891, when Dr Themistocles Glück performed the first total hip replacement [1]. Innovation and research generated by the growing need of arthritic patients to maintain a good quality of life, led to the introduction of the first modern, low friction, total hip replacement by Sir John Charnley [2]. His pioneering work laid the foundation to an industry expected to be worth 9.1 billion dollars by 2024 [3]. Numerous types of fixations, various prosthesis shapes and different bearing surfaces have been introduced since then. Their overall results were good enough to make total hip replacement one of the most popular and successful operations in orthopaedic surgery.

However, apart from good functional outcome and pain alleviation, component survival has also been a concern. The increase in life expectancy increased also the number of people suffering from arthritis. In addition, it highlighted the need for implants that would last long enough and prevent younger patients from having revision surgery.

Numerous studies demonstrated that the survival of hip arthroplasty implants was inversely proportional to the size and number of static and dynamic loads they bear. Longevity could therefore vary according to patient body weight, age and lifestyle [4,5,6]. Moreover, implant wear is related to the material and size of the load bearing surfaces [7,8].

Aseptic loosening is the primary cause for hip revision. This devastating complication is resulting from a particle disease caused by femoral head movement on

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the acetabular liner [9]. Tribology was used to investigate the reasons causing osteolysis. The latter is the science that studies the behavior of various materials that are in relative motion. It is considered fundamental for the study of prostheses survival and the development of new bearings.

The bearing surfaces used in modern hip replacements are either ceramic on ceramic (CoC), metal on polyethylene (MoP) or ceramic on polyethylene (CoP).

CoC bearings exhibit increased hardness and scratch resistance. These features warrant optimal lubrication thus lowering friction and consequently preventing debris accumulation. Furthermore, CoC allow the use of larger femoral heads irrespective of the thickness of the acetabular liner. Thus, greater femoral head-neck ratio and increased jump distance are achieved that offer better range of motion and improved stability [10]. Hernigou et al found an additional reason for CoC's lower dislocation rate. He observed that the capsule in COC bearings was thicker, thus providing greater stability than the elastic tissue seen when polyethylene cups are used. He therefore attributed the lower dislocation rate to a different joint capsule histology. [11].

The major weaknesses of CoC bearings are their brittleness, high cost and the production of annoying squeaking sounds. Brittleness of alumina ceramics was a big concern when CoC were first used. That issue was addressed with the introduction of strontium oxide platelets and zirconium particles. Consequently, the incidence of fractures dropped significantly from 0.021% to 0.003% [12]. However, their relatively high cost and squeaking sound issues have yet to be addressed.

MoP was first introduced by Sir John Charnley in 1961. Ultra high molecular weight polyethylene (UHMWPE) is a material with chemical inertness, low antigenicity and low friction coefficient. These advantages made it the most popular bearing in hip arthroplasty. However, despite the good post-operative outcome, the wear rate of UHMWPE was considerably high. The articulation between the metal head and UHMWPE produced significant amount of wear particles that induced an inflammatory response. Consequently, osteolysis and loosening occured that ultimately increased the need for revision surgery.

The development of highly cross-linked polyethylene (XLPE) offered solutions to the problems caused by UHMWPE and played an important role in retaining the popularity of MoP [13,14,15]. XLPE is the outcome of a process responsible for altering the molecular structure of polyethylene, thus making it more durable to adhesive and abrasive wear. Some studies even suggested that it decreased wear in vitro by 92%[16]. These properties instigated a remarkable decrease of linear penetration and volumetric wear, even though the former is also affected by the size of the femoral head. The incidence of osteolysis and implant loosening decreased by 69.4% at 15 years after primary hip replacement [14]. Moreover, XPLE decreased the revision rates of MoP to an extent that they are now comparable with other modern bearings [13].

MoP continue to be the most commonly used bearings in hip arthroplasty, however they are not anymore the most common in young patients. Next generation XLPE may have offered peace of mind to arthroplasty surgeons, however CoC exhibit lower rates for revision, osteolysis, aseptic loosening and dislocation [17,18,19,20]. The superiority of CoC is indisputable but the issues of squeaking and brittleness are still preventing surgeons from using it. In fact, over the last 7 years arthroplasty surgeons exhibit a steadily increasing preference for CoP bearings, especially in younger patients [13].

CoP bearings combine the properties of ceramics and next generation XLPE. They are hard-on-soft bearings linked with considerably lower fracture risk than CoC. Furthermore, they have not been linked yet with squeaking sounds [21]. CoP have similar Harris hip scores, loosening rates and dislocation rates with CoC [22]. However, due to volumetric polyethylene wear being dependent to the size of femoral heads, ceramic heads larger than 36mm are not recommended [13]. Moreover, they have higher survival rate than MoP and CoC, even though their wear rate is higher than CoC [23].

Second generation highly cross-linked polyethylene use vitamin E as an antioxidant to further reduce polyethylene oxidization. Since they have been in the market for less than 10 years, only a small number of

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studies have investigated the survival of these components. Apart from preventing polyethylene oxidization, vitamin E diffusion is believed to improve fatigue strength, reduce the biological activity of wear debris and lower the risk for infection [24]. A recent study about the 5-year in vivo experience with vitamin E diffused XLPE, showed that the latter demonstrated lower head penetration compared to non-vitamin E diffused liners [25]. Moreover, other studies demonstrated that second generation XPLE were superior to older polyethylene liners in restraining damage caused after neck and liner impingement [26].

Discussion

MoP remains the most used bearing in hip arthroplasty. But this is because the majority of people having hip replacement are over 70. In young patients there is an evident preference towards using ceramic bearing surfaces. Since their issues with brittleness and squeaking haven't been solved there was a need for a third option. The production of XLPE made CoP bearings a good option for young people that need implants with greater longevity.

Conclusion

Even though the information coming for vitamin E diffused polyethylene is promising, more time is needed to understand if the perfect polyethylene has been created. However, it is safe to say that with the application of new materials and the gradual drop of revision rates we are on the right track for making hip replacement an even more successful operation.

Conflict of interest:

The authors declared no conflicts of interest.

Abbreviations: ceramic on ceramic (CoC),
metal on polyethylene (MoP),
ceramic on polyethylene (CoP),
ultra high molecular weight polyethylene (UHMWPE),
highly cross-linked polyethylene (XLPE)

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