Wear Characteristics of various Alloys in Hip Prosthesis

A Review

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ABSTRACT

In this paper we are going to do review about the wear characteristics of various metal alloys on hip prosthesis and we compare the wear characteristics of ceramic on UHMWPE with ceramic-on-ceramic(CoC), metal-on-metal (MoM) & metal on UHMWPE. Here we discuss about various alloys limitations and the advantages of ceramic on UHMWPE on other alloys. We used manual search to identify all relevant studies reporting on ceramic on UHMWPE. The objective is, to determine whether current ceramic on UHMWPE offers a better wear resistance , larger replacement lifetime than the other alloy compositions.

Key words: UHMWPE, CoC , MoM, Metal on Polyethylene and Wear Resistance

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INTRODUCTION

Hip replacement is a surgical procedure in which the hip joint is replaced by a prosthetic implant. Hip replacement surgery can be performed as a total replacement (or) a hemi (half) replacement. In a total hip replacement the damaged bone and cartilage is removed and replaced with prosthetic components. The damaged femoral head is removed and replaced with a metal stem that is placed into the hollow center of the femur .A hemiarthroplasty involves half of the hip ,which replaces only the ball portion of hip joint, not the socket portion. In total hip replacement, the socket is also replaced.[1-a]

Ceramic on UHMWPE is one of the most commonly used alloys in biomedical implant materials. This alloy is used for artificial hip prosthesis replacement. This alloy is well known for its wear resistance and also good mechanical properties and by its biocompatibility. These type of alloys are frequently used in the practical purpose, there also other alloys which have its unique features. [1-b]

Here we focus on the current ceramic on UHMWPE. It is made by many composition and one of its composition is referred from the journal. UTEC-UHMWPE-BRASKEM. The manufacturing of ceramic bearing for the prosthesis is taken under strict control and carefully done with international quality standards.

The following figures shows the femur head and socket region at various conditions. figure-I shows the normal thigh bone structure and figure-II shows the damaged structure which is mainly caused by accidents that needs replacement and finally figure-III shows the structure after hip prosthesis is done.

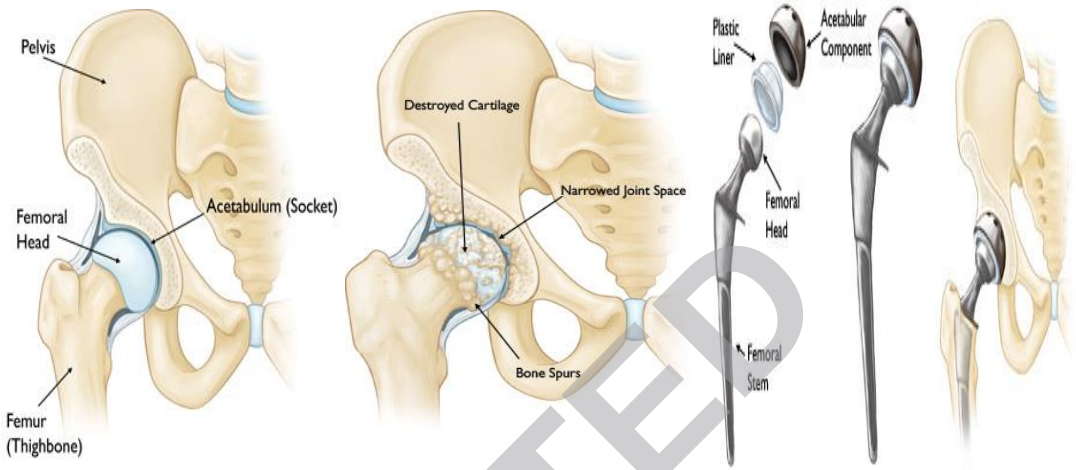

Figure-I Figure-II Figure-III

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Metal-on-Metal Alloy

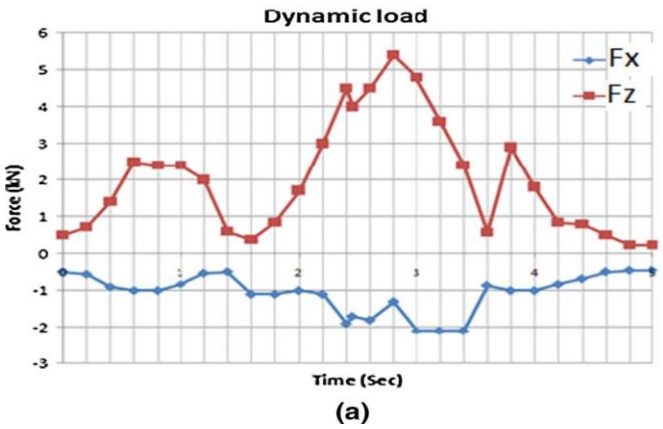
These alloys of hip implants were used even longer than the other three alloys. They generally cobalt-chromium alloy, titanium alloy or stainless steel sometimes were used since 1955.

The modes of wear takes on basically four types the first one is that the ball is articulating within the socket and the second one is due to micro separation or complete dislocation. The third one is severe that the entrapped particles broken away from a porous coating. The fretting at the morse tapper junction is the fourth one [1]. Apart from these modes the alloy has other wears such as abrasive, fatigue, tribo-chemical, corrosion, scratching, polishing and cracks [2].

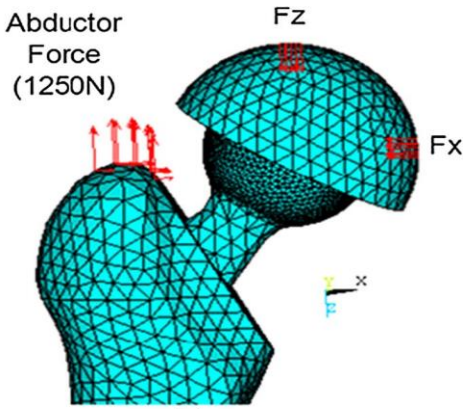
These alloys also releases the metal ion and the metal tends to corrode which leads to the allergy of patient. These alloys forms a surface of oxide film which is a continuous process that leads to the partial dissolutional reprecipitation in the aqueous solution [3].

Metal-on-Plastic

Metal-on-Plastic (polyethylene) is the longest tried and tested bearing. The convex femoral stem is constructed of metal (usually a cobalt chrome alloy) and the concave cup liner is made of a plastic called polyethylene.



(a)



(b)

The maximum lifetime of these alloys were just 14 years when a force of 1250N were applied at 20 degree angle to the proximal area . The following figure shows the reffered analysis of the bone structure [2]. So the entire prosthesis setup, hence is to be replaced once in 14 year as a major complication and is highly at risk [4].

Ceramic on Ceramic

CoC alloys are majorly incorporated in the 21st century hoped to provide better results in the hip prosthesis. The wear rate of ceramic is minimum and also the materials has no toxic (or) side effects in the human body [6]. Ceramic is one of the hardest material and also possess lower wear rate which is almost 1000 times less than metal on polyethylene.

The approximate rate is 0.0001 millimeter each year. Even though these alloy has major advantages still it has its own limitations [7]. The following table-1 [7] compares the different parameters of Ceramic-on-Ceramic alloy with the Metal-on-Metal and metal polyethylene.

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Figure 1

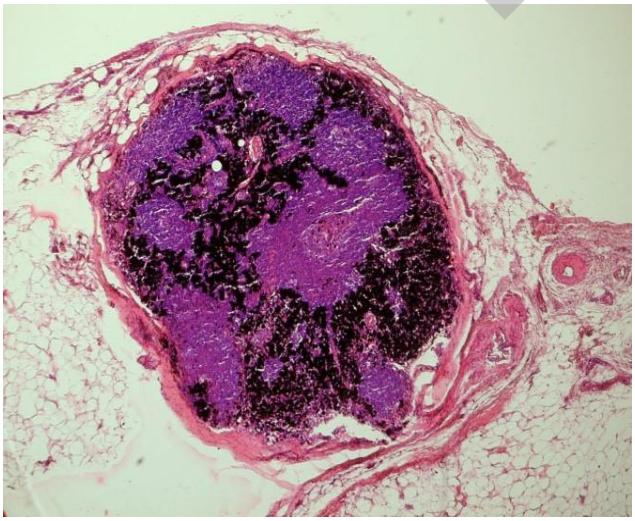

Figure 2

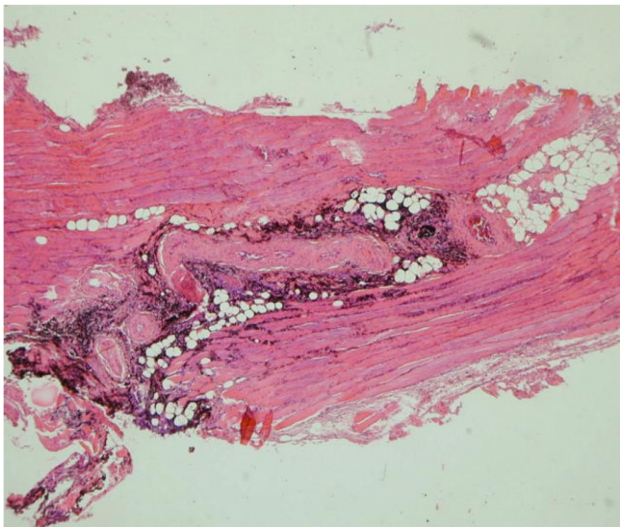

Table-1 Summary for a review on ceramic on ceramic THA.

Parameter	Ceramic on Ceramic	Ceramic/Metal on Polyethylene	Metal on Metal
Wear rate	30.5±7 μm/y[64]	218.2±13.7 μm/y[64]	20–25μm/y[65]
Particle size	0.13–78 μm[66]	30 nm–10 μm[67]	30–100 nm[68]
Cellular response to wear particles	Low	High	High
Hypersensitivity induced by wear debris	No	No	Yes
Tissue necrosis, ALVAL	No or weak	Weak	High grade
Dislocation#	0.78%	0.80%	0.74%
Infection#	0.32%	0.49%	0.53%
Mechanical loosening#	0.39%	0.22%	0.20%
Revision#	1.02%	1.16%	1.12%
Noisy hip	Up to 33%	Rarely	Less frequent
Survivorship, 10 yrs. FU	99% (95% CI; 97–100%)[28]	95.6% (95% CI; 90.1–98.3%)[69]	95.4% (95% CI; 85.8–99.8%)[70]
Survivorship, 20 yrs. FU	84.4% (95% CI; 0.56–1.33)[23]	81.8% (95% CI; 79.0–84.6%)*	84% NA[71]

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The majorly caused damage in the CoC alloy is ceramic head and linear fractures. The figure1 and 2 illustrated above shows that the head of ceramic has a chance of fracture between 0.26% and 13.4% and ceramic liner is between 0.02% and 5.3% [8]. Apart from these, this alloy has major issues in making noises emanating from ceramic bearings which is known as squeaking. Damage of ceramic rim also occurs since the ball and socket material are same [8].

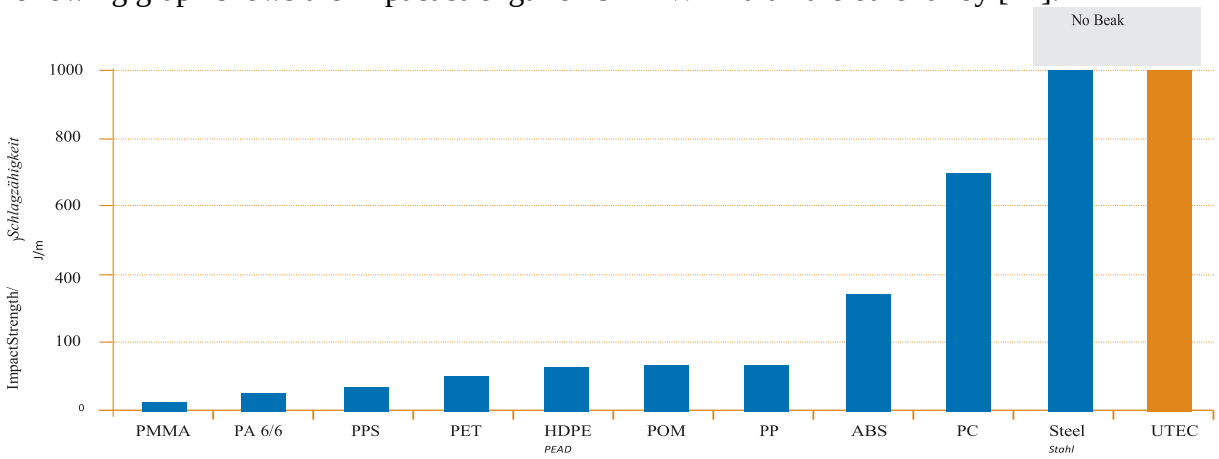
The previous study has proven that the effect for ceramic shell mold parameters can cause failure as hot tearing and shrinkage porosity. Also the failure can occur due to heat transfer cooling conditions [9].

Ceramic on UHMWPE

Ceramic on UHMWPE is a good combination of two reliable materials. Ceramic is chosen for the head part which is harder than metal and most scratch-resistant implant material. The UHMWPE is known for its ultra-smooth surface as well as has high strength which greatly reduce the wear rate on polyethylene bearing [10].

UHMWPE is not just a ordinary polyethylene , it is ultra-high molecular weight polyethylene which composes of many metal and polyethylene alloys in its composition. The

following graph shows the impact strength of UHMWPE than the other alloy [11].



It overcomes the failure faced on CoC implants by eliminating squeaking, ceramic rim distortion and majorly ceramic head and linear problems. The potential wear rate of this type of implant is less than metal on polyethylene and also resulted in reduction of fracture rates to 1% when compared to original brittle ceramics [12].

CONCLUSION

Thus from the above study we learned that major problems faced by many alloys are mainly due to the wear characteristics. But the ceramic on UHMWPE has least possible wear failure. We suggest it would be the future on hip prosthesis. Even though it has some limitations such as more prone to fracture and highly expensive than other bearings the main focus here is the wear resistance and the lifetime of the implant. And hence the ceramic on UHMWPE alloy has reduced ear by improved lubricating and less friction. The performance are higher than the ordinary polyethylene and other metal alloys.

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