

Wear polyethylene particles in failed total hip replacements

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Wear particles produced during articulating artificial joints contribute to aseptic loosening. The biomaterials used to manufacture the artificial joints have different wear rates and liberate particles of different size and different biological reactivity.

The main goal of this work was to compare the results of isolation of wear polyethylene particles from periprosthetic tissues with histological results of two groups of implants. Two groups of implants were examined; in both, the femoral stem was made of Ti₆Al₄V alloy, and the acetabular component was made of polyethylene. Implants differed in the material of femoral head, which was stainless steel or ceramic (Al₂O₃).

1. Introduction

Wear particles are one of the most important problems in artificial joints. They appear during normal function of artificial joints. Every movement causes friction of two surfaces of implant, which can subsequently cause wear of biomaterials. Fragments of materials, which make up the artificial joint surfaces, appear in the joint cavity. The body's reaction to wear particles takes the form of an inflammation. In

response to wear particles, the cells of periprosthetic tissues produce many inflammatory mediators, giving rise to very complicated chain of reactions, which can lead to implant loosening.

The highest concentration of wear particles is found in the synovial fluid in the joint cavity. They can also diffuse into periprosthetic tissue, which tightly surrounds the implant. The cells of periprosthetic tissue are exposed to the influence of wear particles from the very beginning, therefore they are an appropriate material for examining the influence of wear particles.

Polyethylene is a very popular material used in artificial joints. Usually in the total hip joint replacement the cup is made of polyethylene. This material wears very intensively and produces a huge number of wear particles of different size.

The aim of this study was to compare the types of wear particles prevalent in fibrous periprosthetic tissues from two groups of total hip replacements and the histological response of these tissues to such particles. The femoral component in both groups was cemented self-locking stem made of Ti₆Al₄V alloy, and the acetabular one was polyethylene cup. The two groups differed in the material of femoral head, which was either metal or ceramic.

2. Materials and methods

Periprosthetic tissue specimens were collected during revision surgery. Some specimens were frozen and some were fixed in buffered formalin and embedded in paraffin. 5 µm thick paraffin sections were stained with hematoxylin and eosin. Oil-o-red staining was used for polyethylene particles visualization in cytoplasm of macrophages and in giant cells.

The tissues slides were examined under standard and polarized light microscope (E80i, Nikon).

The modified version of the Mirra classification was used to estimate the number of giant cells and acute and chronically inflammatory cells, as well as the areas of necrosis and necrobiosis.

The frozen tissue samples were used for isolation of wear particles. Tissue samples were shaken overnight on the shaker in the mixture of chloroform and methanol (2:1) to extract lipids, and then digested in 5M sodium hydroxide for 4 h at 65 °C. The digest obtained was then centrifuged (1 h at 6 000 rpm) with 5% sucrose. The upper dense layer, which contains polyethylene particles, was collected and hydrolyzed for 1 h at 80 °C and then centrifuged with isopropanol (1 h at 6 000 rpm). Polyethylene particles form thin white band on the top. Isolated polyethylene particles were examined under scanning electron microscope.

3. Results

The experiments give the opportunity to observe great variety in the shape and volume of polyethylene particles. We have obtained small and round particles, thin and longitudinal particles and also huge fragments of polyethylene.

In periprosthetic tissues of the patients who had had titanium stem with stainless steel head, we observed every kind of polyethylene particles. Small, round and ellipsoidal polyethylene particles were present in every sample of tissues. Longitudinal particles with sharp edges can easily be found in these periprosthetic tissue samples. The presence of large fragments of polyethylene can be treated as relevant feature of tissues coming from loosened implant with stainless steel head (figure 1).

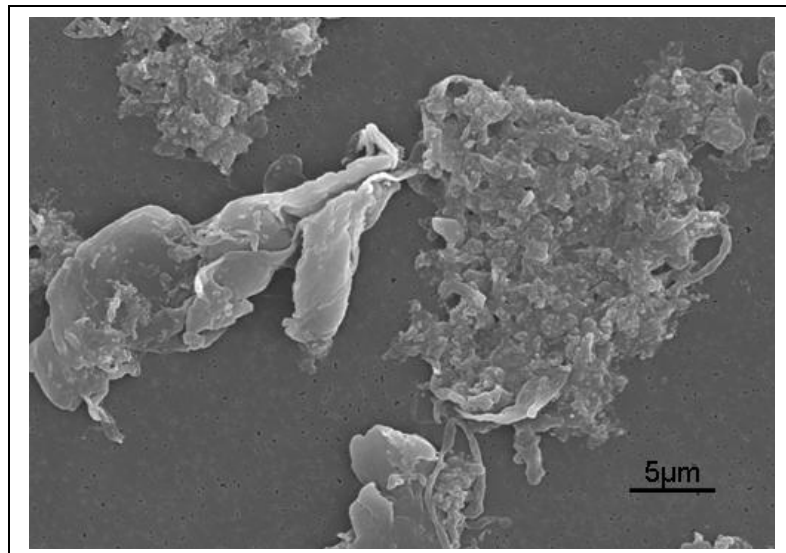


Fig. 1. Polyethylene particles under SEM (magnification 3000 \times)

From the tissues of patients with titanium stem and ceramic head we could isolate only small, round particles smaller than 1 μm in diameter.

No significant differences in cellular reaction between the two groups were observed. We could observe huge and comparable numbers of macrophages, giant cells with polyethylene particles inside (figure 2) and large areas of necrobiosis and also necrosis in fibrous tissue samples retrieved from those two groups of implants.

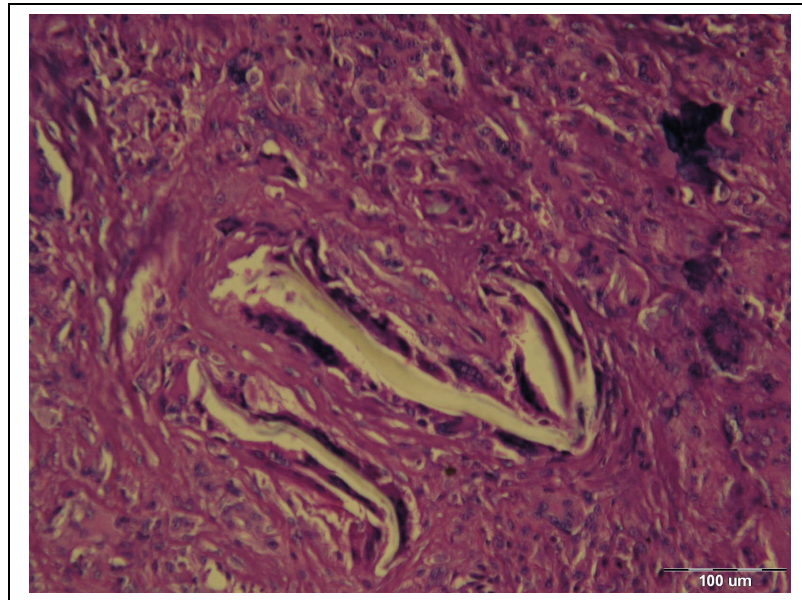


Fig. 2. Polyethylene particle inside giant cell in periprosthetic tissue under polarized light (magnification 200×)

4. Discussion

Polyethylene wears very intensively producing different kinds of particles. The variety in shape and size of polyethylene particles found in the periprosthetic tissues coming from the group of titanium implants combined with stainless steel head could testify to a more complicated process of wear in this kind of implants and could suggest more intensive biological response. Besides polyethylene also titanium stem being in contact with stainless steel head can wear very intensively. An increased number of particles in joint cavity can contribute to the third body wear mechanism of an abrasive character.

In contrast, in the group with ceramic femoral head only submicrometer-sized round particles of polyethylene were isolated. On the basis of these results it could be suggested that the implants with ceramic femoral head are better. The polyethylene particles of one type only are produced during articulation of this kind of artificial joints. This result is in contradiction with the data published, so we decided to conduct histological experiments.

The histological research exhibits similar cellular responses of periprosthetic tissues from two different groups of implants. The modified version of the Mirra [1] classification does not show any differences in histological responses. The average

numbers of macrophages, giant cells and areas of necrosis and necrobiosis in both groups were the same. This suggests that in the group of titanium stem combined with ceramic head, only one kind of polyethylene particles can provoke the same histological reaction as many kinds of polyethylene particles in implants with metal femoral head. The diversity of particles involved in the wear process does not necessarily mean a more intense inflammatory response, a large number of smaller less diverse particles being able to cause similar reaction.

Mainly small polyethylene particles are considered to be most biologically active in periprosthetic tissues [3]. They provoke intense inflammatory reaction, which can lead subsequently to implant loosening [2]. Submicrometer-sized particles are small enough to be phagocytosed by periprosthetic cells. The phagocytosis begins a complicated chain of reactions leading to the production of many inflammatory mediators and enzymes, which digest the periprosthetic tissue making the implant unstable. This could be the reason of the same histological reaction of tissues from different groups of implants. The contribution of the small particles to implant instability is the largest. The big particles are usually surrounded by giant cells, are isolated from the tissue and do not begin any intensive inflammatory reaction.

Acknowledgements

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References

- [1] DOORN P.F., MIRRA J.M., CAMPBELL P.A., AMSTUTZ H.C., *Tissue reaction to metal on metal total hip prostheses*, Clin. Orthop. Relat. Research, 1996, 329S, S187–S205.
- [2] FIGURSKA M., ŚWIESZKOWSKI W., TELEGA J.J., *Influence of wear debris on behaviour and biomechanical properties of bone-implant interface*, Russ. J. Biomech., 2005, 9(2), 20–32.
- [3] GREEN T.R., FISHER J., STONE M., WRÓBLEWSKI B.M., INGHAM E., *Polyethylene particles of a “critical size” are necessary for the induction of cytokines by macrophages in vitro*, Biomaterials, 1998, 19, 2297–2302.