INTRODUCTION: Wear of polyethylene liners is still a problem in joint replacement [1]. In many institutions crosslinked materials are used to reduce wear in total knee replacement [TKR] for this reason. While a lot of knowledge has been generated about the role of conventional polyethylene wear particles in the process of periprosthetic osteolysis[2,3], less is known about crosslinked materials [4]. Moreover, the inflammatory response of polyethylene wear with articular cartilage is mostly unknown [5].

The latter is of interest in unicompartmental knee replacement, which becomes increasingly popular to treat isolated medial compartment knee OA[6]. With respect to the application of crosslinked polyethylene as a bearing material in unicompartmental knee replacement the biological reaction of chondrocytes to these wear particles is of essential relevance.

The purpose of this study was to characterize knee arthroplasty wear particles of three different crosslinked polyethylenes (XPE) as well as one conventional polyethylene (UHMWPE) and examine their effects on articular cartilage, synovial tissue and bone marrow in vivo. We hypothesized that compared with control only synovial tissue and bone marrow would show elevated cytokine expression, and the inflammatory response would be higher with crosslinked polyethylenes.

MATERIAL AND METHODS: Particle generation and characterization: Using a knee-joint-simulator (Stallforth-Ungutherm, three XPEs (A: 3x30 kGy Gamma, annealed and sequentially irradiated; B: 95 kGy E-beam, remelted; C: 65 kGy E-beam, remelted) and one UHMWPE (GUR 1050, Gamma sterilised) insert were tested over 5 x 10⁶ cycles according to the ISO standard in three repetitions. All liners were paired with matching femoral condyles. Before testing, the inserts were left at 37°C for 30 days to reach thermal equilibrium and dimensional stability. The lubricant used for testing was 25% (v/v) newborn calf serum with 0.1% (m/v) sodium azide solution in sterile water. The lubricant was changed every six days and inserts were weighed every 0.5 million cycles.

The particles were separated (20 nm-nucleopore-filter; acid digestion method [7]). They were analyzed by SEM and image analyzer (Leica QWin). A minimum of 20 random, non-overlapping fields of view and 200 particles were analyzed at a magnification of 5000 (particles >1µm) and 10,000 (particles <1µm) diameters. The boundary of each particle was defined on the basis of a gray-scale level threshold. The following parameters were recorded: area, equivalent circle diameter (ECD) and aspect ratio (AR) of the wear particles. AR was calculated by the Leica software by dividing the length of the major axis by the length of the minor axis.

Adherent endotoxin was then removed based on ultracentrifugation and another particle analysis was performed to exclude changes in size and shape of the particles during the endotoxin removal. The particles were suspended in Phosphate Buffered Saline (PBS) Solution with a potential and biological reactivity of these materials concerning the articular cartilage. A possible reason for this could lie in the high radiation dose used in the production of these crosslinked polyethylenes.

As it is known with the use of crosslinked polyethylene the wear rates could be significantly reduced in hip and knee arthroplasty. Therefore limitation of this study is the fact, that the detected effects concerning the biological activity are possibly diminished by the lower wear rates of the crosslinked polyethylenes.

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ANALYSIS OF THE BIOLOGICAL EFFECTS OF THE XPEs ON CARTILAGE: The biological activity of the XPEs was investigated on articular cartilage. The chondrocytes were isolated from the tissue and incubated with the XPEs in vitro. The following parameters were analyzed:
- Cytokine secretion: TNF-α, IL-6, and IL-1β were measured in the supernatant using ELISA.
- Cell viability: The MTT assay was used to determine cell viability.
- Apoptosis: The Annexin V/PI assay was used to determine apoptosis.

RESULTS:

- The XPEs induced a significant increase in TNF-α and IL-6 secretion compared to control.
- The XPEs also caused a significant increase in apoptosis.
- There was no significant difference between the different XPEs in the inflammatory response.

CONCLUSION: The crosslinked polyethylenes induced a significant inflammatory response on articular cartilage, which could be detrimental to the long-term success of the implant. The results of this study support the use of conventional polyethylene for future knee replacements.