UHMWPE debris:

which chemical characteristics?

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The wear involves the loss of material as a consequence of relative motion between two surfaces.

The mechanism of debris formation is very complex and it depends by different parameters of the surface: the chemical-physical composition and the characteristic, the hardness, the type of motion, the lubrication….

The wear produce debris, in our case PE particles.

"The loosening of prosthetic joints in the absence of infection is by far the most common reason for revision …..a significant part is undoubtedly played by the generation of wear debris ….. and the cellular reaction to this in the implant bed" (1)
"The PE debris reactivity is function of its dimension: the small particle are intracellular in macrophages, while larger particles are included within by foreign body multinucleated giant cells" (1)

1. P. Revell "The combined role of wear particles, macrophages and lymphocytes in the loosening of total joint prostheses "J.R.Soc. Inter 2008, 5 1263-1278

Small particle (order less then micron)

UHMWPE (normal or crosslinked) sterilized by EtO

UHMWPE not oxidized

Larger particles (order of ten microns)

UHMWPE sterilized by Gamma (in air)

PE oxidized

The interaction between debris and cells is surface process.

Therefore are the dimensions or also the chemical characteristics of the surface of the debris that can play a important role in the interaction process?

We can analysis chemically only big PE debris after the separation with the living materials.

The debris are produced by abrasion of the surface. We can substituted the analysis of the debris with the analysis of the surface of the prosthetic component in UHMWPE

The UHMWPE components used actually are made:

UHMWPE with or without Vitamin E

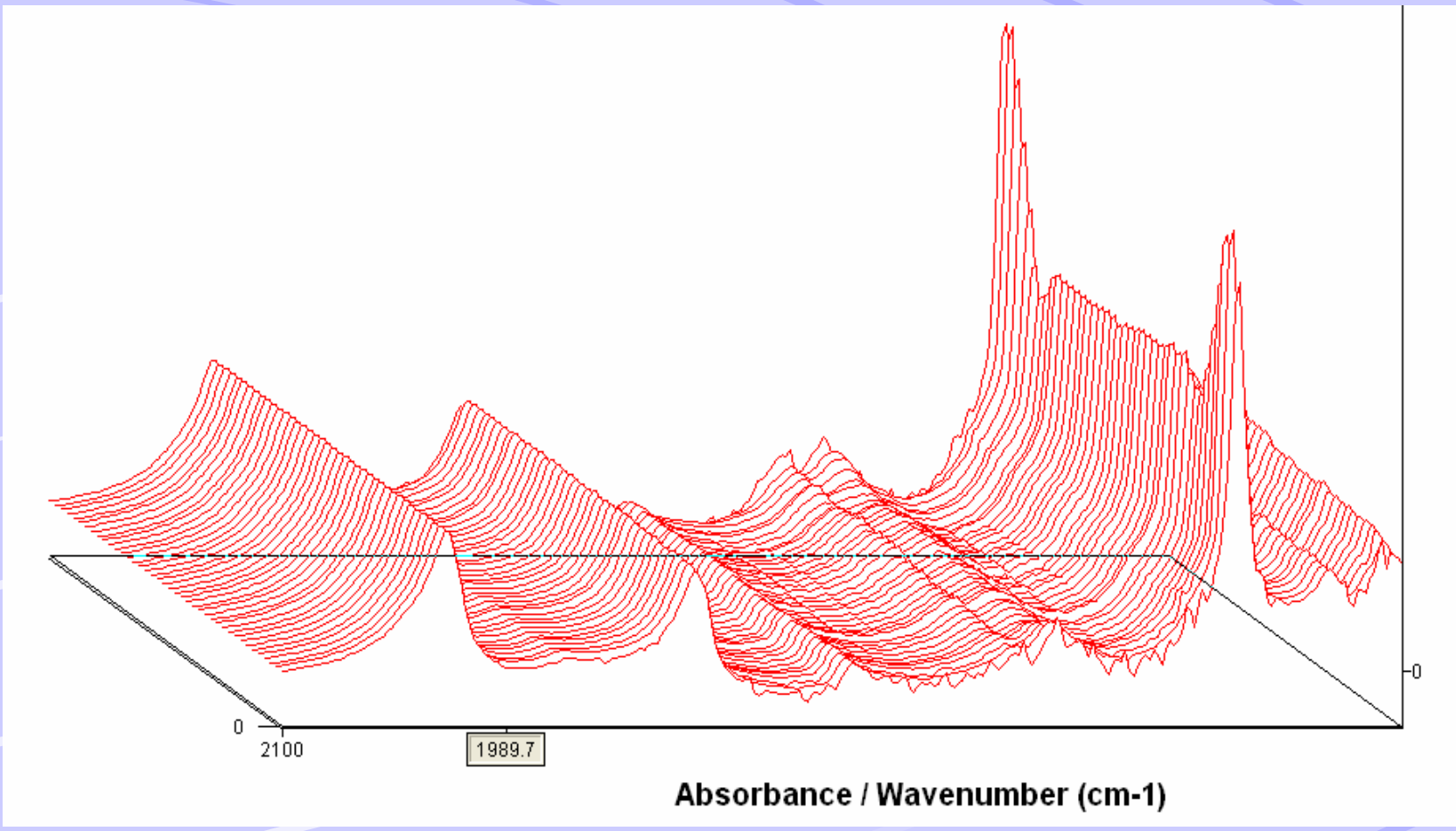
UHMWPE crosslinked with or without Vitamin E

Sterilized with high energy radiation, EtO or plasma.

The chemical structure of the UHMWPE surface is function of the sterilization process and the thermal treatment.

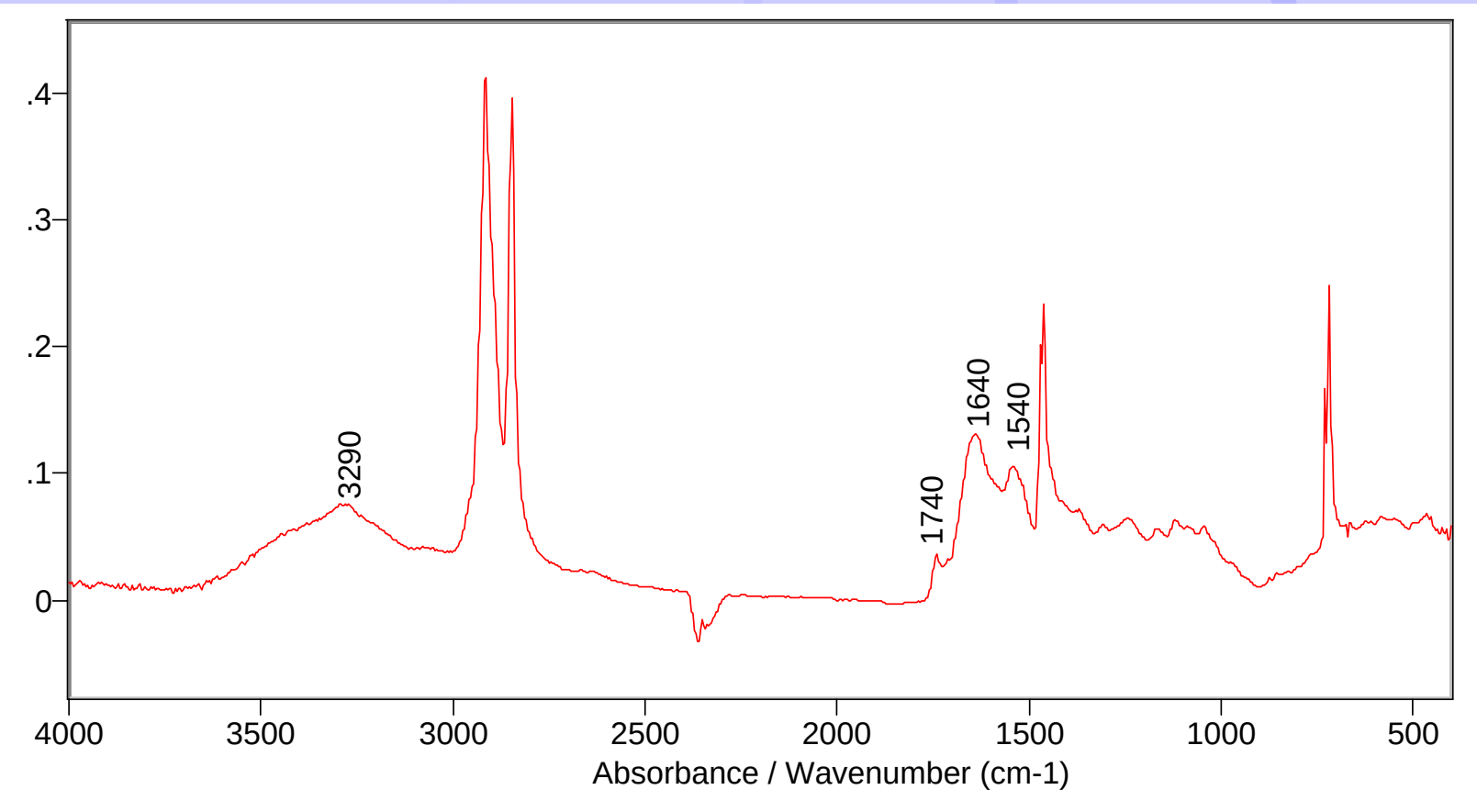
The surface can be oxidized at different level

L. Costa, P. Bracco, E.M. Brach del Prever, S:M. Kurtz, and P. Gallinaro, "Journal of Biomedical Materials Research Part B: Applied Biomaterials, 2006, 78B, 20-26



In vivo what happens?

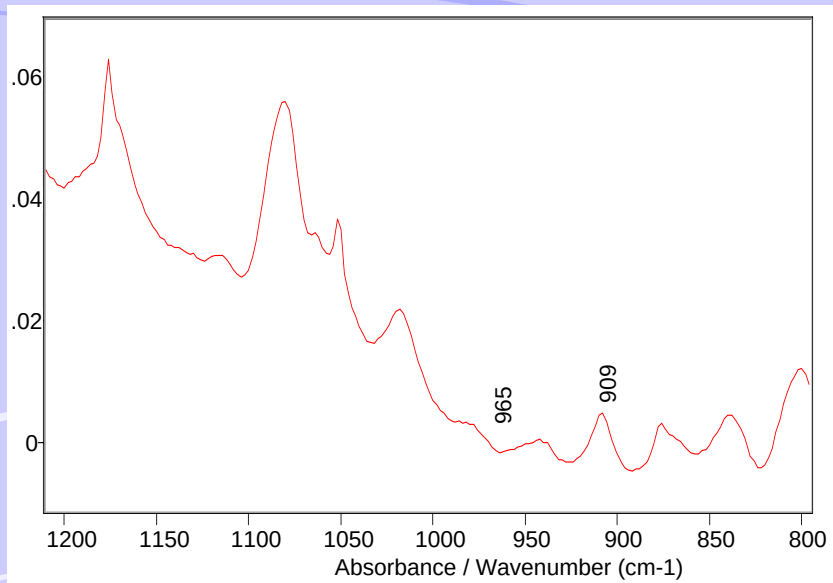
SURFACE ANALYSIS OF AN ETO STERILIZED PE CUP WITH ATR-MICROSCOPY FTIR

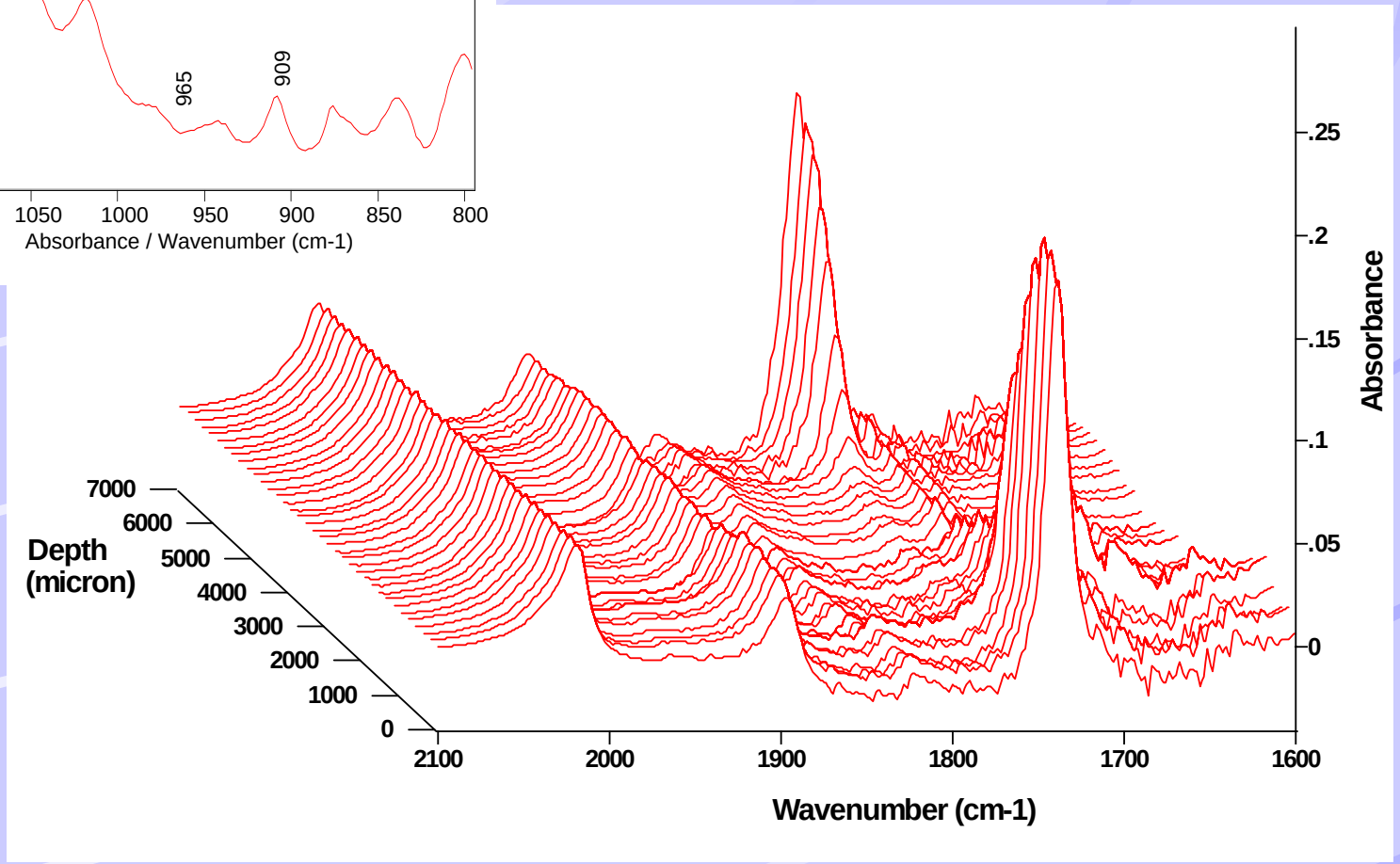


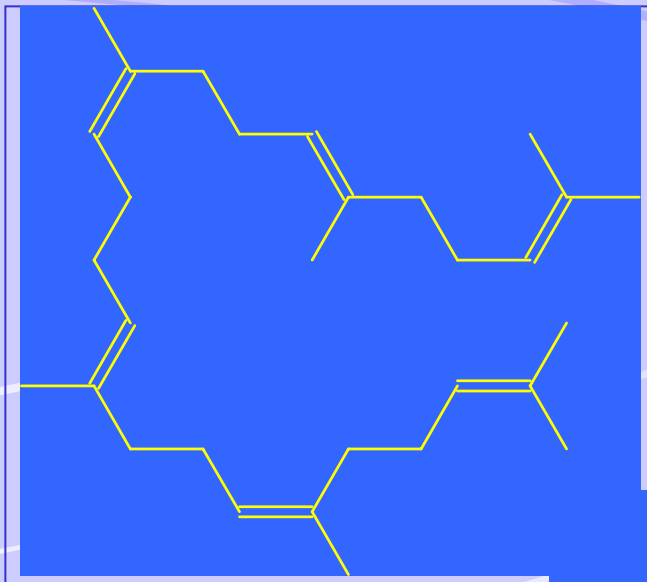
1740 cm^{-1}:ester species

3290, 1640, 1540 cm^{-1}: N-monosubstituted amides: proteins absorbed on surface of UHMWPE

FTIR of EtO sterilized retrieved cup

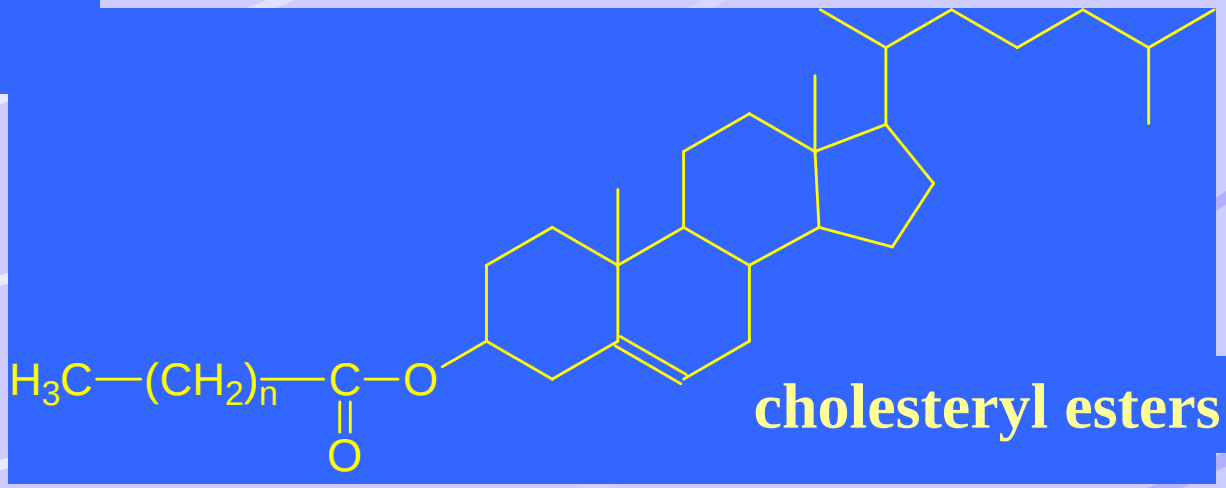






squalene

cholesterol



cholesteryl esters

•L. Costa, M.P. Luda, L.Trossarelli, E.M. Brach del Prever, M. Crova, P. Gallinaro *Oxidation in orthopaedic UHMWPE sterilised by gamma-radiation and ethylene oxide*. Biomaterials, 19, (1998) 659-668.

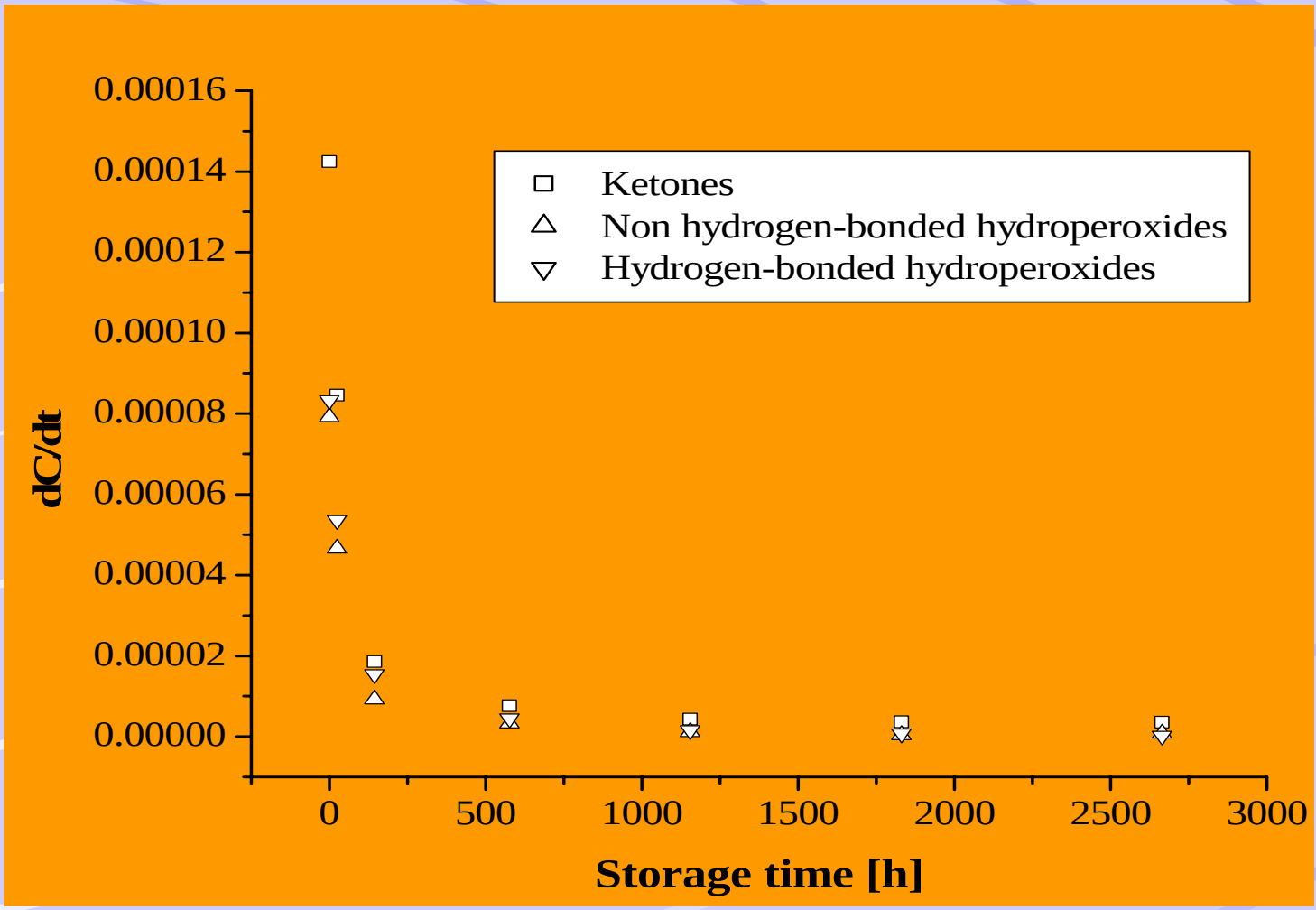
In Vivo oxidation

Can the UHMWPE oxidize *in vivo*?

We have two different situations of UHMWPE *in vivo*.

1°) The bulk of UHMWPE component. The oxidation process is normal chemical oxidation process

Rate of oxidation = K x [O_2] x [R°]



Rate of formation of oxidation products in function of the storage time in a film of UHMWPE irradiated in vacuum 60 kGy and ageing in air at RT

If the macroradicals are present into UHMWPE (sterilization process) we need oxygen for oxidation process .

Oxygen can be present in the original materials (0.5 mmol/l) but it can arrives from synovial fluid.

The oxygen dissolved in synovial fluid is in equilibrium to oxygen dissolved into the blood plasma.
The [O_2] in the plasma is around the 3 ml of oxygen for liter of plasma (0.04 mmol/l).

2°) The UHMWPE debris are intracellular in macrophages or in multinucleated giant cells.

The process of the cell is to eliminate the foreign-body.

The reaction of UHMWPE elimination can be only oxidation reaction and this process will be surface process.

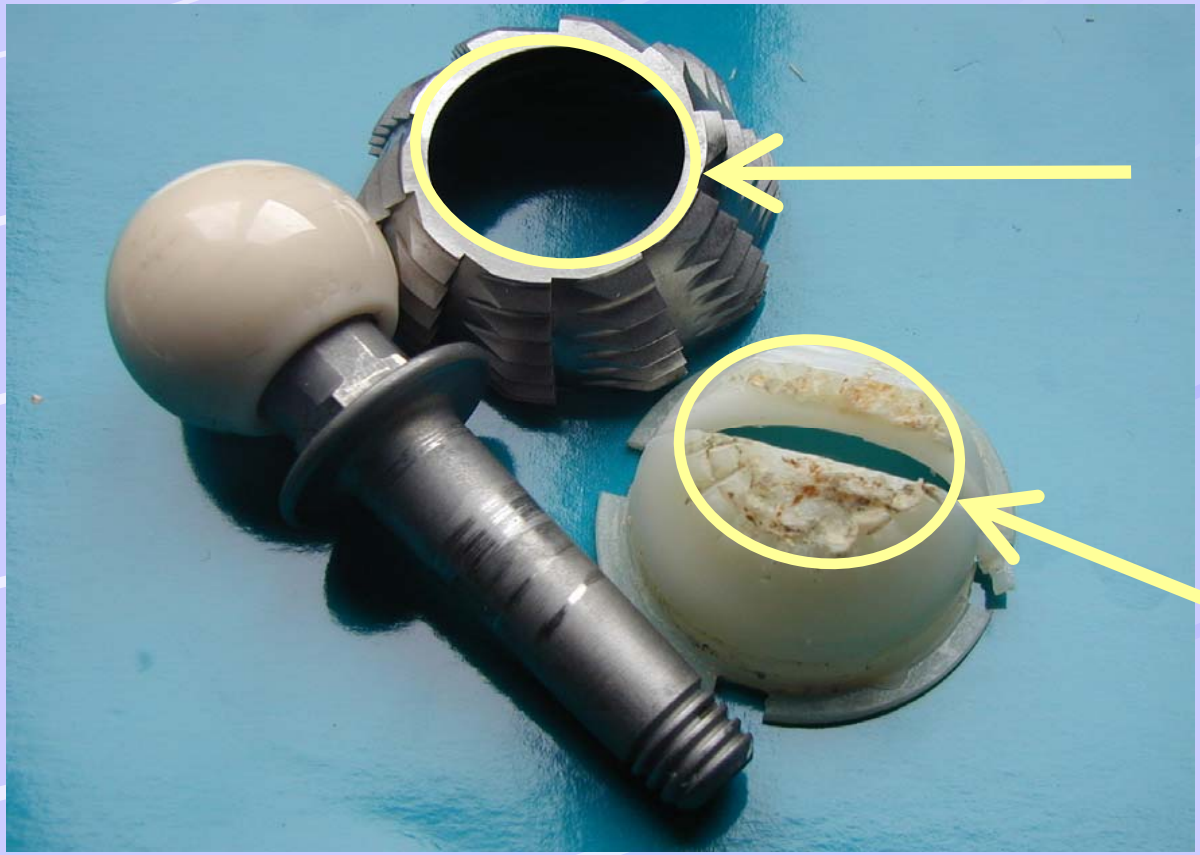
We need oxidize agent (H_2O_2, superoxide anion …) and

and oxygen.

In the cells the oxygen is transported by the Hemoglobin and the [O_2] concentration is 2.6 mmol/l of plasma.

In other word, in present of Hemoglobin there is oxygen to oxidize UHMWPE.

Anomalous degradation observed on UHMWPE of retrieved hip prosthetic components in the area in contact with bone and cells



Conclusion

The chemical structures of UHMWPE debris depends of the sterilization process (oxidation level)

The UHMWPE debris absorbed protein and the apolar components of synovial fluid.

The oxidation in vivo of UHMWPE into the joint component not in contact with cells is very difficult due to the low concentration of O_2 and [R°]

The PE debris can be oxidized into or in contact with the cell.

Thank you