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Relationship between in vivo stresses and oxidation of UHMWPE in hip joint replacement

M. Regis[1], P. Bracco[2], L. Giorgini[1], S. Fusi[1], L. Costa[2], C. Schmid[3]

[1] Lima Corporate S.p.A., Via Nazionale 52, Villanova di S.Daniele (UD), Italy
[2] Dipartimento di Chimica IFM, Via P. Giuria 7, Univ. di Torino, Italy
[3] Dipartimento di Ingegneria Industriale e dell'Informazione, Ingegneria dei Materiali, Via Valerio 6A, Univ. di Trieste , Italy

Overview

- UHMWPE is still the gold standard in joint replacement

  → Purpose: enhancing UHMWPE *in vivo* lifetime

- We need first to understand the retrieval causes
  - Wear
  - Delamination

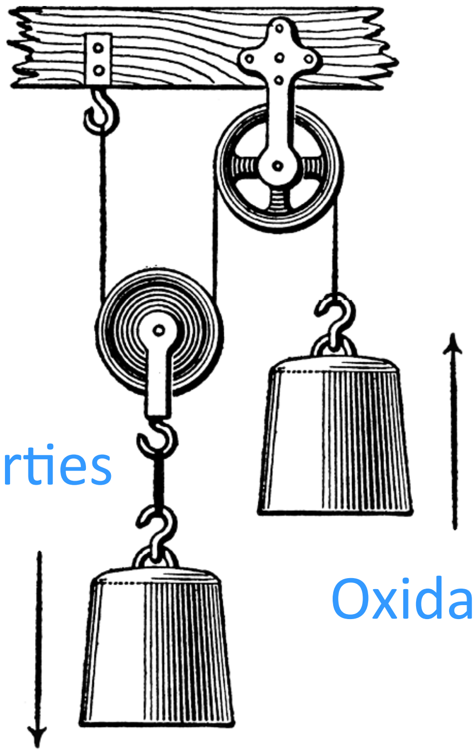
- Several studies[1] indicated that these failures are related to the UHMWPE oxidation

1. *Kurtz SM. The UHMWPE handbook. Elsevier academic press ed. 2009*
Brach Del Prever EM, Costa L, Crova M, Dallera A, Camino G, Gallinaro P. Biomat 1996;17:873-878
Costa L, Jacobson K, Bracco P, Brach Del Prever EM. Biomat 2002;23:1613-1624

Overview

- Tailoring UHMWPE properties to enhance the lifetime of the material is of great interest

- Despite all the effort, oxidation in retrieved components is still observed



Aim of this study

- Oxidation is a complex and not yet fully understood mechanism

- The results achieved so far assure a 0-free radical material at the beginning of its *in vivo* lifetime

!Hypothesis:

oxidation comes from *in vivo* conditions that is from mechanical stress

Materials

4 retrieved hip liners + 1 shelf aged hip liner and 1 unloaded, un-machined UHMWPE block (LimaCorporate)

Sample	Size	Material	Years of Implant
E0	Ø28 mm	GUR 1120 UHMWPE	Shelf aged
E1	Ø28 mm	GUR 1120 UHMWPE	16
E2	Ø28 mm	GUR 1120 UHMWPE	4
E3	Ø32 mm	GUR 1120 UHMWPE	12
E4	Ø32 mm	GUR 1120 UHMWPE	9
Ref.	Block	GUR 1120 UHMWPE	-

- GUR 1120 UHMWPE
- All samples were EtO sterilised

Methods

- ▶ FE analysis of the mechanical stress acting on the replaced joint
- ▶ FTIR mapping on the liners cross section
- ▶ Dimensional analysis

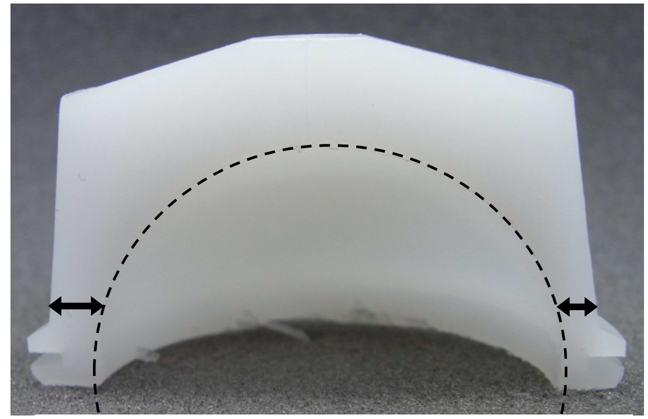
- ✓ Direct comparison between oxidation product presence and mechanically loaded areas of the UHMWPE liner
- ✓ Qualitative wear evaluation

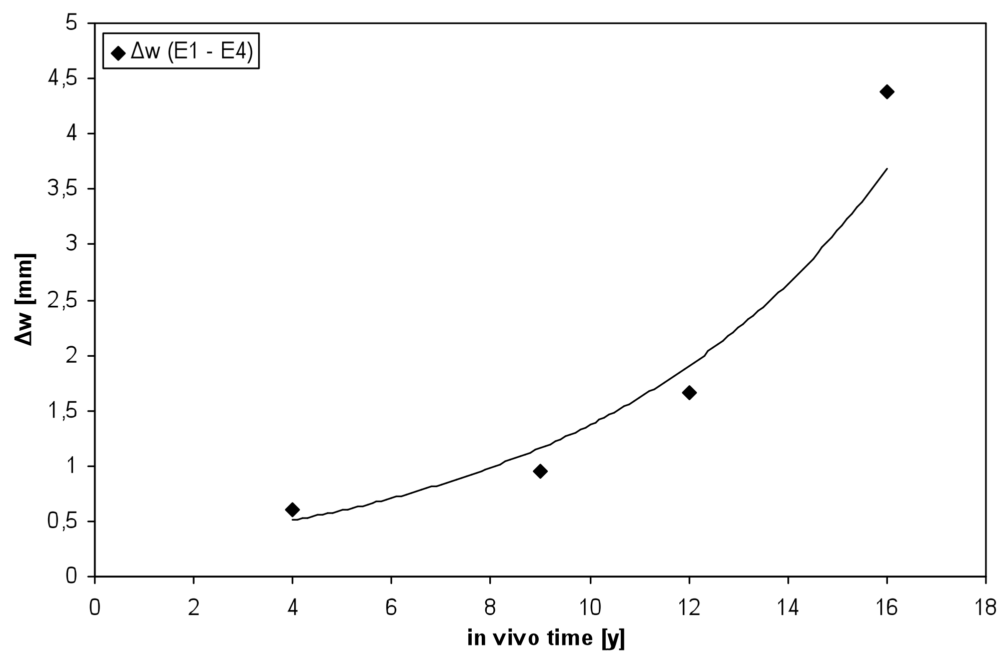
Wear evaluation

$$\Delta w = 2t^* - (T + t)$$

- T = maximum measured liner circumferential thickness
- t = minimum measured liner circumferential thickness
- t* = nominal thickness value

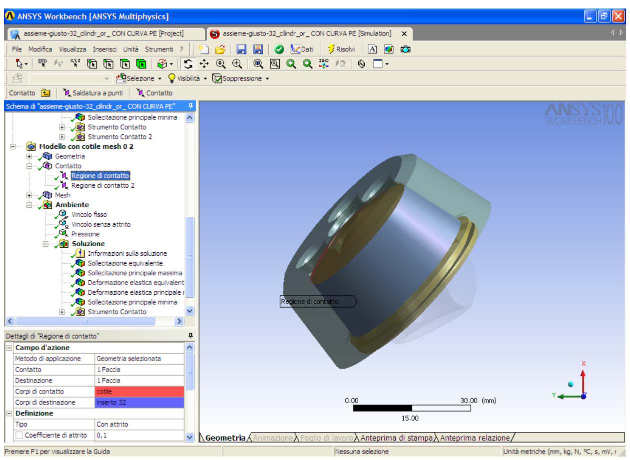
longer *in vivo* lifetime, higher wear

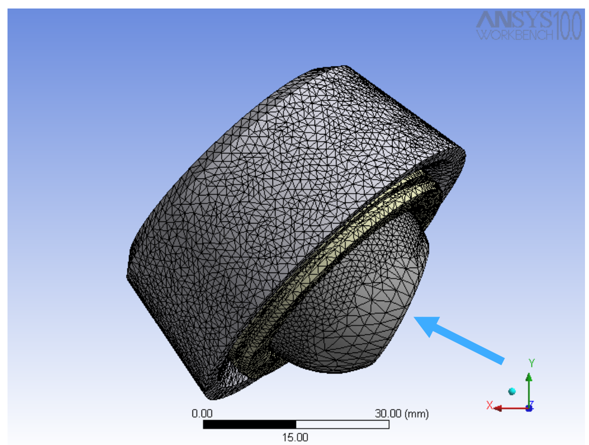


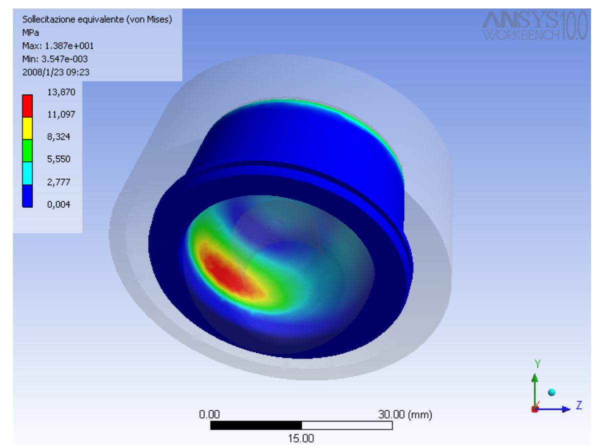


FEM analysis

- Numerical simulation
- Anatomic configuration (components, geometry, loads, materials)
- Quantification of the *in vivo* mechanical stress acting on the components



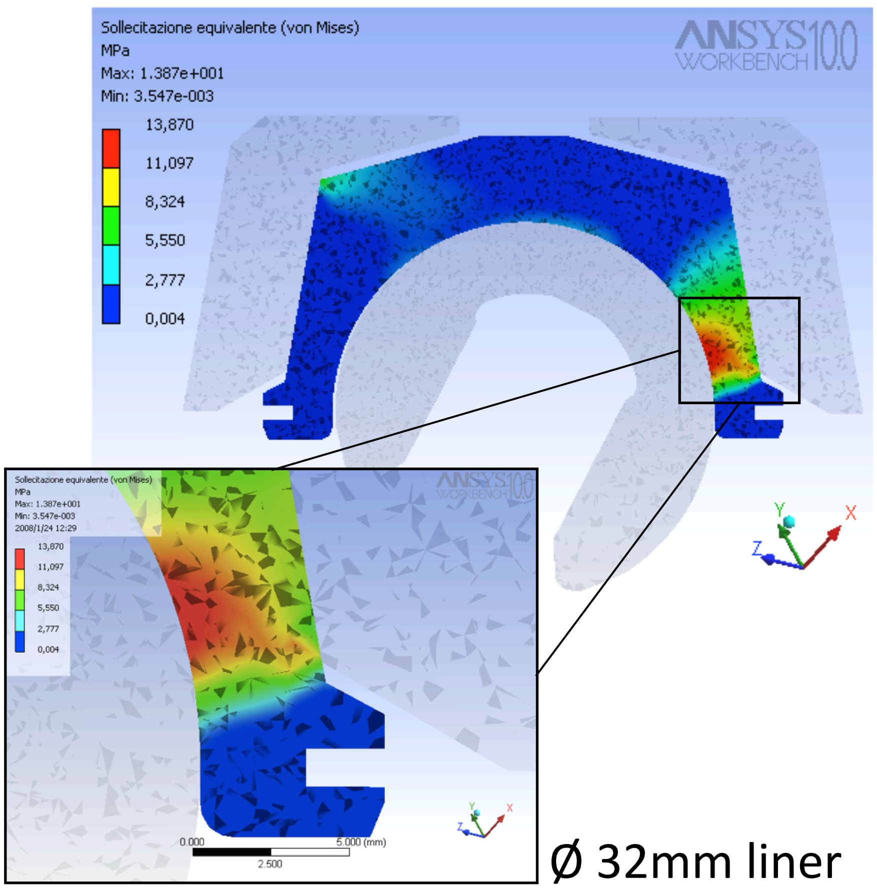




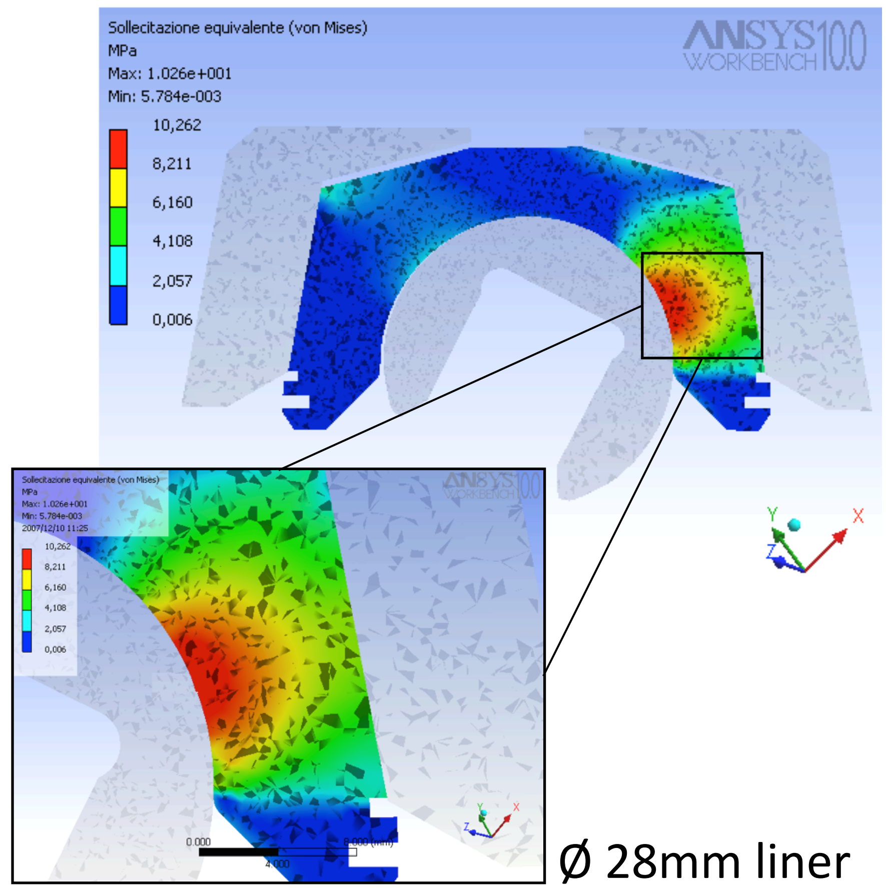
Stress acting on the UHMWPE liner

FEM analysis

Results of mechanical stress on the two different UHMWPE liner cross sections

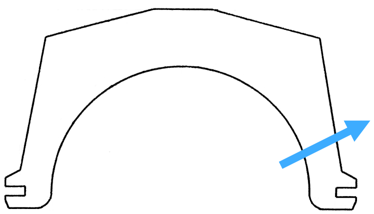


Ø 32mm liner

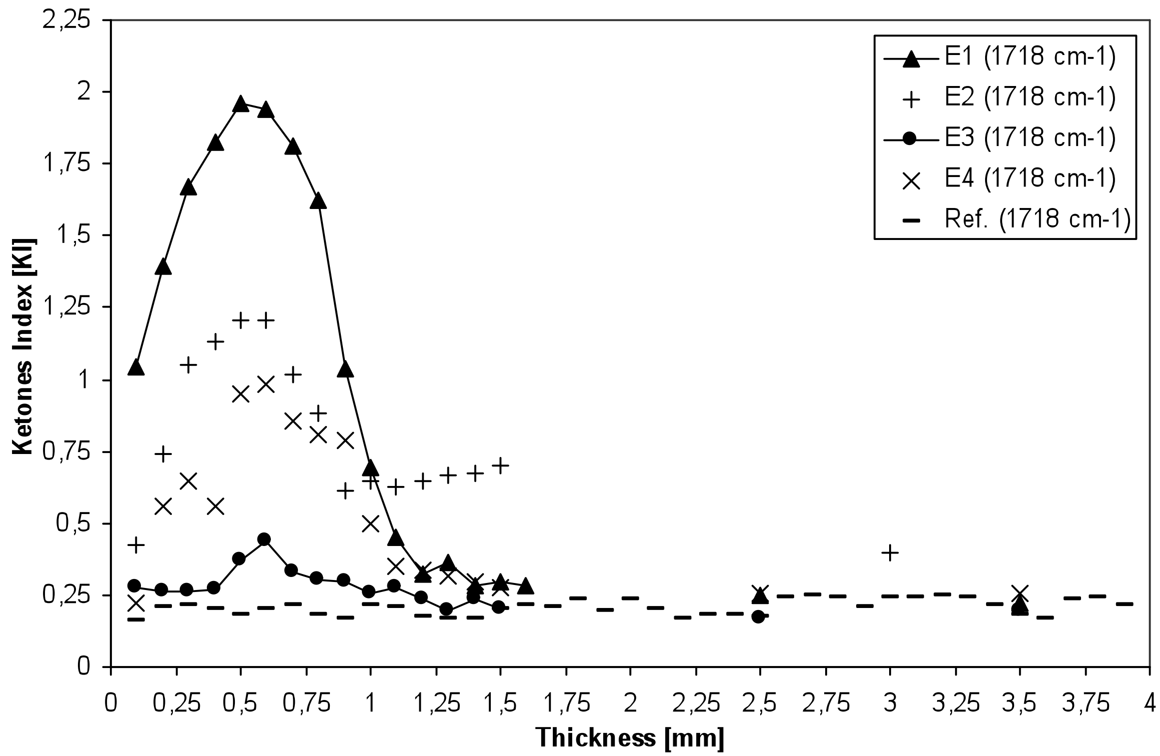


Ø 28mm liner

FTIR measurements



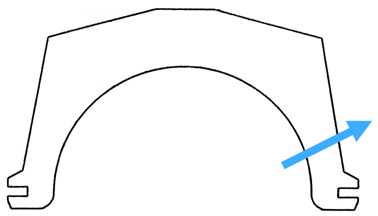
- E1-E4 oxidation profile (K.I.) along the stress-affected area cross section
- Ketones (1718 cm^{-1}) peak area values



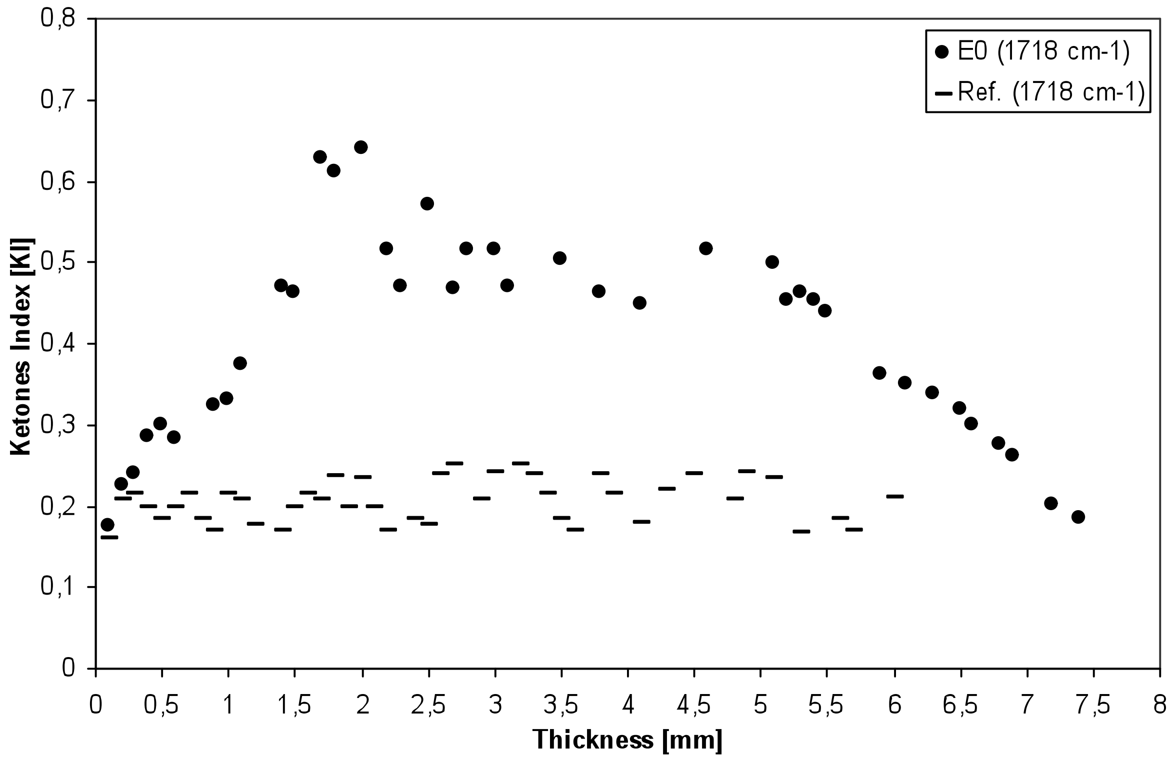
→ Non diffusive trend

→ Highest oxidation for the longest *in vivo* time

K.I. - shelf aged liner



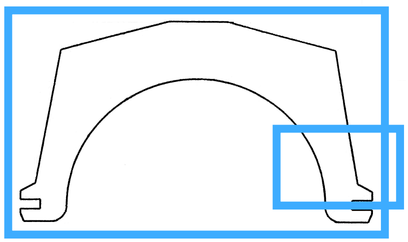
- Oxidation profile in the shelf aged liner cross section
- Ketones (1718 cm^{-1}) peak area values



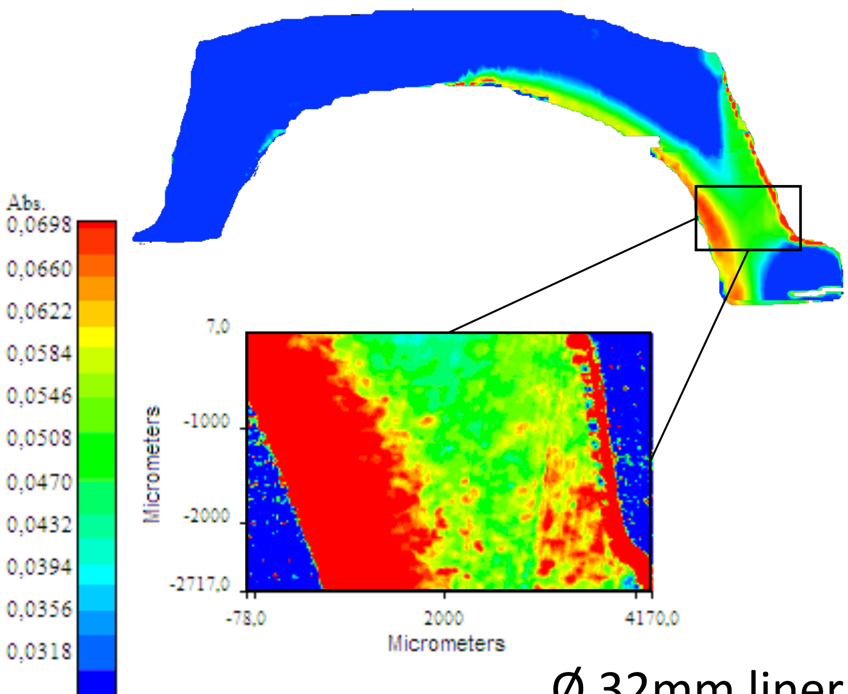
→ K.I. is lower than in E1-E4 samples

→ Different profile compared to E1-E4 samples

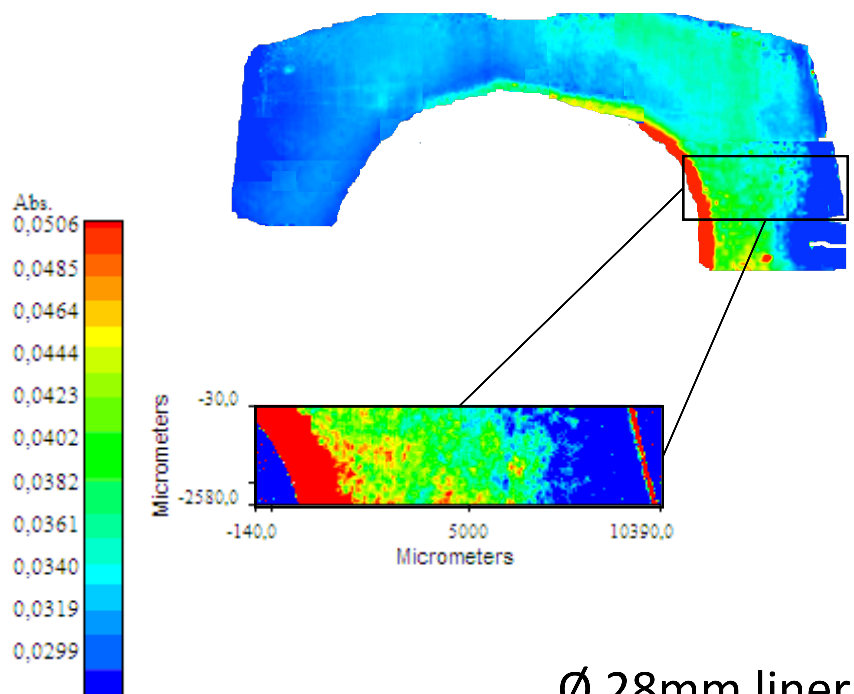
FTIR measurements



- Retrieved liners oxidation product maps
- Ketones absorbance along the cross section
- Spot size: 150 µm (whole area), 25 µm (worn part)

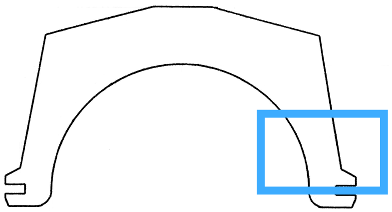


Ø 32mm liner



Ø 28mm liner

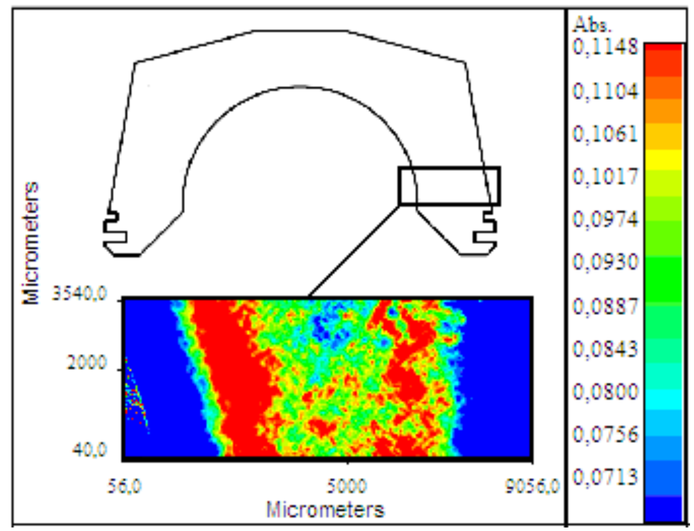
FTIR map - shelf aged liner



- Ketones absorbance in the shelf aged liner
- Spot size: 25 µm

→ Similar results in literature[1]

→ it has different oxidation profile compared to E1-E4 FTIR maps

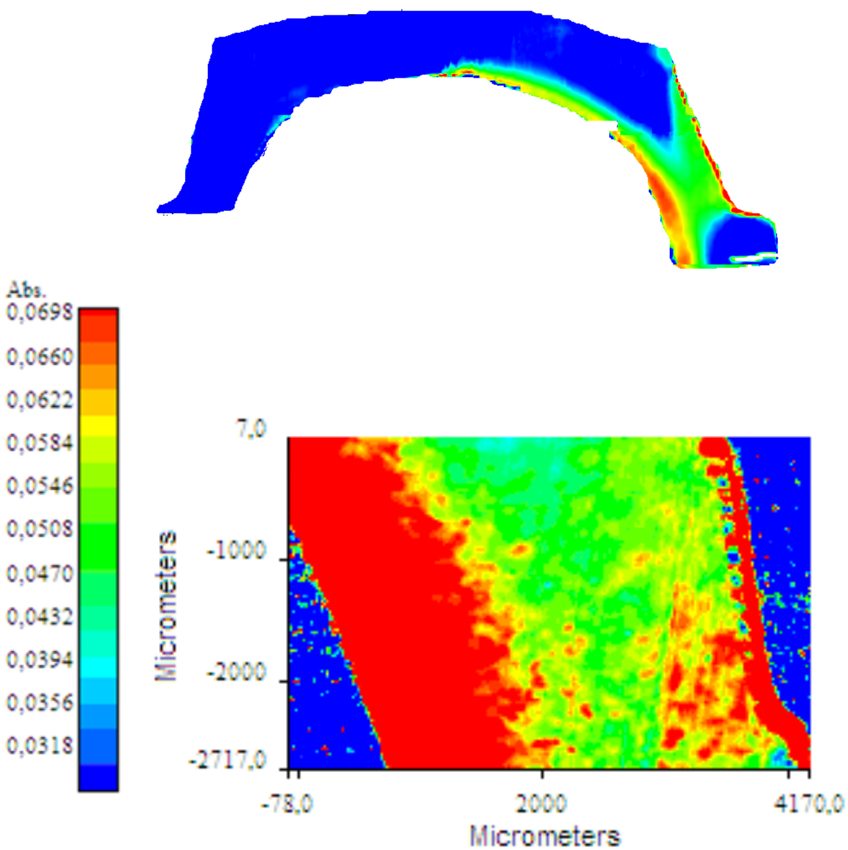


1. Costa L, Jacobson K, Bracco P, Brach Del Prever EM. Biomat 2002;23:1613-1624

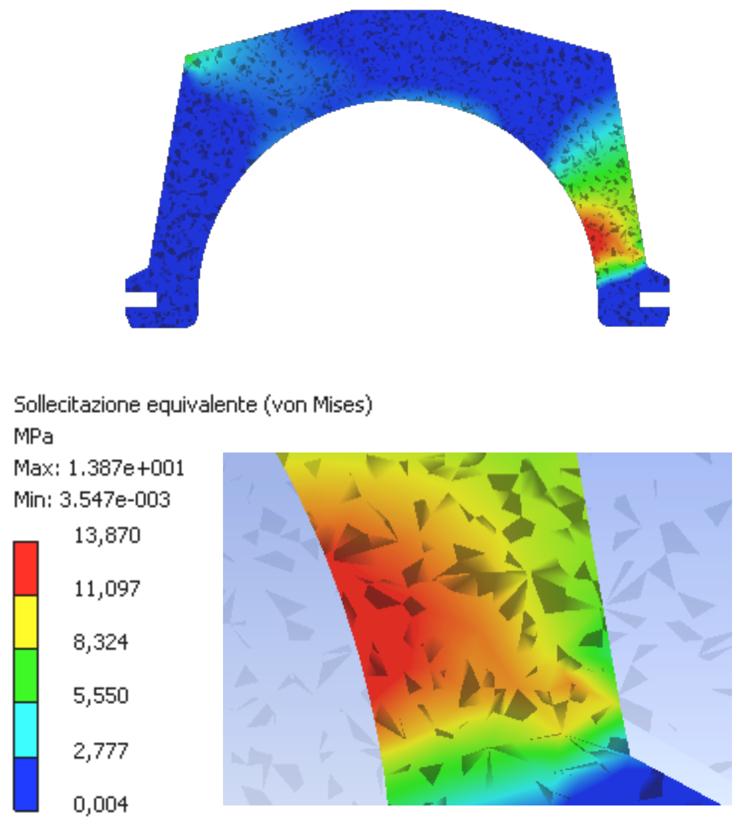
! No similarities in oxidation profiles between retrieved liners (*in vivo* conditions) and shelf aged liners

Comparison

FTIR



FEA



The higher oxidation level has been found at the most stress-affected area

Critical discussion

- Limited sample outline + great variety of patient conditions
- Longer *in vivo* time

→ higher wear

→ oxidized material removal

→ enhanced degradation mechanism

! Overlapping phenomena

Need of further studies to confirm from a quantitative PoV what the evidences show in qualitative terms

Conclusions

- EtO sterilized Gur1120 UHMWPE gets oxidized
- Shelf ageing oxidation is different from the observed oxidation in retrieved components
- Stress and oxidation profile (retrieved liners) match in terms of:
  - Distribution (K.I.)
  - Oxidation level and appearance (FTIR maps)
- There is correspondence between *in vivo* time and oxidation

! *In vivo* mechanical stress and oxidation are strongly connected - stress induces free radical formation

Thank you!

Udine by night