Development of synthetic synovia for tribological testing

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Introduction

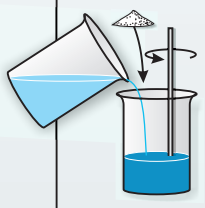
Implants sometimes fail *in-vivo* although they have been tested successfully in simulators. This is mainly due to the fact that laboratory tests are not performed realistically. One example is the test liquid:

	Synovia	Hip-Simulator (HiSi) Mix ISO 14242-1, based on bovine serum
proteins (albumin, IgG)	✓	✓
hyaluronic acid	✓	-
salts	✓	(✓)
phospholipids	✓	-
enzymes	✓	-
cells	✓	-

The aim of this study was to develop a synthetic test liquid mimicking synovia but based on commercial pure substances to allow for a high reproducibility among testing laboratories, and this at reasonable costs.

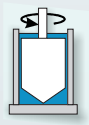
Materials & Methods

Test liquids



Components	HiSi-Mix	HA NCS	HA NCS RS	HA BSA RS	HA BSA/ IgG RS	HA BSA/ IgG RS PL
NCS (newborn calf serum)	✓	✓	✓			
Deionized water	✓	✓				
HA (hyaluronic acid)		✓	✓	✓	✓	✓
RS (Ringer solution)			✓	✓	✓	✓
BSA (bovine serum albumin)				✓	✓	✓
IgG (immunoglobulin G)					✓	✓
PL (phospholipid lecithin)						✓

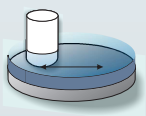
Viscosity (dynamic)



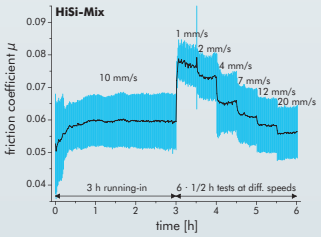
Couette geometry viscometer (MCR 300, Anton Paar, Austria)
shear rates 1-1000/s and back

Friction

UHMWPE pins (γ-sterilized, curved)
vs. polished CoCrMo discs

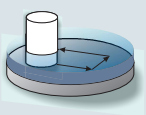


in test liquids, n=3
1 N load, ~5 MPa
10 mm reciprocal
Device: V. Schmid,
FH Bern, Switzerland

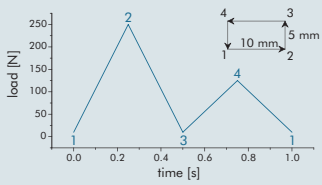


Wear

UHMWPE pins (γ-sterilized, flat)
vs. polished CoCrMo discs



in test liquids, n=3
0.1-3.5 Mpa
20-40 mm/s
2 million cycles
Device: AMTI Ortho-POD



Wear particles

collected during wear experiments
scanning electron microscopy (SEM, Zeiss EVO Ma25)
laser diffraction (Beckmann Coulter LS 13320)

Results & Discussion

Viscosity

Adding HA to the test liquid led to an increased viscosity (Fig. 1), similar as the synovia [1]. Salts lowered the viscosity by reducing the effect of H-bonds.

Friction

The higher viscosity (using HA) led to a change from boundary lubrication to mixed lubrication, as predicted by the Stribeck curve (Fig. 2). Surprisingly, the phospholipid lecithin had no effect on the friction.

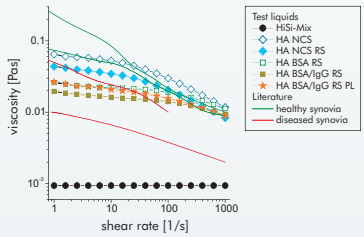


Fig. 1: Viscosity, compared to Nuki et al. [1].

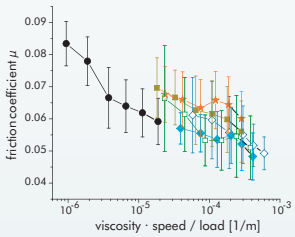


Fig. 2: Friction of UHMWPE pins vs. CoCrMo.

Wear

The obtained wear (Figures 3-4) was in agreement with clinically observed wear, which is in the range of 0.09-7.2·10⁻⁶ mm³/Nm [2].

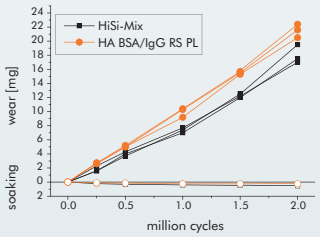


Fig. 3: Wear and soaking of the UHMWPE pins.

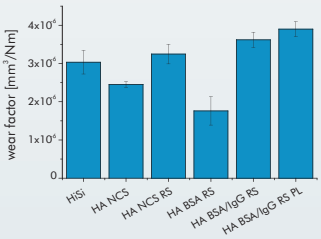


Fig. 4: Wear factor of the UHMWPE pins.

Wear particles

Round particles, fibrils and agglomerates were found in the used test liquids (Figures 5-6).

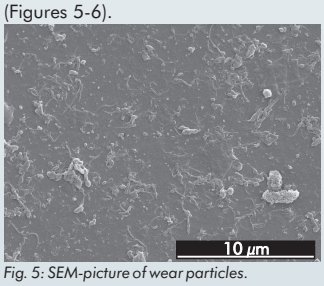


Fig. 5: SEM-picture of wear particles.

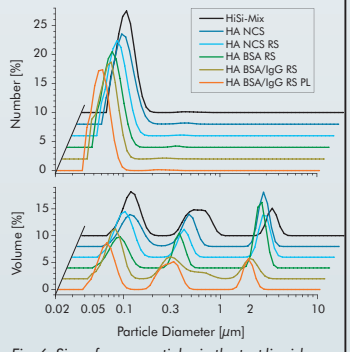


Fig. 6: Size of wear particles in the test liquids.

Conclusions

A reproducible test liquid based on hyaluronic acid, the pure proteins BSA & IgG, Ringer solution and the phospholipid lecithin was successfully developed in order to mimic the synovia - in terms of the chemical composition, the viscosity and the tribological behaviour. This at about the same costs as the existing HiSi-Mix.

References:
[1] G. Nuki, J. Ferguson; Rheologica Acta 1971; 10; p.8-14.
[2] V. Saikko; Journal of Tribology 2003; 125; p.638-642.