

Tribological evaluation of joint fluid and the development of a synthetic lubricant for use in hip joint simulators.

by

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Abstract

Title: Tribological evaluation of joint fluid and the development of a synthetic lubricant for use in hip joint simulators.

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Key words: Hip, simulator, synovial fluid, joint fluid, viscosity, lubricity, lubricant, non-Newtonian, wear debris, wear

Over the years, different lubricants have been used to operate hip simulators. The current applicable ISO standard (ISO 14242-1:2002) recommends the use of 25% calf serum diluted with deionised water. The standard further recommends that the fluid be changed and the acetabular cup be weighed every 500 000 cycles. This procedure results in a loss of both the third body wear particles and the wear pattern. The purpose of this study was to develop a synthetic lubricant that would map the viscosity and lubricity properties of joint fluid ("synovial fluid") over the whole duration of a simulator test, which is typically five million cycles.

The first objective of this study was to find the effect of temperature increase on the viscous and lubricative properties of joint fluid retrieved from both primary and revision patients prior to surgery.

The lubricity tests were done on a Linear-Oscillation Test Machine (SRV machine). Three test temperatures were used namely 38°C, 50°C and 60°C. The load at failure and the average coefficient of friction were parameters measured during these tests. A decrease in the load at failure was found for an increase in test temperature, while the coefficient of friction stayed relatively stable.

The viscosity tests were done using a Brookfield Viscometer. The three test temperatures mentioned above, were copied. The joint fluid tested showed pseudoplastic flow behaviour. An increase in the viscosity as a function of test temperature increase and a magnitude of shear rate was observed.

The second objective of this study was to develop a synthetic lubricant that had the same average properties than that found for the retrieved joint fluid. A mixture of three different chemicals, namely Poloxamer 188, Xanthan Gum and Lube Booster[®] II was used to map the viscous and lubricative properties of the joint fluid.

A comparative test using the synthetic lubricant and bovine serum was performed in a custom-built simulator. Wear debris was sampled at 500 000 cycle intervals up to 4 500 000 cycles. During these intervals the bovine serum stations were drained and washed with deionised water, but not stripped and weighed as specified in the ISO standard. This was done intentionally to preserve the wear pattern during the entire test. The synthetic lubricant stations were not stripped or drained during these intervals. This ensured that the wear pattern was maintained and that the effect of accumulative wear could be investigated throughout the duration of the test. The wear debris from the test was then compared to wear debris retrieved from scar tissue of revision patients.

The wear debris that was found in the scar tissue retrieved from patients was similar in shape and size to that which was found in the simulator using bovine serum and the synthetic lubricant. It can thus be concluded that an acceptable lubricant had been developed to replace the current test medium in the simulators.

Samevatting

Titel:	Tribological evaluation of joint fluid and the development of a synthetic lubricant for use in hip joint simulators.
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Sleutel terme:	Heup, simulator, sinoviale vloeistof, gewrigsvloeistof, viskositeit, smeervermoë, smeermiddel, nie-Newtoniese, slytasiepartikels, slytasie

Verskillende smeermiddels is oor die jare heen gebruik as toetsmediums in heupsimulators. Die huidige internasionale standaard (ISO 14242-1:2002) beveel aan dat 'n mengsel van 25% kalfserum en gedeïoniseerde water as toetsmedium gebruik moet word. 'n Verdere aanbeveling is dat die toetsmedium elke 500 000 siklusse vervang moet word en dat die gewrigsholte geweeë moet word. Gevolglik gaan die derde liggaam partikels asook die slytasiepatroon verlore. Die doelwit van hierdie studie was om 'n sintetiese smeermiddel te ontwikkel wat dieselfde viskeuse- en smeereienskappe as gewrigsvloeistof (sinoviale vloeistof) het. 'n Verdere vereiste van die sintetiese smeermiddel was dat dit chemies stabiel moet bly oor 'n tydperk soortgelyk aan die duur van 'n simulatortoets, wat tipies 5 000 000 siklusse duur.

Die eerste doelwit van hierdie studie was om vas te stel wat die effek van 'n temperatuurstyging op die viskeuse en smeereienskappe van gewrigsvloeistof is. Die gewrigsvloeistof was afkomstig van pasiënte wat primêre en reëvisie chirurgie ondergaan het.

'n Lineêr-ossillerende toetsmasjien (SRV masjien) was gebruik om die smeertoetsing te doen. Drie toetstemperature naamlik 38°C, 50°C en 60°C was gebruik. Gedurende die smeertoetsing is twee parameters, naamlik die wrywingskoeffisiënt en lasdravermoë gemeet.

'n Afname in die lasdravermoë was gevind vir 'n styging in temperatuur, terwyl die wrywingskoëffisiënt redelik stabiel gebly het.

Die viskositeitstoetsings was gedoen deur gebruik te maak van 'n Brookfield Viskosimeter. Dieselfde drie toetstemperature, naamlik 38°C, 50°C en 60°C was gebruik. Die gewrigsvloeistof het pseudoplastiese vloeie-eienskappe getoon. 'n Styging in die viskositeit van gewrigsvloeistof as funksies van toetstemperatuur styging en skuifkrag was waargeneem.

Die tweede doelwit van hierdie studie was om 'n sintetiese smeermiddel te ontwikkel wat dieselfde eienskappe toon as die gemiddelde viskeuse en smeereienskappe van gewrigsvloeistof afkomstig van pasiënte. 'n Mengsel van drie chemikalieë naamlik Poloxamer 188, Xanthan Gum en Lube Booster[®] II was gebruik om die smeermiddel te meng.

'n Vergelykende toets tussen die sintetiese smeermiddel en kalfserum is gedoen op 'n simulator. Gedurende die toetsperiode van 4 500 000 siklusse is daar na elke 500 000 siklusse monsters geneem. Die slytasiepartikels is dan herwin uit die monsters uit. Gedurende die intervale is die kalfserum stasies dan ook gedreineer, uitgewas met gedeïoniseerde water en hervul met nuwe kalfserum, maar nie uitmekaar gehaal en geweeg soos vereis in die internasionale standaard nie. Dit was opsetlik gedoen om te verseker dat die slytasiepatroon nie verlore sal gaan gedurende die toetstydperk nie. Die simulator stasies wat die sintetiese smeermiddel gebruik het was nooit uitmekaar gehaal of gedreineer nie, dus het die slytasiepatroon behoue gebly asook die slytasiepartikels en kon die effek daarvan ondersoek word oor die hele tydperk van die simulatortoets. Die slytasiepartikels herwin vanuit die simulator stasies was dan vergelyk met die slytasiepartikels herwin vanuit die bindweefsel van pasiënte.

Die slytasiepartikels wat in die bindweefsel gevind is, het dieselfde vorm en grootte gehad as die slytasiepartikels wat gevind is in die simulatortoetsing. Die gevolgtrekking kan dus gemaak word dat 'n aanvaarbare sintetiese smeermiddel ontwikkel is vir die gebruik in heupsimulators.

Glossary

Coefficient of friction	The ratio between the tangential force (F) needed to move a body and the weight (W) applied to that body. Formulated by: $F=\mu W$
Joint Fluid	Fluids retrieved, from synovial joints, for both primary and revision patients groups.
Load at failure	The load obtained from the Linear-Oscillation Test Machine (SRV machine) as being the load at which the lubricant cannot support lubrication anymore.
Lubricity	The ability of a fluid to support lubrication.
Lymph	A liquid similar to blood plasma, but has less proteins and food materials and more waste materials than blood plasma.
Lymphatic	Is similar to veins but carries only lymph.
Newtonian	A linear relationship displayed between the shear rate and the shear stress, see Figures 2.7 and 2.8.
Non-Newtonian	A non-linear relationship is found between the shear rate and the shear stress, see Figures 2.7 and 2.8.
Osteolysis	Foreign body reaction caused by the wear debris in and around the joint.
Polysaccharide	Group of carbohydrates whose molecules consist of long chains of monosaccharides, also known as gums.
Primary patient	A patient receiving his or her first replacement surgery due to the failure of the natural joint.
Pseudoplastic	Also known as shear-thinning fluids are fluids of which the viscosity would decrease as the shear rate is increased.
Revision patient	A person whose prosthetic joint has failed and is thus due to receive a replacement.
Synovial fluid	The fluid found in a healthy synovial joint, like hip and shoulder joints
Viscosity	Quantity measuring the force needed to overcome internal friction.