Effects of surface gel layer on adsorption of proteins and frictional properties of articular cartilage

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Introduction

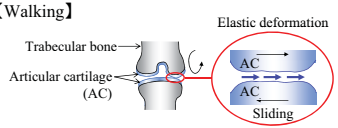
The lubrication properties of articular cartilage have excellent tribological performance in the human life.

The lubrication appears to be not elastohydrodynamic lubrication (EHL) but a combination of various modes; mixed, weeping, and boundary lubrication, corresponding to the severity conditions.

Recently, it has been reported that the existence of the hydrogel layer consisting of proteoglycan on cartilage surface contributes on the low friction. However, the lubrication mechanism of the hydrogel layer has not been evaluated.

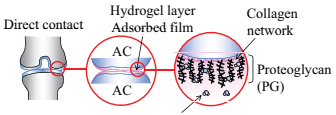
The purpose of this research is to investigate lubrication property of the hydrogel layer on cartilage surface.

【Walking】



Elastohydrodynamic lubrication

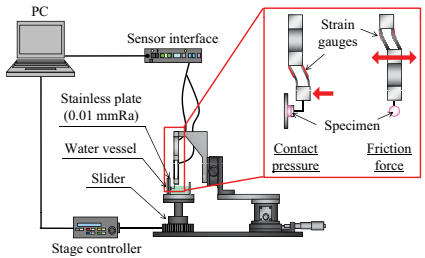
【Movement after standing position and resting】



Mixed, Weeping, and Boundary lubrication

Materials and Methods

Frictional testing apparatus



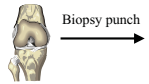
Contact pressure

A normal load was applied to the specimen by the reaction force of the lower leaf springs and the load was measured with the strain gauges.

Frictional force

A frictional force was measured with strain gauges attached to the upper leaf springs.

Specimen



Biopsy punch

The femoral patella groove of 6-month-old pigs about 100 kgf

Intact group

The cartilage surface was preserved.

Wiped group

The cartilage surface was gently wiped with wiper to remove the hydrogel layer.

Condition of reciprocating friction test

Contact pressure (kPa)	0.35
Sliding velocity (mm/s)	0.05, 0.10, 0.25, 0.50, 1.0
Diameter of specimen (mm)	4*1, 6, 8*1
Sliding time (minute)	15
Lubricant	physiological saline solution without and with*2 albumin

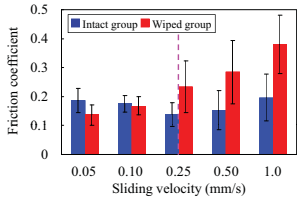
*1 : carried out under the condition of 0.05 mm/s , 0.01 N and saline without albumin.
*2 : carried out under the condition of 0.05 mm/s and ϕ6 mm.

The friction coefficient at the start of the friction test was defined as the initial friction coefficient (μ_{ini}).

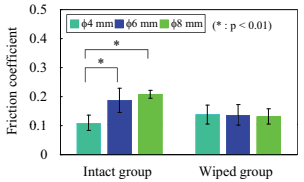
Results and Discussion

Effects of hydrogel layer

μ_{ini} for the sliding velocity

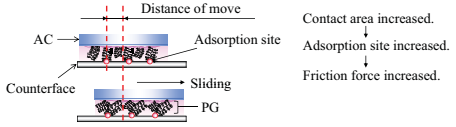


μ_{ini} for the contact (0.05 mm/s, 0.01 N)



Adsorption force

For frictional of polymer, adsorption is dominant.



Sliding velocity > 0.25 mm/s

- Intact group μ_{ini} < Wiped group μ_{ini}
- μ_{ini} decreased with decreasing of sliding velocity.

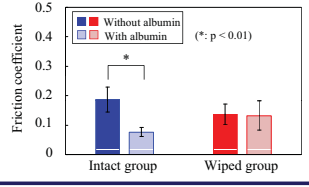
Fluid lubrication carried out.
Hydrogel layer contribute low friction and wear.

Sliding velocity < 0.25 mm/s

- Intact group μ_{ini} > Wiped group μ_{ini}
- Intact group μ_{ini} increased with decreasing of sliding velocity.
- Intact group μ_{ini} significantly increased with increasing of contact area.

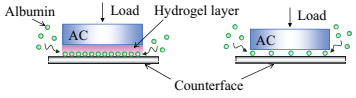
Hydrogel layer consist of proteoglycan (PG) aggregated as polymer.
The adsorption of PG with the counterface was occured the friction force.

Lubricant dependency of the hydrogel layer (0.05 mm/s, ϕ6 mm)



Intact group μ_{ini} significantly decreased due to addition of albumin, whereas **Wiped group μ_{ini}** did not change.

- Protepglycan is high hydrophilicity.
- Albumin have many hydrophilic groups.



Albumin adsorbed on hydrogel layer kept low friction.

Conclusions

The friction coefficient of articular cartilage was increased due to adsorption against the counter face in the condition of low sliding velocity and low contact pressure.

The hydrogel layer on cartilage surface attracted albumin in the lubricant, and kept friction coefficient low by preventing adhesion between cartilage and counterface at starting motion.