Friction Measurement of Articular cartilage using Nano Tribometer

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The aim of this study is to investigate the effects of surface gel layer on friction properties of articular cartilage in the mixed lubrication regime. In this work, the frictional characteristics of articular cartilage with different treatments have been studied over a range of sliding speed and normal loads by Nano Tribometer. The results show that the preprocessing with the ultrasonication removed a part of surface gal layer and produced a significant increase in COF compared with the control cartilage; the effect of preprocessing with the tube mixer was limited. Synovial fluid has an effective lubrication effect on both the intact and the damaged cartilages.

Keywords: cartilage, friction, gel layer

1. Introduction

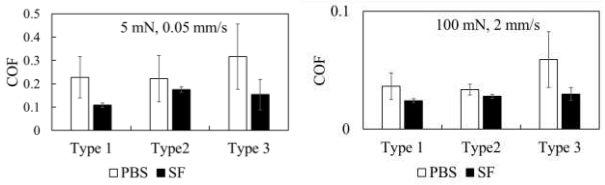
Many previous studies suggested the expected lubricating role of the gel layer on cartilage surfaces under the boundary lubricating condition [1]. However, the boundary lubrication mechanism of natural synovial joints and the lubricating function existing in the cartilage surface are still topics for very active discussions. In this study, we examined the friction properties of 3 types of cartilage specimens with different preprocessing to elucidate the lubricating function of surface gel layer.

2. Methods

2.1. Bovine cartilage preparation and treatment
Square cartilage samples (side length 8mm) were harvested from the proximal joint of the bovine middle phalanx within 24h of sacrifice. 3 types of samples were tested: untreated bovine cartilage (Type 1), bovine cartilage washed in a solution of 10%(v/v) detergent (Triton-X-100) with a tube mixer (Type 2) or ultrasonic cleaning (Type 3) for 30min.

2.2. Friction tests
Rotational (angular) reciprocating tests (α=30°) were performed using a pin-on-disk configuration with a smooth glass probe (2 mm diameter) in a Nano Tribometer (Anton Paar NTR3, Austria). The sample was fully immersed in a liquid bath filled with lubricant (PBS or SF) and rotationally reciprocated beneath the probe at constant speed (0.05, 0.1, 0.2, 0.5, 1, 2 mm/s) and 3 different contact loads (5, 20, 100 mN).

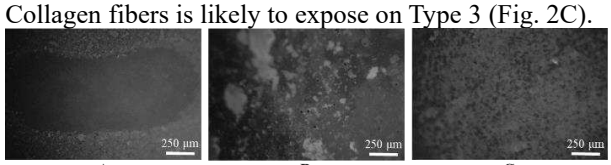
2.3. Results
As indicated in Fig. 1, Type 3 produced a significant increase in COF compared with Type 1 and enhance the speed dependence of COF; the friction increase was lager at the lower sliding speed. On the other hand, Type 2 produced an almost identical frictional characteristics to the control specimen.
SF did not reduce COF of Type 2 compared with PBS, whereas significant reductions in COF were observed in Type 1 and Type 3 at the lowest speed condition (Fig. 1 (a)). Meanwhile, Type 1 showed the minimum COF compared with Type 2 and Type 3 in SF. At the highest speed condition, the COF decreased significantly compared with the lowest speed condition (Fig. 1 (b)). Nevertheless, the lubrication effect of SF was still recognized for Type 1 and Type 3.



(a) (b)

Figure 1: COF plotted versus 3 types specimens.

The cartilage surfaces were fluorescently stained and observed within PBS by using a fluorescent microscope. The surface of Type 1 seems to be smooth (Fig. 2A) and Type 2 appears to be slightly damaged (Fig. 2B). Collagen fibers is likely to expose on Type 3 (Fig. 2C).



A B C

Figure 2: Flourescent images of 3 types specimens.

3. Discussion

It is indicated that the sliding tests were conducted under the mixed lubrication condition in this study. Results of this study suggest that the hydrated gel layer play a dominant role in reducing the COF of articular cartilage. The adhesion between cartilage and glass probe was the main factor exerting the friction force especially under the low sliding speed condition. The surface gel layer of cartilage might reduce adhesive interaction between surfaces and keep low friction under such conditions. The removal of the surface gel layer had a certain impact on friction even under the high sliding speed condition. SF appears to have an effective lubrication effect not only on the intact cartilage but also on the severely damaged cartilage. The friction reduction of the damages cartilage was considered to be brought by the recovery of the lubricating absorbed film on cartilage surface with partial gel layer and hydration lubrication becomes partly effective.

4. References

[1] S. Jahn. et al., “Lubrication of articular cartilage,” Annu Rev Biomed Eng, 18, 2016, 235-258.