THE EFFECT OF TOTAL MENISCECTOMY ON BIOTRIBOLOGICAL BEHAVIOUR OF SHEEP KNEE JOINT

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ABSTRACT

The meniscus is an important tissue to protect the knee joint from high joint loads therefore total meniscectomy leads to increase in friction and wear on knee joint and eventually causes osteoarthritis. It is difficult to investigate friction and wear on the whole joint in vivo and in vitro and the biotribological effect of meniscus was not widely studied in the articulating knee joint. The aim of this study was to investigate the effect of meniscus on biotribological behavior of sheep knee joint using a joint friction and wear simulator. For this purpose adult sheep knee joints were cut and attached to a self-made joint simulator, which was used to apply a physiologic load and range of motion to the knee joint. The friction coefficient was read from the force/torque sensor on the simulator and the wear of the articular cartilage investigated virtually by using Indian ink. The friction coefficient increased for the knee joint without meniscus. Knee joint with meniscus showed no significant cartilage wear and degradation. However, the articular cartilage was entirely worn around the center of the contact upon removal of the meniscus. This study demonstrated that total meniscectomy leads to increase in friction coefficient which cause the surface fibrillation and eventually cartilage wear and degradation.

Keyword: Knee Joint, Meniscus, Articular Cartilage, Biotribology, Meniscectomy

INTRODUCTION

Despite the increase in knee osteoarthritis, researchers were able to show very little progress in finding a treatment to reduce the progression of the disease. One of the most important reasons of that was the difficulty of experimental studies on humans. Therefore the most of the studies were performed on animals or in vitro [1-3]. Such studies with clinical observations develop significant hypotheses for the biomechanical factors affecting the formation and progression of the disease. Some researchers put forward a hypothesis that changes in the joint kinematics as a result of muscle injuries, caused an overloading on the previously unloaded parts of the joint, and this leads to damage in that area [4-6].

Total meniscectomy leads to osteoarthritis in the natural knee joint by effecting the underlying articular cartilage and bone [7], so that the meniscus plays an important protective role in the load-bearing capacity of the knee joint. The meniscus reduces the contact stress by distributing the contact forces to a larger area on the articular cartilage, which makes the knee joint more congruent [8]. Recent studies on biotribological response of articular cartilage have shown that friction and wear properties are dependent on duration of loading and contact stress. However, the relationships between the biphasic structure and time-dependent tribological response of articular cartilage are complex [9-11].

It is very difficult to predict the tribological response of the whole joint from simple cartilage specimens [9-11]. The investigation of friction and wear in whole joint is difficult and there are limited studies on the biotribological effect of meniscus. It is well known that lack of the meniscus leads to increase the coefficient of friction on the knee joint. This increase in friction also increases the contact stress which leads to wear and joint failure. However, there is no direct experimental evidence for this relationship between friction, contact stresses and cartilage degradation. An understanding of degradation mechanisms of articular cartilage after meniscectomy is important for researchers because the decision of the treatment method of the meniscus damage depends on these researches.

The aim of this study was to investigate the friction and wear responses of sheep knee joint with and without the meniscus by using a self-made friction and wear simulator.

MATERIALS AND METHODS

Healthy adult sheep (6-12 months old) knee joints were obtained from the market 24 h after slaughter and frozen at −18 °C until testing; previous studies concluded that the mechanical properties, the friction coefficient of the cartilage was not effected by freezing [11-13]. Before the test, sheep knee joint were defrost in phosphate buffered saline (PBS) to preserve lubrication properties, at 4 °C for 24 hours.

Purposefully designed molds were used to hold knee joints during tests (Fig. 1a,b). A self-made friction and wear simulator was used for tests as shown in Fig. 1c. The wear simulator machine loaded the knee joint under a constant load (P) of 500 N and 150 000 cycles. The knee joint was placed in the simulator so that the contact area stayed within in a bath containing bovine serum as a lubricant (Fig.1b). To determine the wear surfaces on contact area of the knee joint, Indian ink was applied on

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contact surfaces. Flexion-extension (FE) motion was applied to the joint by a servo motor (Fig.1c) which was adjusted as 0° for extension and 46° for flexion. Internal-external rotation (IE) was attained by a slider crank mechanism (Fig. 1c) which rotated the bath ±2° about its vertical center with 1 Hz of cycle frequency. Also an anterior-posterior translation (AP) was applied to the joint as ±5 mm. The effective radius (re) for internal-external rotation was then measured from the contact area of the knee joint after test to calculate the coefficient of friction (μ).

Fig.1: a) Knee joint was held in molds, b) placed in bovine serum bath, and c) attached to the wear simulator.

In all experimental configurations, the frictional torque between articulating surfaces was transmitted to the force/torque sensor. The sensor data were processed via PLC unit of the simulator and recorded on a PC. Coefficients of friction (μ) for knee joint with and without meniscus were then calculated as $\mu = T_f / (P \cdot r_e)$, where $T_f$ is frictional torque, $P$ is applied load, and $r_e$ is effective radius, described above.

RESULTS AND DISCUSSION

The friction coefficient for the sheep knee joint with and without meniscus was transferred to computer at 0.1 s intervals, however, the number of data was reduced to clarify the figures as shown on Fig. 2. The friction coefficient was determined as 0.03 for articular cartilage with meniscus while it was determined as 0.052 for articular cartilage without meniscus after 150 000 cycles. These values were in agreement with the results of McCann et al (2009) which determined the friction coefficient in bovine knee joint with meniscus between 0.01 and 0.03 and without meniscus between 0.04 and 0.07 [14].

Fig. 2: The friction coefficient of sheep knee joint with and without meniscus.

In order to evaluate the effect of meniscus on biotribological behavior of sheep knee joint, not only the coefficient of friction was determined but also the wear on contact surfaces was investigated in this study. Contact surfaces of the knee joint were virtually investigated after simulator tests. Although the India ink was removed on the contact surface (especially on medial
part) of the knee joint with meniscus, there was no significant wear observed on the articular cartilage and meniscus (Fig. 3a). However, for the absence of meniscus, the articular cartilage was entirely worn around the center of the contact area (Fig. 3b). It can be concluded that the possibility of total knee arthroplasty increases for the patients who had meniscectomy which leads to cartilage degradation according to our results.

Fig. 3: Wear on knee joint a) with meniscus and b) without meniscus (after 150 000 cycles at 500 N load).

This study has shown that lack of the meniscus increases coefficient of friction and causes surface fibrillation which leads to wear of articular cartilage. There was no significant wear observed on knee joint with meniscus. This finding was in agreement with the previous studies on the biomechanical effect of meniscus [7, 15]. The meniscus has absorbed the most of the joint load therefore the large joint loads effect the articular cartilage when the meniscus has been removed [8]. In this study, a small flexion-extension motion of 0° to 46° has produced a shorter sliding distance which may have reduced the rehydration of the cartilage tissue, causing a rise in frictional coefficient [16, 17]. Experimental studies on animals have shown that meniscectomy can cause cartilage damage in the short term [18, 19].

CONCLUSION
This study shows the effect of meniscus on biotribological behavior of the knee joint. The friction coefficient increases with the removal of the meniscus. Also the lack of meniscus causes surface fibrillation, cartilage wear and degradation of the cartilage. It can be concluded that the meniscus must be retained in knee joint surgery as much as possible because the removal of the meniscus leads to osteoarthritis in the long-term.

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REFERENCES

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