230 A New Dynamic Contact Pressure Sensor for In-Vitro Knee Joint

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In this study, we report the development of a microcapacitance pressure sensor for measuring dynamic contact stress of the tibio-femoral joint. In order to verify the accuracy of the sensor, dynamic contact pressure was measured for an in-vitro cow joint with intact ligaments at the flexion angle from 0 degree to 90 degree.

Key Words: Contact Pressure Sensor, Knee Joint, Biomechanics

1. Introduction

Accurate measurement of the dynamic contact pressure at the tibio-femoral joint during physically meaningful activity such as flexion/extension motion at standing position with two feet contact on the ground, is one of the very important task to understand the human knee joint function because of the frequent major ligament injury and osteoarthritis at the knee joint[1-3]. However, almost all previous studies are limited to static measurement. Also, some dynamic contact measurement method had another meaning of limitation, cannot use for hidden surface or had to cut all the ligaments[1]. Brown et al.[1], presented a technique for measuring instantaneous in-vitro contact stress distributions in articular joint, cadaveric knee , using miniature piezoresistive contact stress transducers. The major limitation of this study was to cut all the ligaments in order to do the implementation of transducers on the geometrically complicated articular joints, which could not represent realistic human joint function. Recently, we presented a dynamic transducer used at the in vitro knee joint of an animal[3] and human[2]. In these studies, the diameter of the sensor was 5 mm and the experimental apparatus developed in our laboratory was limited to 2-D motion.

In the present study, we report the development of a new dynamic contact pressure measurement transducer including less hysteresis and better dynamic response compared to the previously reported our system for measuring dynamic contact stress on a cow's tibio-femoral joint. In addition, full three-dimensional observation is made employing a commercially available MTS machine.

2. Material and Methods

Schematic diagram of capacitance pressure sensor is given in Figure 1.

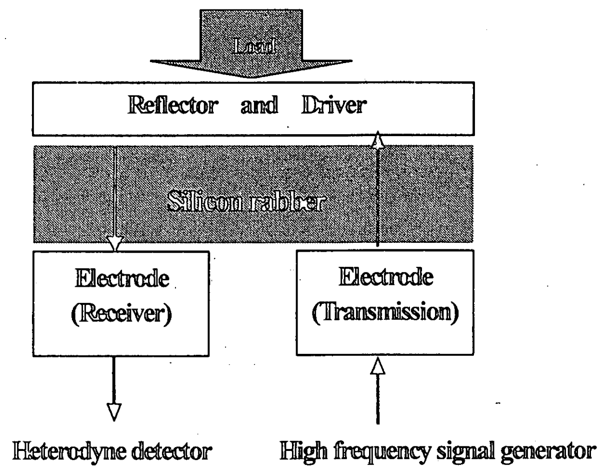

Fig. 1. Schematic diagram of capacitance pressure sensor

The sensor is composed of a main electrode (copper) and a reflector (copper) separated by a silicon rubber (elastic material and thickness of $200\mu m$). Silicon rubber was sandwiched with a layer of electrode and a layer of reflector by an etching technique. A high-frequency signal, generated by the main electrode, is passes through the silicon rubber and is reflected by the reflector.

Since there is no electrical circuit on the reflector, the sensor can be made very thin. When a load is applied to the sensor, the silicon rubber is compressed a small amount δ which is proportional to the loading condition.

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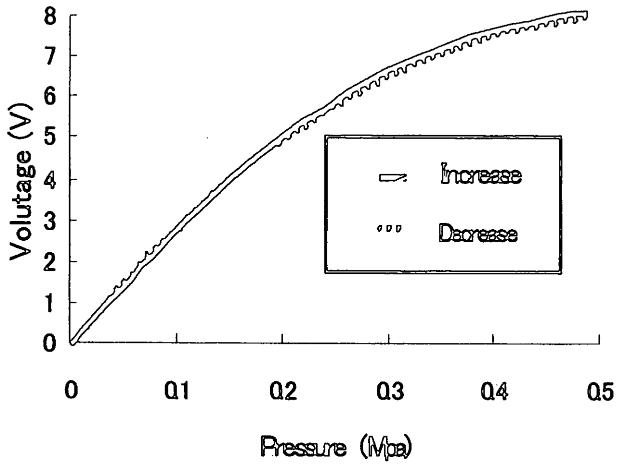

Fig. 2. Characteristics of the capacitance pressure sensor

The high-frequency signal is transferred from the main electrode to the reflector and from the reflector to the detector so that the total path difference is multiplied by 2 δ. The thickness and diameter of the sensor were 500 micro-meter and 3 mm, respectively. A water-resistance capsule consisting of PTFE was used around the transducer. The characteristic of the developed capacitance pressure sensor is given in Figure 2. A total of eight sensors were attached on the medial tibia surface as shown in Figure 3. In the figure, each number represents the sensor position. The dynamic response of the developed sensor during 0.1 second time period when 900 g is applied on the developed sensor is given in Figure 4.

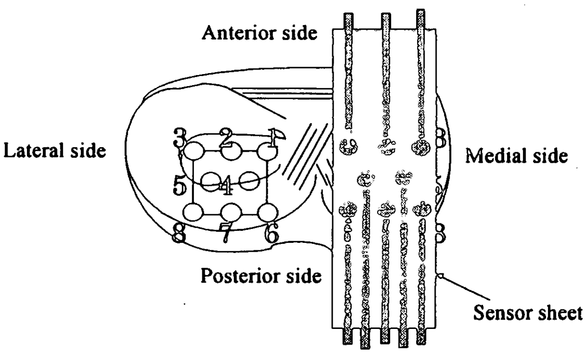

Fig. 3. Schematic diagram of capacitance pressure sensor

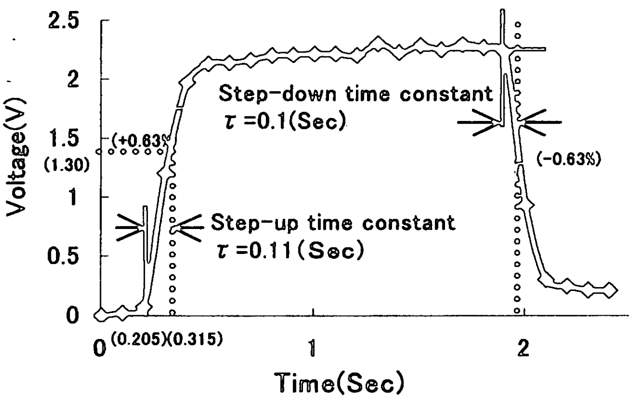

Fig. 4. Dynamic response of the developed sensor

3. Results

In order to verify the accuracy of the developed transducer, dynamic contact pressure was measured for an in-vitro cow knee joint with intact ligaments at the flexion angle from 0 degree to 90 degree. As the flexion angle increase, anterior/posterior movement is observed as shown in Figure 5. In addition, at the 20 degree flexion stage, sudden contact pressure change is measured, mainly due to the starting of the rotation as other previous study reported[2].

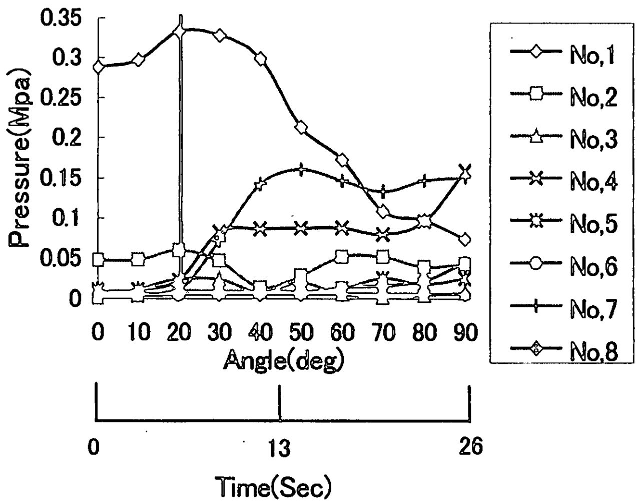

Fig. 5. Contact pressure on the tibio-femoral joint

4. Conclusion

Mun et al[2], reported that rotation of human joint starts from 20 degree flexion angle. Following our experiment using the newly developed transducer, the similar behavior on a cow joint was observed compared to human joint. Thus, we conclude that cow joint maybe used for the understanding of the human joint function. In order to support this hypothesis, we will perform the additional experiments including ACL, MCL and/or PCL instability condition in the near future using the developed contact pressure measurement sensor.

5. References

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