INTRODUCTION:
Articular cartilage has a limited healing capacity and therefore, feasibility of cell-based therapies has been investigated. For effective cell delivery, synthetic or animal-derived scaffolds are frequently used; however, the long-term safety and efficiency of such scaffolds still remain unclear. We have recently established a novel scaffold-free 3-D synthetic tissue (3DST), composed of synovial-derived mesenchymal stem cells (MSCs) and their native extracellular matrix [1, 2]. At the last ORS meeting, we reported the successful repair of porcine partial thickness chondral defect by the 3DST. In the present study we investigated the mechanical properties of the repaired tissue, specifically focused on compressive and frictional properties.

METHODS:
Synovium-derived MSCs obtained from the synovial membrane of porcine knee joints were cultured in DMEM in monolayer. Seven days after the addition of ascorbic acid 2-phosphate, the monolayer culture complex was allowed active contraction for 8 hours after detachment from the substratum to develop 3-D synthetic tissues (3DST). A round shaped cartilage defect of 8.5 mm in diameter and 1.5 mm in depth was created on the medial condyle of the femur. The defect was filled with the 3DST, and the pig was allowed cage activity. Six months after surgery, a cylindrically shaped cartilage-subchondral bone specimen of 4 mm in diameter and 5-8 mm in depth was harvested.

The quasi-static and dynamic axial unconfined compression tests were performed for the specimen using a custom made micro compression tester [3]. The quasi-static compression was applied to the specimen soaked in the normal saline solution at 37°C at a speed of 4 µm/s and 100 µm/s with the maximum stress of 70 kPa. The dynamic compression was then applied to the specimen at a speed of 100 µm/s in the range of 5-10 kPa. After the compression tests, the specimen was subjected to a reciprocating friction test, using a custom made friction tester [4]. The surface of the specimen was rubbed against a glass plate in the normal saline solution at 37°C. The frictional speed was 20 mm/s, while the normal load was 0.88 N (70 kPa). In addition, after compressive force of 300 seconds was applied, the adhesive force of the cartilage against a glass plate was measured at a speed of 100 µm/s.

RESULTS AND DISCUSSION:
Histological observation indicated that the cartilage defect was repaired by the 3DST with intense staining of Safranin-O (Fig.1), conversely the untreated cartilage defect had only partial coverage with scar-like tissue.

In the compression test, the tangent modulus of the repaired cartilage with the 3DST was similar to that of normal cartilage at both 4 and 100 µm/s of compression speed (Fig.2). Note that the modulus of the repaired tissue with the 3DST was significantly higher than that of the repaired tissue without the 3DST at 100 µm/s (Fig.2(b)). These results suggested that the permeability of the repaired cartilage with 3DST was recovered well in response to quasi-static loadings.

In the friction test, the coefficient of friction of repaired cartilage with 3DST against the glass plate immediately after the application of compressive force of 0.88 N was same level as that of normal cartilage (Fig.3(a)). However, 60 seconds after the application of compressive force, the coefficient of friction became significantly lower than normal cartilage (Fig.3(b)). Meanwhile, the adhesive force between the tissue and the glass plate was lower in the cartilage repaired with the 3DST than in normal cartilage (Fig.4). These results suggested that the surface of the repaired cartilage with the 3DST had lower friction than normal cartilage after load application.

Taken together, the mechanical properties of repaired cartilage with the 3DST were comparable with those of normal cartilage at 6 months after implantation.

Fig.1: Histological observation (safranine-O staining) of the repaired cartilage with (a) and without (b) 3DST.

Fig.2: Tangent modulus of the repaired cartilage with and without 3DST at a speed of 4 µm/s (a) and 100 µm/s (b).

Fig.3: Coefficient of friction of the repaired cartilage at the beginning of the friction test immediately after (a), 60 seconds after (b) the application of compressive force of 0.88 N.

Fig.4: Adhesive force of the repaired cartilage to glass plates with the initial compressive force of 0.88 N.

REFERENCES:

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