The Effect of Gradual Weight-Bearing on Regenerated Articular Cartilage after 9 Weeks of Joint Distraction and Motion

Introduction:
Mechanical stimulation through joint distraction and motion is beneficial for cartilage regeneration. In an earlier study, we have reported good results in terms of cartilage repair through gradual weight-bearing (GWB) applied for 3 weeks; GWB was applied after 6 weeks of distraction and motion by using an external fixation device (EFD) in a rabbit model [1]. However, the degree of regeneration in the GWB group was less than that observed in the control group rabbits that had EFDs attached without the application of weight-bearing, continuous passive motion (CPM), or anesthesia. We believe that the duration, 6 weeks, of joint distraction and motion is inadequate and subsequent fixation of an EFD for GWB with anesthesia influences the results to a great extent. Therefore, we investigated the long-term (9 weeks) effects of GWB after joint distraction and motion in the same model. Further, we studied a second control group in which anesthesia was induced but GWB and CPM subject to the same conditions as the other two groups.

Materials and Methods:
The study was approved by the University Committee for Animal Experimentation. We used 27 Japanese white rabbits (16-week-old males; mean weight, 3.0 kg). Under general anesthesia, the EFD was fixed on the left knee of each rabbit. The cruciate and collateral ligaments were divided, and the menisci were resected. Subsequently, a full-thickness defect was created on the articular cartilage of the entire surface of the tibial plateau by using an oscillating saw. A space was formed in the femorotibial joint because of the resected osteochondral defect, resulting in joint distraction. The rabbits were divided into 4 groups (Fig. 2). In the GWB group (n = 6), GWB was initiated 9 weeks after surgery. GWB (0.5 kg in the first week; 1 kg, second week; and 2 kg, third week) was applied with CPM for 2 hours every day. In the CPM group (n = 7), CPM with EFD was applied in the same manner but without GWB. In the anesthesia (ANE) group (n = 7), the EFD was connected to the movement device under anesthesia, but neither GWB nor CPM was applied. The EFD was connected to a movement device, and CPM and controlled pressure were applied to the knee joint of the rabbits sedated by an intramuscular injection of medetomidine hydrochloride and midazolam. The control (CON) group (n = 7) received only joint distraction without GWB or CPM. All rabbits were sacrificed 12 weeks after the surgery. The proximal tibia was decalcified, and sagittal sections at the midportion of the medial and lateral tibial plateaus were obtained for histological analysis. These sections were stained with hematoxylin and eosin, safranin-O/fast green (SO), and a monoclonal antibody for type-II collagen (Col-II). The central one-third of the regenerated tissue was assessed and scored blindly using a grading scale of the International Cartilage Repair Society (ICRS) visual histological assessment scale. The area of regenerated soft tissue and that stained by SO and Col-II was assessed and scored using this system 6 weeks postoperatively, although the findings in the CON group were the best [1].

In the present study, we initiated GWB and CPM 9 weeks after joint distraction and motion using this system 6 weeks postoperatively, although the findings in the CON group were the best [1].

In a previous study, we have shown the benefit of joint distraction and motion in the repair of large, full-thickness defects of the articular cartilage by using a hinged external fixator in the rabbit model, identical to the one used in the present study [2, 3]. Furthermore, we developed an EFD with a controllable weight-bearing system and CPM to investigate the effects of weight-bearing applied on regenerated cartilage after distraction and motion in a clinical rehabilitation setup [1]. In a previous study, we have reported the initiation of GWB and CPM by using this system 6 weeks postoperatively, although the findings in the CON group were the best [1].

In the present study, we initiated GWB and CPM 9 weeks after joint distraction and motion using the EFD. The results show that mechanical stress such as GWB is essential for the maintenance of the regenerated cartilage and for its differentiation into mature cartilage. We believe that the contradictory findings in the previous study can be attributed to the short duration of joint distraction and motion and the daily administration of anesthesia for 3 weeks during the application of GWB and CPM. Therefore, we added the ANE group as an optimal control for the GWB and CPM groups. Among the 3 groups, the ratio of the SO-stained area was statistically larger in the GWB group than in the other 2 groups. Thus, we conclude that to ensure cartilage regeneration in this model, it is better to start GWB and CPM 9 weeks after joint distraction and motion rather than after 6 weeks.

In empirical rehabilitation programs, we have gradually applied weight-bearing at appropriate time points to patients after cartilage repair procedures [4, 5]. We hope that our findings provide evidence to clarify the in vivo effects and the efficacy of GWB in rehabilitation.

References: