INTRODUCTION
Partial disc replacement (PDR) is an emerging surgery, and promise to overcome the limitations of current treatments for degenerated symptomatic intervertebral discs (IVD). It is generally expected that PDR will relieve discogenic pain and prevent further degeneration of IVDs by restoring the height and biomechanics of discs. Although some authors reported that PDR has beneficial clinical outcomes, there are few controlled animal studies in which the therapeutic effects of this procedure have been demonstrated. Difficulty of using animal studies to examine PDR resides with the problems with immobilization of the implant in the disc space of animals. For this study, we established a surgical model of PDR of rabbit lumbar IVDs. The model was used for radiological and histological evaluation of the therapeutic effects of PDR in a controlled trial.

MATERIALS AND METHODS
The implants used in this study were made of poly (vinyl alcohol) (PVA) hydrogel and rod-shaped (1.9 mm in diameter and 20mm in length). They contained 30%−40% water when hydrated. The L2/3 or L3/4 IVDs of Japanese white rabbits were pierced with a 2.0 mm Kirschner wire at the midpoint of the left side in a lateral direction and implants were inserted into the stab wounds. Because the implants were longer than the lateral diameters of the rabbit lumbar IVDs, their tips were expected to protrude on the right sides of the IVDs, even when a few millimeters of the base of the implant extended from the left side. For comparative purposes, the adjacent discs underwent sham treatments or control treatments in which the disc was pierced but no implant was inserted. The animals were kept in cages without immobilization, and euthanized at 1, 3, or 6 months postoperatively. In total, 30 PVA discs, 15 control discs, and 15 sham discs from 30 rabbits were used for radiological and histological evaluations.

Disc-height indexes (DHI) were calculated using ratios of disc heights to adjacent vertebral body heights in lateral radiographs of all the specimens (Fig. 1). The percentage change in DHI after the operation (%DHI) was calculated as: %DHI = [(postoperative DHI) / (preoperative DHI)] × 100. (Fig. 1). The percentage change in DHI after the operation (%DHI) was significantly lower than that of the control discs throughout the period (Kruskal−Wallis test and Sheffe’s test, P < 0.05), and almost equal to those of the sham discs.

Histologically, lamellar disorganization of the PVA discs was confined to the inner third of the AF at Month 1, but gradually spread out to the middle third thereafter (Fig. 2A). The nucleus pulposus (NP) space of the PVA disc was mostly occupied by the implant, and severely reversed lamellae of the AF were not observed. Degeneration of the control discs was excessive; degeneration of the sham discs was mild throughout the observation period (Fig. 2B and C). The NP tissue of the control discs was markedly reduced and was replaced by dense fibrocartilaginous tissue or AF with a severely reversed contour. Data on AF degeneration were summarized in Fig. 3. Histological grade of the PVA discs was significantly lower than that of the control discs throughout the period (Kruskal−Wallis test and Sheffe’s test, P < 0.05), but gradually progressed with time. Mean implant heights were 1.80 mm, 1.70 mm, and 1.66 mm at 1, 3, and 6 months, respectively. Mild surface abrasion was observed at several spots on surfaces of the implants, but neither cracks nor fissures were observed with a stereomicroscope.

DISCUSSION
Therapeutic effects of partial disc replacement surgery were demonstrated by quantitative radiological and histological analyses. Implant displacement was prevented by using long implants. Radiological analysis revealed that short-term preservation of disc height by the PDR was satisfactory. Implant height loss was considered one of the causes of decrease in the %DHI of the PVA discs. Histological assessment revealed that the progress of degeneration of pierced IVDs was significantly delayed by the PDR. Disc height preservation and prevention of AF migration into the NP space appeared to be playing an important role in delaying degeneration. There are several potential causes of histological deterioration. Firstly, the antidegenerative effect of the PDR may have gradually been lost as the %DHI of the PVA discs slowly decreased. Secondly, the progress of degeneration of the pierced IVDs may have been hard to prevent completely PDR. Antidegenerative effect of PDR was demonstrated to be satisfactory in the short term. Properly designed implants and minimal invasive techniques are necessary for long-term success.

Fig. 1. Left: Measurement of disc height from a lateral radiograph. Disc-height index = (BC+FG+JK) / 2 / (AB+CD+E+F+GH+IJ+KL). Right: Changes in %DHI. Mean %DHIs of the PVA discs were significantly greater than those of the control discs.

Fig. 2. Histological changes of AF at 6 months after each procedure. Degeneration of the PVA discs (A) was much milder than the control discs (B). Degeneration of the sham discs remained mild (C).

Fig. 3. Changes in mean histological grade. The grades of the PVA discs were significantly lower than those of the control discs throughout the period. Differences between PVA discs and sham discs were not significant at Months 1 and 3.

THERAPEUTIC EFFECTS OF PARTIAL DISC REPLACEMENT IN A RABBIT MODEL

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