Effect Of Centralization For Extruded Meniscus Extrusion In A Rat Model

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Introduction: Meniscus extrusion is reported in knees with osteoarthritis, meniscus injury, after partial meniscectomy and so on. Several studies demonstrated that the medial meniscus extruded more in osteoarthritis knees than in healthy knees, and there was correlation between the extrusion of the medial meniscus and joint space, therefore meniscus extrusion is a risk factor of osteoarthritis progression (1, 2). However, little is known about the treatment for meniscus extrusion. Recently, we reported a noble procedure of arthroscopic centralization for an extruded lateral meniscus in human cases (3). Centralization was achieved using suture anchor technique, and the meniscus was stabilized on the edge of the lateral tibial plateau. MRI finding and the symptoms of pain and swelling was improved at 3 months postoperatively. However, no animal model of centralization for extruded meniscus was reported and it was unclear whether this procedure could prevent the progression of osteoarthritis. In this study, we developed a rat model for centralization of extruded medial meniscus and investigated effectiveness of this procedure.

Methods: Wild type male Lewis rats at 10 - 12 weeks old were used for the experiments. All animal care and experimentation were conducted in accordance with the institutional guidelines of the Animal Committee of Tokyo Medical and Dental University. After the straight skin incision, patellar tendon was dislocated laterally, and the medial meniscotibial ligament was transected to induce the extrusion of the medial meniscus. For the centralization, suture nylon was passed through the peripheral margin of the medial meniscus, then inserted from the edge of the medial tibial plateau and pulled out to the anterior portion of proximal tibia through the bone tissue. After two sutures were passaged, knot tying was secured with the medial meniscus repositioned on the original location, which provided the stabilization of the medial meniscus on the edge of the medial tibial plateau (Figure 1A). The rats were allowed to walk freely in their cages, and were sacrificed for the micro-CT assessment at 1 day, 1, 2, 4, and 8 weeks after the surgery (centralization group; n=5). As a control, the same number of rats had the surgery of only medial meniscus extrusion (extrusion group, n = 5). Macroscopic observations for meniscus and cartilage, and histological assessment for cartilage degeneration were performed.

Results: Centralization for extruded meniscus improved the meniscus coverage of medial tibial plateau, and the effect remained up to 8 weeks. Micro-CT demonstrated that the medial meniscus displaced completely out of the medial tibial plateau at one day after the surgery in the extrusion group (Figure 1B). No improvement of displacement was obtained spontaneously throughout the study. On the other hand, the mid body of the medial meniscus
located on the medial tibial plateau in the centralization group and the effect remained up to 8 weeks, though the slight extrusion was detected (Figure 1B). For the quantitative analysis of the medial meniscus extrusion, ratio of meniscus extrusion length (RMEL; ratio of the length of lower part of extruded meniscus and the length of lower part of medial meniscus), and ratio of meniscus coverage (RMC; ratio of the length of lower part of meniscus on tibial plateau and the length of medial tibial plateau) were calculated. RMEL showed less extrusion of medial meniscus in the centralization group than in the extrusion group (Figure 1D), and RMC showed better meniscus coverage in the centralization group than in the extrusion group (Figure 1E). Macroscopic finding of meniscus revealed medially displaced anterior portion of medial meniscus (Figure 2A, arrows) and less meniscal coverage of the medial tibial plateau in the extrusion group. On the other hand, the displacement was small and meniscal coverage was almost similar to normal one when the rat had the centralization of medial meniscus (Figure 2A).

Centralization for extruded meniscus delayed cartilage degeneration.

We then investigated whether the centralization of extruded meniscus could delay the cartilage degeneration. Macroscopically, the medial tibial plateau appeared obvious cartilage erosion in the extrusion group at 8 weeks after the surgery (Figure 2B), on the other hand, the cartilage was better preserved throughout the study when the centralization was performed. While safranin-o staining for medial tibial plateau showed cartilage degradation appeared at 2 weeks further progressed at 4 and 8 weeks in the extrusion group (Figure 3A), mild cartilage degeneration was detected only at the surface area at 8 weeks in the centralization group. Mankin score indicated cartilage was better preserved in the rat that had centralization surgery at 4 and 8 weeks than in the rat that had only extrusion surgery (Figure 3B).

**Discussion:** To accomplish the centralization for the extruded meniscus in rats, we performed pulled-out suture technique, which was different from our suture anchor technique we reported in human because of the lack of small devices suitable for rat knees. However, the concept of the centralization, which function to reposition the extruded meniscus and to stabilize the meniscus on the edge of the tibial plateau, is completely the same. For the assessment of the meniscus extrusion, micro-CT was used in this study. The innate calcification of the rat meniscus enables us to confirm the position of the meniscus body in the coronal view of micro-CT.

Once the medial meniscus was extruded, the displacement was not improved spontaneously. Centralization for the extruded meniscus increased the meniscal coverage of the medial tibial plateau and the effect remained up to 8 weeks. Most importantly, the centralization for the extruded meniscus could delay the cartilage degeneration. This animal study will support the usefulness of the centralization for the extruded meniscus in human cases.

One of the limitations of the current study includes no biomechanical analysis for the centralized meniscus. In addition, the current procedure was not able to move the extruded meniscus back to the normal position perfectly. It was due to weak security of knot tying with the nylon suture, but we can resolve this problem by way of using strong sutures in large animals or in human cases. In conclusion, we developed a rat model for centralization of extruded medial meniscus and demonstrated effectiveness of this procedure.

**Significance:** Centralization of the extruded medial meniscus is a promising procedure to delay the progression of knee osteoarthritis.
Figure 1

A

Medial Meniscus → Medial meniscus extrusion → Centralization

Meniscotibial ligament

B

Centralization

Extrusion

C

Ratio of meniscus extrusion length (RMEL)
Length of lower part of extruded meniscus (b) / Length of lower part of medial meniscus (a)

Ratio of meniscus coverage (RMC)
Length of lower part of meniscus on tibial plateau (b) / Length of medial tibial plateau (a)

D

E

RMEL

RMC

D

E

* p<0.01, ** p<0.05
Figure 2

A

Extrusion Centralization

1d | 1w | 8w | Normal
---|---|---|---
P | P | P | P
A | A | A | A
1mm | 1mm | 1mm | 1mm

B

Extrusion Centralization

1d | 1w | 8w | Normal
---|---|---|---
P | P | P | P
A | A | A | A
1mm | 1mm | 1mm | 1mm

Arrows indicate the direction of extrusion.
Figure 3

A

Centralization

1d | 1w | 2w | 4w | 8w

Extrusion

1d | 1w | 2w | 4w | 8w

B

Mankin score (0-14)

Better

1d | 1w | 2w | 4w | 8w

Centralization

* p < 0.05

Extrusion

Normal

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