

Comparison of the Clinical Effects of Open and Closed Chain Exercises after Medial Patellofemoral Ligament Reconstruction

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Abstract. [Purpose] To compare the effects of open-chain exercise (OCE) and closed-chain exercise (CCE) for patients after medial patellofemoral ligament (MPFL) reconstruction. [Subjects and Methods] Forty patients after MPFL reconstruction were randomly divided into an OCE group and a CCE group. All the patients were evaluated at four different time points. [Results] The mean change of thigh circumference decrease in the CCE group was lower than that in the OCE group at both the 3rd and 6th month after surgery. The Lysholm score of the CCE group was higher than that of the OCE group at both the 3rd and 6th month. At the 3rd month after surgery, the visual analog scale score of the CCE group was lower than that of the OCE group. [Conclusion] CCE is better than OCE for both short and long term outcomes of patients after MPFL reconstruction.

Key words: Medial patellofemoral ligament reconstruction, Open-chain exercise, Closed-chain exercise

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INTRODUCTION

Patella dislocation is a common orthopedic disease¹⁻⁴⁾. Anatomical research has demonstrated that the medial patellofemoral ligament (MPFL) is the major medial soft-tissue restraint preventing lateral displacement of the distal knee-extensor mechanism, and provides approximately half of the total restraint force^{1, 2)}. Moreover, it has been reported that patella dislocation is accompanied with MPFL injury or tear in most patients^{3, 4)}. MPFL reconstruction is an effective surgical treatment for patella dislocation⁵⁻⁷⁾. However, the clinical effect depends not only on the surgical operation, but is also closely associated with appropriate rehabilitation intervention after surgery.

There are two types of knee rehabilitation exercise, open chain and closed chain exercises. The straight leg raise is the typical open-chain exercise while the half-squat is a well-known type of closed-chain exercise. Two kinds of rehabilitation exercises are used widely in clinical practice^{8, 9)}. The clinical application of open chain and closed chain for chondromalacia patella¹⁰⁾, patellofemoral pain¹¹⁾, and anterior cruciate ligament reconstruction has been reported¹²⁾. However, there has been no standard rehabilita-

tion procedure for MPFL reconstruction, and no study has compared the clinical effect of open chain and closed chain exercises on patients after MPFL reconstruction. This study prospectively compared the clinical effect of open chain and closed chain exercises in order to provide clinical evidence for selecting the proper rehabilitation procedure after MPFL reconstruction surgery.

SUBJECTS AND METHODS

Subjects

Forty inpatients were recruited from the Department of Joint Surgery at our hospital from March 26 of 2008 to June 30 of 2009. They were randomly divided into 2 groups: the open chain exercise (OCE) group (12 males, 8 females; mean age 29.8±12.6 years) and the closed chain exercise (CCE) group (11 males, 9 females; mean age 28.6±14.3years). All the procedures were approved by the Academic Ethics Committee of Hebei Medical University.

Methods

Inclusion criteria were as follows: unilateral knee with recurrent patella dislocation, and a normal contralateral knee; patella dislocation without knee ligament and collateral ligament injury; patellar instability following the initial dislocation persisting for more than three months.

Exclusion criteria were as follows: previous knee injury or surgery; arthroscopic meniscus repair or total meniscectomy; osteonecrosis with cartilage damage greater than

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grade II (Outerbridge classification); patella alta (Insall-Salvati index greater than 1.2); Q angle greater than 20°; trochlear angle greater than 150°, with patellar dysplasia grade IV and V (Wiberg classification); tibial tuberosity-trochlear groove (TTTG) distance greater than 15 mm; concomitant knee cruciate ligament or collateral ligament injury.

All surgery procedures were performed by the same senior surgeon, and were described in our previous study¹³. The semitendinosus tendon was harvested for ACL reconstruction by a closed-end tendon stripper. The “Y” shaped graft was made with an interlacing suture on the femoral and patellar ends. The femoral attachment of the MPFL was positioned in the saddle between the adductor tubercle and the medial epicondyle, and the patellar attachment point was on the medial third section of the proximal patellar margin.

The 1st rehabilitation stage (1st day to 3rd day after surgery)

All patients wore braces for fixation of the knee, and they started to do isometric quadriceps training in order to prevent muscle atrophy and increase muscle strength. In addition, ankle pump exercise was encouraged to promote blood circulation, reduce swelling, and prevent deep vein thrombosis.

The 2nd rehabilitation stage (3rd day to 6th week after surgery)

In the open chain exercise group, straight leg raise exercise was done by every patient. The patients lay on a bed, slowly lifted the involved lower limb with the knee extended until 45° hip flexion, held that position for 5 seconds, then lowered the leg and rested for 3–4 seconds. This was a complete exercise movement. From the 3rd day after surgery, the patient did this exercise 5 times, twice daily. Five more times were added every 2 days. By the end of the 6th week after surgery, the subjects were performing 100 straight leg raises twice a day.

In the closed chain exercise group, a half-squat exercise was done by every patient. The patients stood on their lower limbs and held the bed rails with their hands. The patients were ordered to flex the extended knee 15–20°, and hold this position for 3–4 seconds, then full extended the knees and rest in the standing position for 3–4 seconds. This was a complete exercise movement. From the 3rd day after surgery, the patients did this exercise 5 times, twice daily. Five more times were added every 2 days. By the end of the 6th week after surgery, the subjects were performing 100 half-squats, twice a day.

At the 4th week after surgery, all the patients could flex the extended knee 90°. They began to try to walk on two legs with equal load gradually.

The 3rd rehabilitation stage (6th week to 12th week after surgery)

In this period, all the patients continued to do their exercises 100 times, twice a day, as described above, until the 12th week after surgery.

Table 1. The rehabilitation scheme for the patients 12 weeks after surgery

Period	Exercise program
13–16 weeks	jogging, backward run, deep squat by the involved leg
17–24 weeks	quadriceps femoris resistance exercise and isokinetic training
18–28 weeks	accelerative run
29–32 weeks	jump and knee joint rotatory movement
33–52 weeks	normal athletic sports

The 4th rehabilitation stage

From 12 weeks after surgery, the main task was to improve the whole function of knee to enable the performance of sports. Specific items included isotonic and isokinetic knee extension exercises, progressive resistance training within a tolerable range, and the combination of short distance accelerative running and long distance slow running, as described in Table 1.

All the patients were evaluated at 3, 6 and 12 months after surgery. The visual analog scale was used to measure the pain level during rest. A universal goniometer was used to measure the joint range of motion. A tape measure was used to measure the thigh circumference at 5 cm above the patella superior border, and the one leg hop distance. The Lysholm score was used to evaluate knee function. The patients were evaluated barefoot. For the single leg hop test, the distance was normalized by the height of the patients.

In order to reduce measurement error, the measurements were repeated 3 times and the average value was used in the analysis. The data were analyzed using two-way analysis of variance, and the time (before and after) and the group (OCE, CCE) were assumed to be factors. If a significant interaction between groups was found, oneway ANOVA and the t-test were used for each group or between groups. Analyses were performed using SPSS 16.0 for Windows (SPSS Inc, Chicago, IL, USA). The data are presented as Mean ± SD. The level of significance was chosen as 5% for all analyses.

RESULTS

All patients were followed for one year. In the follow-up period, there was no report of recurrent patellar dislocation or unsteadiness. The results are shown in Table 2.

Overall, the visual analog scale score, mean change of thigh circumference and motion defect of joint showed decreasing trends ($p < 0.05$), and the single leg hop test and Lysholm score showed increasing trends ($p < 0.05$). The interaction between time points and intervention group was also significant ($F(1, 343) = 37.2, p < 0.05$). The results of post hoc tests are demonstrated as follows.

Before surgery, there were no significant differences in baseline data between the two groups ($p > 0.05$). At 3 months after surgery, the visual analog scale score and mean change of thigh circumference in the CCE group was lower than that in the OCE group, while the Lysholm score of the

Table 2. The pre-operation and post-operation follow-up measurement values of the open chain exercise group and the closed chain exercise group (Mean±SD)

Evaluation method	Open chain exercise group	Closed chain exercise group
Visual analog scale (0–10)		
pre-operation	5.9±1.6	5.9±1.3
three months after operation*	2.5±0.4	2.2±0.4 *
six months after operation	1.5±0.7	1.4±0.9
twelve months after operation	1.0±0.4	0.9±0.5
Motion defect of joint (degrees)		
pre-operation	13.7±3.5	13.2±3.7
three months after operation*	6.1±2.7	5.7±2.6
six months after operation	2.2±1.3	2.0±1.3
twelve months after operation	2.1±0.4	2.0±0.5
Thigh circumference 5 cm above patella (cm)		
pre-operation	38.9±1.9	38.3±3.2
Mean change of thigh circumference 5 cm above patella (cm)		
three months after operation*	1.7±0.6	1.3±0.5 *
six months after operation*	1.3±0.2	1.1±0.3 *
twelve months after operation	1.1±0.2	1.0±0.2
Lysholm score (0–100)		
pre-operation	53.2±5.6	52.7±6.4
three months after operation*	74.8±4.6	80.3±3.9 *
six months after operation*	85.1±3.9	88.2±3.9 *
twelve months after operation	89.7±5.0	91.3±5.5
Single leg hop test (involved side in % of uninvolved side)		
pre-operation	47.5±7.1	48.1±6.7
three months after operation	75.3±4.5	77.7±4.4
six months after operation*	85.1±4.2	90.1±5.2 *
twelve months after operation*	93.3±2.8	95.5±2.6 *

*indicates a significant difference between the two groups.

CCE group was higher than that of the OCE group ($p < 0.05$). There was no significant difference in the motion defect of the joint or the single leg hop test between the two groups ($p > 0.05$). At 6 months after surgery, the Lysholm score and single leg hop test of the CCE group were higher than those of the OCE group, while the mean change of thigh circumference in the CCE group was lower than that in the OCE group ($p < 0.05$). There was no significant difference in the visual analog scale or motion of the joint between the two groups ($p > 0.05$).

At 12 months after surgery, the single leg hop test result of the CCE group was higher than that of the OCE group ($p < 0.05$). There was no significant difference in the VAS score, mean change of thigh circumference 5 cm above patella, Lysholm score or motion of joint between the two groups ($p > 0.05$).

DISCUSSION

Previous studies have proved the effectiveness and safety of the surgical technique of medial patellofemoral ligament reconstruction for patellar dislocation patients^{5–7}). In addition, the final function of patellar dislocation patients is mainly dependent on the rehabilitation exercise after the operation. However, there is no standard rehabilitation procedures for after surgery. Therefore, it is important to select appropriate rehabilitation procedures for such patients.

Previous studies have reported that long term joint immobilization might result in dehydration of the extracellular matrix and the loss of ground substance^{14, 15}). It is not always possible to move joints immediately after surgical operations, but early motion is clearly beneficial for the patients¹⁶). Furthermore, early motion seems to be helpful for the limb as a whole, as it alleviates pain, promotes healthy development of cartilage and periarticular tissues, and prevents scar formation and capsular contractions¹⁷). In a word, rehabilitation exercises after surgery are necessary for patients.

In this study, we used the two types of exercise for the rehabilitation process after medial patellofemoral ligament reconstruction to determine which was more suitable as a post-operation exercise item. The single leg hop test was used to measure the maximal explosive strength of the patients. The result of the single leg hop test for the CCE group was better than that for the OCE group at both 6 and 12 months after surgery, indicating that the closed chain exercise is better than the open chain exercise after MPFL reconstruction at improving the maximal explosive strength of patients, especially the long term outcome.

The mean change of thigh circumference decrease in the CCE group was lower than that in the OCE group at both 3 and 6 months after surgery, indicating that closed chain exercise is better than open chain exercise at alleviating muscle atrophy in the early and middle stages after surgery. The Lysholm score of the CCE group was higher than that of the OCE group at both 3 and 6 months after surgery, indicating that the closed chain exercise is better than the open chain exercise at improving knee function after surgery. At 3 months after surgery, the visual analog scale score of the CCE group was lower than that of the OCE group, indicating that the closed chain exercise is better than open chain exercise at reducing pain in the early stage after surgery.

In open chain exercises, the exerciser moves the end of the upper or lower limb freely in space without contact. Closed chain exercises, the exerciser moves the adjacent joints with lower limb in contact with an immobile surface¹⁸). A previous study reported that closed chain exercises might provide more sensory feedback than open chain exercises, which is beneficial for motor control¹⁹).

Open chain exercise and closed chain exercises are commonly used in prospective treatments for many musculoskeletal system diseases, especially in patellofemoral joint dysfunction, including lateral patellar compression syndrome⁶), patellar chondromalacia⁸), and patellofemoral pain⁹). A previous study indicated that both open and closed chain exercises improved the subjective and clinical

cal outcomes of patients with patellofemoral pain, and that the closed chain exercise was a little more effective than the open chain exercise in functional results according to the tested parameters²⁰). Although, open chain exercise was beneficial for the development of strength and endurance of the knee extensor mechanism following anterior cruciate ligament reconstruction, and could be used effectively in a rehabilitation program²¹), closed kinetic chain exercise seems to be more effective at improving dynamic balance ability than open kinetic chain exercise within a six-week training period²²).

According to the results of electromyographic analysis, one-legged squats and step-ups are effective for muscle rehabilitation after anterior cruciate ligament reconstruction. In addition, closed chain activities might avoid the risk of anterior cruciate ligament graft injury in the rehabilitation process, and closed chain exercises, exercises cost less to implement than open chain exercises with expensive equipment; therefore, the clinical application of closed chain exercise is more convenient²³).

The results of this study also indicate that closed chain exercise is better than open chain exercise for both short and long term outcomes, reducing patellofemoral pain, alleviating muscle atrophy and improving knee function.

Furthermore, several studies of rehabilitation methods after ACL reconstruction have indicated that electrical stimulation was effective at reducing postoperative abnormalities of gait and strength compared to voluntary contractions alone^{24–26}). A previous study also reported that electrical stimulation in combination with voluntary exercises was superior to voluntary exercises alone at improving normal gait and strength²⁷). Therefore, in future studies, we will study whether electrical stimulation is beneficial for the rehabilitation of patients after MPFL reconstruction.

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