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Mid-term study on the effects of arthroscopic discoid lateral meniscus plasty on patellofemoral joint

An observational study

Zaihang Zhang, MD[a,b], Chang She, MD, PhD[a], Liubing Li, MD, PhD[a], Yongtao Mao, MD, PhD[a], Zhigao Jin, BD[a], Zhiying Fan, MD[a], Qirong Dong, MD, PhD[a], Haibin Zhou, MD, PhD[a], Wei Xu, MD, PhD[a,*]

Abstract

In the present study, we aimed to investigate the clinical outcomes of arthroscopic discoid lateral meniscus (DLM) plasty and the adaptive changes in the patellofemoral joint after surgery. From September 2010 to March 2012, 25 patients with DLM injuries who underwent arthroscopic meniscus plasty were enrolled in the prospective study. All patients underwent clinical evaluation before the operation and at the last follow-up, and imaging evaluation was performed by upright magnetic resonance imaging before and 1 month after the operation as well as at the last follow-up. Clinical evaluation included Lysholm score, Kujala score, McMurray's sign, patellar mobility, patella grind test, and quadriceps atrophy. Imaging evaluation included bisect offset index, patella tilt angle (PTA), and cartilage damage. Lysholm score, Kujala score, McMurray's sign, and quadriceps atrophy at the last follow-up were significantly improved compared with the preoperative levels ($P < .05$). At the last follow-up, there were no statistical differences in patella mobility and patella grind test compared with the preoperative levels. In addition, bisect offset index and PTA showed a dynamic trend of rising and then falling over time ($P < .05$). At 1 month after the operation, bisect offset index and PTA were significantly increased compared with the preoperative levels or the values at the last follow-up ($P < .05$), while there were no differences between the preoperation and the last follow-up. Cartilage damage became worse with time ($P < 0.05$), and the 2 were positively correlated (Spearman = 0.368). At the last follow-up, the degree of cartilage damage was significantly increased compared with the preoperative level ($P < .017$), while there was no significant difference between the 1-month postoperative grade and the preoperational grade or the last follow-up grade. The effect of arthroscopic DLM plasty on the patellofemoral joint was dynamic, with the position of the patella deviating in the early stages and recovering in the mid-term, especially when the knee was in the biomechanical standing position. In addition, the patellofemoral joint cartilage might undergo accelerated degeneration after the operation, while the mid-term effect of the operation was positive, and the patellofemoral joint function was acceptable.

Abbreviation: ACL = anterior cruciate ligament, BSO = bisect offset index, DLM = discoid lateral meniscus, ICRS = International Cartilage Repair Society, LPA = lateral patellofemoral angle, LPD = lateral patellar displacement, MRI = magnetic resonance imaging, PTA = patellar tilt angle.

Keywords: arthroscopic meniscoplasty, discoid lateral meniscus, patellofemoral joint, upright magnetic resonance imaging

1. Introduction

Anterior knee pain is one of the most common orthopedic complaints that cause patients to consult a physician. Although the etiology of anterior knee pain is complex, numerous studies have shown that anterior knee pain is closely related to patellofemoral diseases and may be a manifestation of instability at the patellofemoral joint.[1–5] Factors that are involved in the patellofemoral disease include abnormal quadriceps and hamstring muscle recruitment, medial patellar soft-tissue defect,

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The authors declare that they have no competing interests.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

This clinical study was approved by the Ethics Committee of the Second Affiliated Hospital of Suzhou University. All procedures performed in studies involving human participants were in accordance with the ethical standards of institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from all patients included in this study.

[a] Department of Orthopedics, the Second Affiliated Hospital of Soochow University, Suzhou, Jiangsu Province, China, [b] Department of Orthopedics, Suqian First Hospital, Suqian, Jiangsu Province, China.

** Correspondence: Wei Xu, Department of Orthopedics, the Second Affiliated Hospital of Soochow University, Suzhou, Jiangsu Province 215004, China (e-mail: 13962157016@139.com).*

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reduced lateral patellar soft-tissue length and flexibility, periarticular soft tissue irritation, intra-articular cartilage damage, femoral trochlear dysplasia, torsion of the lower limb, valgus knee, Q-angle increase, and so on. In short, multifactorial natures of nonosseous and osseous structures affect the biomechanism of the patellofemoral joint and cause instability of the patellofemoral joint. Anterior knee pain and patellar instability are closely associated with the lateral shift of the patella relative to femoral trochlea.[1–5]

A discoid meniscus is a congenital morphological variant of the meniscus, which is prevalent with an incidence of 10 to 13% in Asian,[6] and discoid lateral meniscus (DLM) is more commonly diagnosed by magnetic resonance imaging (MRI).[7,8] The discoid meniscus not only has a hypertrophic shape and abnormal size, which cannot effectively perform normal physiological functions, such as load transfer, but also has abnormal vascularity and microarchitecture, which is prone to tearing.[9,10] When the discoid meniscus is uninjured, patients usually have no obvious symptoms. Symptoms typically occur in torn DLM, which include knee pain, effusion, snapping, extension or flexion loss, and joint locking. The outcome of the conservative treatment for the torn DLM generally remains poor, and surgical intervention is often needed. Arthroscopic meniscoplasty also named saucerization can reshape the DLM to restore its physiological function as much as possible, which has gradually become one of the mainstream surgeries for the treatment of torn DLM due to minimally invasive arthroscopic technology and good outcomes.[11,12]

Many studies have shown that symptoms of torn DLM are significantly improved after arthroscopic meniscoplasty of DLM.[11–14] However, the lateral compartment of the knee covered with DLM can have different load transfer and contact pressure from the normal knee joints with a semilunar-shaped lateral meniscus. Some studies have reported that discoid lateral meniscectomy reduces the support of the lateral tibiofemoral compartment and causes the axial alignment of the lower limb deviation, resulting in valgus inclination and increased Q-angle of knee.[15–17] Most of the mid- and long-term follow-up studies of DLM meniscoplasty have focused on the changes in the lateral tibiofemoral compartment of knee.[13,15–20] Ding has reported that 16 knees of 103 knees are accompanied by cartilage injury of the lateral tibiofemoral joint after DLM arthroscopic meniscoplasty.[18] Okazaki has found that lateral joint space narrowing and lateral tibiofemoral osteoarthritis occur due to obvious valgus inclination.[15] Meanwhile, little research has focused on the change in the patellofemoral compartment of the knee after DLM meniscoplasty. Theoretically, valgus inclination and increased Q-angle both increase patellar lateral shift and patellofemoral contact pressures.[1–3] Our previous study has found that the patella of the injured limb tends to lateral translation relative to the femur in 1 month after DLM meniscoplasty.[21] Dong has evaluated the position of the patella after arthroscopic DLM plasty by CT and found lateral shift of patella within 2 years after the operation.[22] In clinical practice, some patients complain of anterior knee pain during the early postoperative period of DLM meniscoplasty. The relationship between anterior knee pain and patellofemoral changes needs to be explored. Moreover, it remains largely unknown about the medium to long-term impact of DLM meniscoplasty on the patellofemoral joint, especially on the position and tracking of the patella and the change in patellofemoral cartilage.

MRI is the most sensitive and effective noninvasive examination for musculoskeletal change and articular cartilage, especially for evaluation of congruence between the patella and femoral trochlea, patella tracking, and cartilage change of the patellofemoral joint. Conventional MRI is usually performed in a standard supine position under nonweight-bearing conditions. However, Draper has reported the differences in patellofemoral kinematics between weight-bearing and nonweight-bearing conditions and found that unloaded tasks do not accurately represent the joint motion during weight-bearing activities.[23] Patellofemoral joint kinematics can change with quadriceps contraction and joint loading. Upright MRI, in which the knee is examined under a weight-bearing condition, can evaluate the change of the knee better under physiological conditions.[24] Therefore, weight-bearing MRI of the knee has more clinical practical significance.[25]

The current study was a continuation of our previous study.[21] We prospectively evaluated the mid-term (average 6.9 years) effect of arthroscopic meniscoplasty of DLM on the patellofemoral joint by clinical assessment and image measurement of upright MRI. Moreover, we also explored the possible change of kinematics and cartilage of the patellofemoral joint.

2. Materials and methods

2.1. Study design

From September 2010 to March 2012, 41 patients who were diagnosed with torn DLM in our hospital were enrolled in this study before the arthroscopic meniscoplasty of DLM. Inclusion criteria were as follows: typical symptoms and signs of DLM injury, such as knee pain, snapping, joint locking, and loss of range of motion; isolated DLM injury diagnosed by MRI without ipsilateral knee injuries, for example, anterior cruciate ligament (ACL) injury, medial meniscus injury or fracture; patients undergoing arthroscopic meniscoplasty in our hospital; and patients agreeing to participate in the study and willing to be followed for a long time. Exclusion criteria were as follows: concomitant with ipsilateral knee injuries (such as ACL injury and medial meniscus injury) found by arthroscopic operation; previous history of ipsilateral knee trauma or operation; previous history of patellar dislocation or subluxation; instability at the patellofemoral joint and severe knee osteoarthritis (Grade IV of the International Cartilage Repair Society (ICRS)[26] diagnosed by MRI or arthroscopy; and patients undergoing arthroscopic subtotal meniscectomy or total meniscectomy or meniscus suture for serious tear of DLM. A total of 30 patients participated in this study after these above-mentioned exclusion criteria were applied, and 25 patients were followed up from July 2018 to June 2019. A weight-bearing MRI of the knee was conducted before the operation, at 1 month after surgery, and the last follow-up. This prospective clinical study was approved by the Ethics Committee of the Second Affiliated Hospital of Suzhou University in June 2010, in which the rough follow-up period was divided into 3 stages, early stage (1–6 months after surgery), mid term (5–8 years after surgery), and long term (10–15 years). The written informed consent was obtained from all participants before surgery. Then this study was supplemented at the Chinese Clinical Trial Registry http://www.chictr.org.cn/ (registration number: ChiCTR2100045435).

2.2. Arthroscopic meniscoplasty for torn DLM

The patients were placed in a supine position under general or spinal anesthesia. The standard anterolateral and anteromedial arthroscopic portals were established (Fig. 1A), and arthroscopic instruments were inserted. With the assistance of the probe hook, the knee was examined thoroughly to confirm the torn position and shape of DLM (Fig. 1B) and exclude other knee injuries, such as ACL tearing. The torn and hypertrophic parts were removed by basket forceps (Fig. 1C), and the edge of the meniscus with a width of at least 5 to 6 mm was cautiously retained (Fig. 1D). Sometimes, a horizontal tear in the peripheral portion of the meniscus was present, and a small redundant or unstable leaflet was resected. The free edge was trimmed with radiofrequency ablation to remodel the saucer shape of the meniscus as much as possible.[6,8] The stability of residual meniscus was ensured, and the patients whose DLM was unstable and performed with subtotal meniscectomy or total meniscectomy

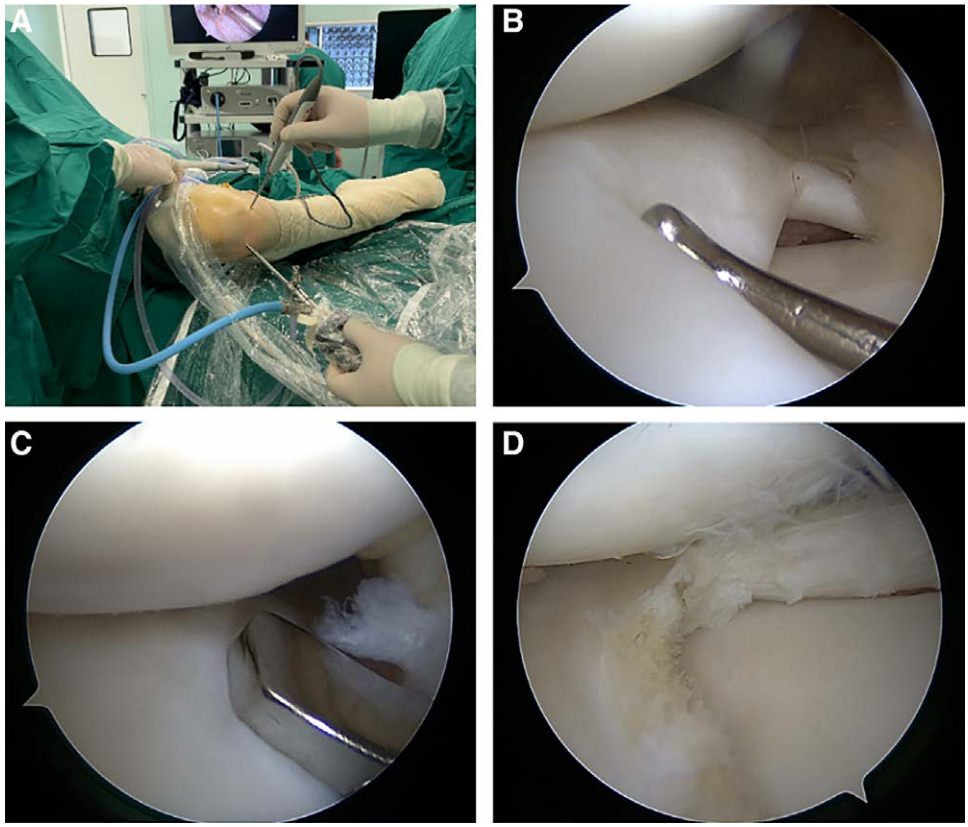

Figure 1. Surgical procedures of arthroscopic meniscoplasty. (A) The patients were placed in a supine position, and the standard anterolateral and anteromedial arthroscopic portals were established. (B) With the assistance of the probe hook, the knee was examined thoroughly to confirm the torn position and shape of the DLM. (C) The torn and hypertrophic parts of DLM were removed by basket forceps. (D) DLM was trimmed into "C" shape, and the edge of the meniscus with a width of at least 5 to 6 mm was cautiously retained. DLM = discoid lateral meniscus.

or meniscus suture were excluded from this study. All the operations were performed by 3 senior surgeons with rich experience in arthroscopy using the Smith & Nephew arthroscopy system.

2.3. Rehabilitation guidance and early postoperative follow-up

Patients began rehabilitation exercises under the guidance of 2 rehabilitation doctors or surgeons on the first day after the operation. The patients were permitted to start weight-bearing walking with frames on the first day after surgery. Rehabilitation programs within 1 month after the surgery included cold compress, ankle pump movements, quadriceps isometric contraction, as well as the exercises of straight leg raise, and joint mobility exercises 3 times a day. From 1 to 3 months after the surgery, the exercises of straight leg raise with different angles and positions, and bedside knee bending exercises were carried out to improve the muscular strength around the knee and enhance joint mobility. All rehabilitation exercises were performed as much as possible under the condition of painless. After 3 months of the surgery, patients could carry out balance feeling and proprioception exercises, and participate in light-load exercises, such as swimming and cycling. From 4 to 6 months after the surgery, moderate activities, such as fast walking and jogging, were allowed. Strenuous activities could be resumed 1 year later after the operation. To guarantee the quality of postoperative rehabilitation, each patient was educated through rehabilitation videos, and the rehabilitation record card was established for each patient. In the first 3 months after the surgery, the patients visited our outpatients for follow-up once a month, and 2 rehabilitation doctors further guided the patients for rehabilitation. Then 2 rehabilitation doctors followed up the patients by telephone and investigated the patients' postoperative outcomes and rehabilitation status from 4 to 6 months after the surgery.

2.4. Clinical assessment

The clinical assessment contained 2 parts, including knee physical examination and knee functional evaluation. Physical examination included McMurray's sign, patellar grind test, patellar mobility, and atrophy of quadriceps femoris. The examination of McMurray's sign, patellar grind test, and patellar mobility was performed according to the references.[27,28] The atrophy of the quadriceps femoris was evaluated by measuring the difference in bilateral thigh circumference at 10 cm above the upper border of the patella. If the difference in circumference was more than 1 cm, the atrophy of the quadriceps femoris was considered positive. Functional evaluation of knee included Lysholm score[29] and Kujala score.[30] These physical examinations and functional scores were mainly used for the evaluation of the therapeutic effects of DLM meniscoplasty and the function of the patellofemoral joint.

In the early postoperative period (1–3 months after the surgery), the knee function of patients was not fully recovered, and patients were not suitable for the knee physical examination and functional evaluation. The above-mentioned clinical assessments were performed before surgery and at the last follow-up. To ensure objective evaluation, 3 independent and experienced doctors who did not participate in the operations were responsible for the clinical evaluation and data recording.

2.5. MRI assessment

The 0.25-T open MRI unit (G-SCAN, Esaote, Genovawas) was used to evaluate the injured knee under the weight-bearing

conditions. The patient lay on the platform, and then the surface knee coil and the fixed pedal were installed. The platform was rotated to 75 degrees, and patients stood naturally on the pedal with the toes forward. The MRI scan sequence and parameters were as follows: coronal and sagittal: SE T1WI (TR 850 ms, TE 28 ms), the field of view 160 mm × 160 mm; layer thickness 5 mm, matrix 256 × 256, NEX 2; (TR 3800 ms TE 80 ms), the field of view 160 mm × 160 mm; layer thickness 4.5 mm, matrix 256 × 256, NEX 2.

The indexes of MRI evaluation included the bisect offset index (BSO), lateral patellar displacement (LPD), patellar tilt angle (PTA), lateral patellofemoral angle (LPA), and cartilage damage of ICRS.

The indexes of BSO, LPD, PTA, and LPA were measured according to the references.[31–34] BSO and LPD were used to assess patellar lateral shift regarding femoral trochlea (Fig. 2A and B), and an increase in BSO or LPD indicated a more obvious patellar lateral shift. Two parameters of PTA and LPA were used to assess patellofemoral configuration matching and patellar tilt (Fig. 2C and D). An increase in PTA or a decrease in LPA indicated a more obvious patellar lateral tilt.

The cartilage damage of the patellofemoral joint was evaluated by the grade of ICRS.[26] Briefly, Grade 0 referred to normal cartilage, and Grade 4 referred to full-thickness defect with exposure of subchondral bone. A higher grade indicated more serious damage.

All the standing-up MRI examinations were performed in the orthopedic MRI room before surgery, 1 month after surgery, and at the last follow-up. The above-mentioned index of MRI images were measured and evaluated respectively by 2 independent and senior radiologists through the Neusoft PACS/RIS imaging system and MB ruler 5.3. The average value measured by 2 radiologists was used as the final value of each index.

2.6. Data analysis

A sample size calculation was performed in this prospective study. In a prestudy, the changes of 20 patients' MRI parameters, including BSO, LPD, PTA, and LPA, between preoperation and postoperation (1 month) were compared. The *t* test repeated-measures analysis of variance was applied to compare the differences of each index measured before and after surgery. According to the parameter setting of each measurement, the sample sizes were estimated separately, among which the sample size estimated by PTA, one of the important indicators, was the largest. Compared with the preoperative measurement, PTA measured after surgery was increased by about 5.7 on average, and the standard deviation was about 2. Significance level α was set as 0.05, the power of a test 1-β was equal to 90%, and a bilateral test was used. A sample size of 20 was large enough to detect the difference of PTA before and at 1 month after the operation via the procedure "Test (In equality) for one mean" in the software PASS 25.0. Ultimately, the study sample size was set at 30, considering a high slippage rate of loss during the mid-term follow-up.

The clinical physical examination of McMurray's sign, patellar mobility, patellar grind test, and atrophy of quadriceps femoris (qualitative data) was evaluated by Chi-square test. Cartilage damage (ranked data) was analyzed by the Kruskal–Wallis test, and the results were revised by Bonferroni correction. Spearman correlation coefficient of the cartilage damage and time was also calculated. The quantitative data, including the Lysholm score, Kujala score, and MRI indexes of BSO, LPD, PTA, and LPA, were expressed as mean ± standard deviation. Lysholm score and Kujala score were tested by paired *t* test, and MRI indexes of BSO, LPD, PTA, and LPA were analyzed by one-way ANOVA. $P < .05$ was considered statistically significant. SPSS statistics software (version 25.0, IBM Corporation, Chicago, IL) was used to analyze the data of this study.

3. Results

3.1. Demographic information

A total of 30 patients were followed up in the early postoperative stage, and 25 patients were followed up from July 2018 to June 2019. There were 8 males and 17 females, including 11 left knees and 14 right knees at the last follow-up. The average age of patients at the last follow-up was 35.9 (24–47) years. The average duration of symptoms before surgery was 11.95 months, and the average follow-up time was 83.58 months (Table 1).

3.2. Clinical assessment

3.2.1. Physical examination. Compared with the status before surgery, the atrophy of quadriceps femoris was significantly relieved ($P = .017$). All patients had a negative McMurray's sign at the last follow-up, while the number of patients with positive McMurray's sign before surgery was 23 ($P < .001$). There was no significant difference in patellar mobility ($P = .221$) and patellar grind tests ($P = .297$) between the last follow-up and preoperation (Table 2). The results of mid-term follow-up

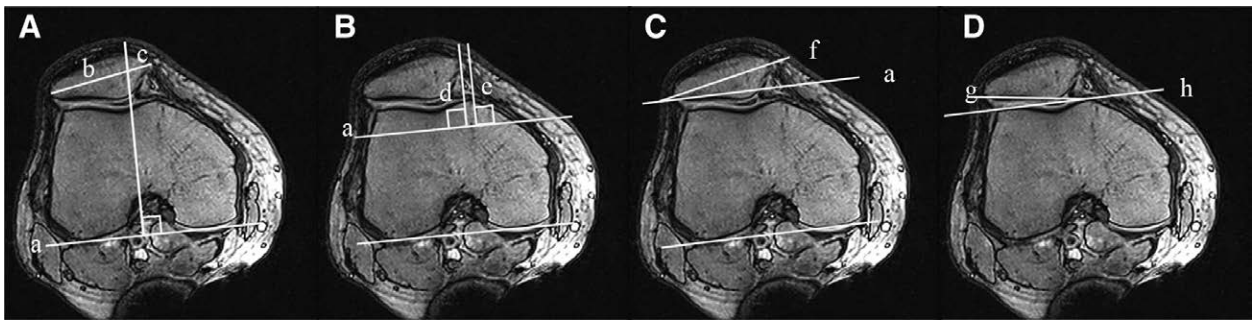

Figure 2. Some indexes of MRI images were used to evaluate patellar lateral shift and patellar tilt relative to the femoral trochlea. (A) BSO was determined by drawing the tangent of the posterior femoral condyle on the axial image showing the most obvious posterior femoral condyle, and then the vertical line of the posterior condyle tangent was projected through the deepest point of the trochlear groove. A line was drawn to connect the widest points of the patella on the axial image and the vertical line divided the patellar line into medial segment (line c) and lateral segment (line b). The ratio of the lateral segment to the medial segment (b/c) was the BSO. (B) LPD was defined as the distance from the medial edge of the patella (line d) to a vertical line of the posterior condyle tangent, which passed through the most anterior point of the medial condyle (line e). (C) PTA was the angle formed by the intersection of the line of the maximum width of the patella (line f) and the parallel line of the tangent of the posterior femoral condyles (line a). (D) LPA was the angle formed by the intersection of 2 lines: one line (g) was drawn along the lateral facet of the maximum width of the patella, and another line (h) was drawn along the anterior aspect of the femoral condyles. LPA = lateral patellofemoral angle, LPD = lateral patellar displacement, MRI = magnetic resonance imaging, PTA = patellar tilt angle.

showed that arthroscopic meniscoplasty increased the size of patients' quadriceps femoris and relieved the sign of torn DLM. The signs of patellar mobility and patellar grind tests, which were associated with patellofemoral joint disease, had no obvious changes between the last follow-up and preoperation.

3.2.2. Functional assessment. Lysholm scores is one of the most common evaluations for meniscus postoperative function. Similarly, the Kujala score is one of the most common evaluations for the function of the patellofemoral joint. Higher scores of Lysholm and Kujala indicate a better function of the knee. The average score of Lysholm before the surgery was 45.13, and it went up to 85.13 at the last follow-up. The average Kujala score was 70.13 before the surgery, and it was 94.38 at the last follow-up. Compared with the preoperative status, the Lysholm score ($P < .001$) and Kujala score ($P < .001$) were significantly improved at the last follow-up (Table 2).

Either physical examination or functional assessment showed that arthroscopic meniscoplasty of DLM significantly improved the symptoms and function of the patient's knee at the last follow-up compared with the preoperative status.

3.3. MRI assessment

During MRI examination, joint effusion was found in 8 cases before surgery, 14 cases at 1 month after the operation, and one case at the last follow-up. The values of BSO, LPD, and PTA at 1 month after the operation were significantly higher compared with their preoperative values ($P < .05$). The values of BSO, LPD, and PTA at the last follow-up were decreased and lower compared with the values at 1 month after the surgery ($P < .05$), and there was no significant difference in the values of BSO, LPD, and PTA between the preoperation and last follow-up. Conversely, LPA at 1 month after the operation was significantly lower compared with its preoperative value. However, the value of LPA at the last follow-up was increased and higher compared with the value at 1 month after the surgery ($P < .05$), and there was no significant difference in LPA between the preoperation and last follow-up. These index changes of MRI images indicated that the patient's patella shifted and tilted to lateral obviously at 1 month after the surgery compared with the patellar position before surgery. Besides, the lateral shift and tilt of the patella were relieved at the last follow-up compared with the patellar position at 1 month after the surgery, which had no significant difference in the patellae position between the last follow-up and preoperation (Fig. 3).

Meanwhile, MRI images showed that the cartilage damages were involved in the patella or femoral trochlea, and the cartilage of the lateral patella and lateral trochlea were more susceptible (Fig. 4A and B). Most of the cartilage grades at the preoperative level were in Grade I or II of ICRS, which were similar to cartilage grades at 1 month after the surgery ($P = 1.00$). Most damaged cartilages were in Grade II or III of ICRS at the last follow-up, and the grades of cartilage damage at the last follow-up were higher compared with the preoperative level ($P = .005$). Besides, the Spearman correlation coefficient indicated a positive correlation between cartilage damage and time ($P = .001$), indicating that there was an increasing trend of cartilage damage over time. On the other hand, cartilage damage of Grade II accounted for the largest proportion no matter before surgery or at last follow-up. The proportion of Grade II was 11/25 before surgery and 13/25 at the last follow-up (Table 3).

Table 1

Basic characteristics of included patients undergoing arthroscopic surgery.

Variables	Discoid meniscus
Case	25
Gender (male/female)	8/17
Affected side (left/right)	11/14
Age (yr)	35.90 ± 8.7
Course of disease before surgery (m)	11.95 ± 14.03
Follow-up time (m)	83.58 ± 6.21

3.4. Complications

The range of motion of the injured knee of all patients had no difference compared with the contralateral knee at 6 months after the surgery. There were no complications of nervous and vascular injuries, hematoma, thrombosis, and infection.

4. Discussion

4.1. Clinical outcomes of arthroscopic meniscoplasty for torn DLM

With the gradual understanding of the importance of meniscus, more and more experts believe that the operation for torn DLM should not only remove the torn portion of the meniscus to relieve the symptoms, but also retain enough functional meniscus as much as possible to achieve good outcomes at long-term follow-up.[35,36] Arthroscopic meniscoplasty has become one of the most popular surgeries due to its advantages of less trauma, more residual meniscus, and better outcomes.[6–8] During the average follow-up time of nearly 7 years, we also found that outcomes of arthroscopic meniscoplasty for torn DLM were satisfactory. Symptoms of the torn DLM, such as pain, snapping, and joint locking, disappeared after surgery. The Lysholm score and Kujala score were significantly increased at the last follow-up compared with their preoperative values. Most patients regained the level of preinjury movement.

4.2. The changes of the patellofemoral joint after meniscoplasty for torn DLM

Some studies have shown that meniscectomy for DLM causes the valgus inclination of the lower limb and increases

Table 2

Clinical evaluation before and at the last follow-up.

Items	Preoperation	Last follow-up	Statistic value	*P*
McMurray's sign (+/-)	23/2	0/25	42.593	$P < .001$*
Patellar mobility (+/-)	5/20	2/23	1.495	$P = .221$
Patella grind test (+/-)	1/24	3/22	1.087	$P = .297$
Quadriceps atrophy (+/-)	9/16	2/23	5.711	$P = .017$*
Lysholm score	45.13 ± 16.05	85.13 ± 10.43	9.083	$P < .001$*
Kujala score	70.13 ± 3.13	94.38 ± 4.93	13.939	$P < .001$*

*Significantly statistical difference, $P < .05$.

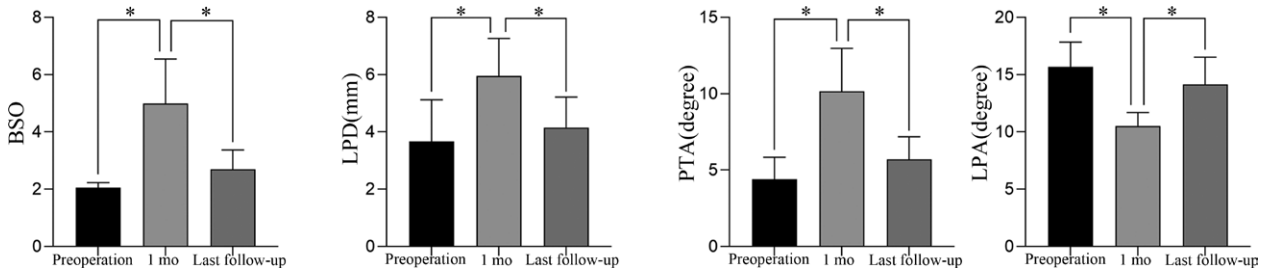

Figure 3. Comparison of MRI indexes of BSO, LPD, PTA, and LPA at different time points. (A) BSO; (B) LPD; (C) PTA; (D) LPA. The values of BSO, LPD, and PTA at 1 month after the operation were significantly higher compared with their preoperative values ($P < .05$). The values of BSO, LPD, and PTA at the last follow-up were decreased and lower than their values at 1 month after the surgery ($P < .05$), and there was no significant difference in the values of BSO, LPD, and PTA between the preoperation and last follow-up. Conversely, LPA at 1 month after the operation was significantly lower compared with its preoperative value. However, the value of LPA at the last follow-up was increased and higher than its value at 1 month after the surgery ($P < .05$), and there was no significant difference in LPA between the preoperation and last follow-up. "*" refers to a statistically significant difference, $P < .05$. BSO = bisect offset index, LPA = lateral patellofemoral angle, LPD = lateral patellar displacement, PTA = patellar tilt angle.

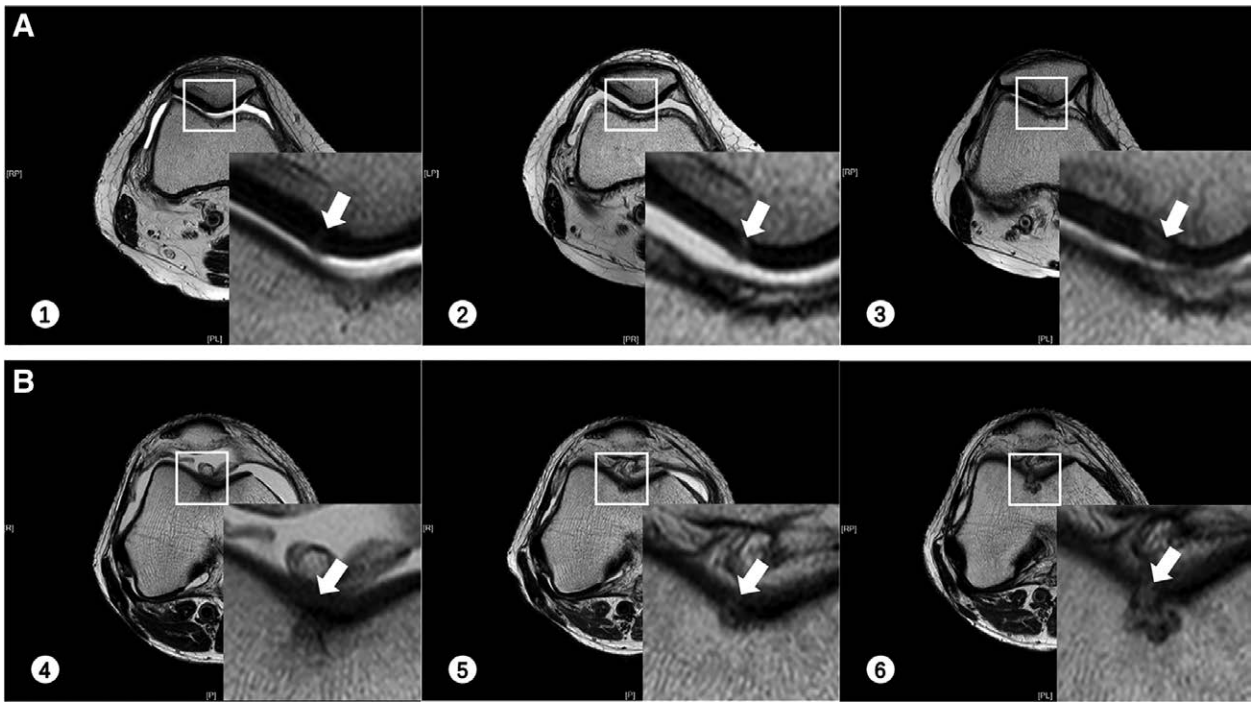

Figure 4. MRI images showed cartilage damage. The evaluation of cartilage damage was based on the grade of the ICRS. The image of the lower right was magnified to show cartilage damage in detail, which was the local area (boxed) of the images at the top left. White arrow showed cartilage damage. (A) Cartilage damage was involved in the lateral patella at different time points. (1) Grade I before surgery; (2) Grade I at 1 month after the surgery; (3) Grade III at last follow-up. (B) Cartilage damage was involved in the femoral trochlear at different time points. (4) Grade I before surgery; (5) Grade I at 1 month after the surgery; (6) Grade III at last follow-up. MRI = magnetic resonance imaging.

Table 3

Cartilage damage of the patellofemoral joint at different time points.

	Cartilage damage				
Time	**0**	**I**	**II**	**III**	**IV**
Preoperation	5	8	11	1	0
1-month after surgery	5	7	11	2	0
Last follow-up	2	2	13	6	2
Statistic value	11.131				
*P**	.004				

Preoperation and 1-month, $P = 1.00$; preoperation and last follow-up, $P = .006$; 1-month and last follow-up $P = .025$.

*Significantly statistical difference, $P < .05$.

Q-angle.[12,13,16,17] The meniscus role of load transfer and shock absorption is weakened, and the support of the lateral compartment of the knee is reduced after lateral discoid meniscoplasty.[9] Patients undergoing subtotal or total meniscal resection develop osteoarthritis in the lateral compartments of the knees due to malalignment.[6,15]

Clinically, coronal alignment and Q-angle are significant parameters for the evaluation of patellofemoral tracking. Valgus inclination and increased Q-angle both promote patellar lateral displacement force and increase patellofemoral contact pressures.[1–3] However, little research has focused on the mid- or long-term changes of the patellofemoral joint after discoid meniscus plasty. In our current mid-term study, the weight-bearing MRI images showed that the lateral shift and tilt of the patella at 1 month after the surgery were increased compared with the last follow-up. Moreover, the position of the patella relative to the femoral trochlea at the last follow-up returned to the preoperative position. The instability mechanism of the patellofemoral joint is complicated, including bone structures, such as the femoral trochlear dysplasia, torsion of the femur, and soft tissue structures, such as peripatellar retinaculum imbalance, atrophy of quadriceps femoris.[4,37] Meniscoplasty of DLM does not change the osseous structure of the knee. Therefore, lateral translation of the patella at 1 month after surgery can be the result of soft tissue changes caused by meniscoplasty. The vastus medialis, one of the quadriceps femoris, is especially important to prevent the lateral shift of the patella. An autopsy has revealed that the relaxation of the vastus medialis can lead to lateral instability of the patella at any flexion angle.[38] Some studies have also found strength loss of knee muscle after arthroscopic partial meniscectomy.[39,40] The strength loss of the vastus medialis may be associated with operative trauma and reduced activities in the early postoperative stage, leading to lateral deviation of the patella at 1 month after the surgery.

Dong has evaluated the position of the patella after arthroscopic DLM plasty by CT in the supine position and found that the patella tends to lateral shift within 2 years after the operation.[22] The quadriceps femoris is generally relaxed in the supine position, which weakens its control over the patella. Senavongse has reported that when the vastus medialis is completely relaxed, the patellar stability is reduced by 30%.[41] Therefore, upright MRI with knee under the weight-bearing condition and quadriceps contracting can evaluate lateral shift of patella better. In our present study, all cases were treated with meniscoplasty, not total meniscetomy, and the width of the meniscus was retained at least 5 to 6 mm. Yamasaki's study has shown that a 5-mm residual meniscal width is the cutoff value leading to the performance of degeneration.[35] Compared with the total meniscectomy, meniscoplasty can retain more meniscus tissue and restore normal meniscus physiological function as much as possible to support the lateral compartment and decrease valgus inclination of the knee. The speed and extent of the changes in the axial alignment after meniscoplasty may be lower compared with the total meniscectomy. Barely changed alignment after arthroscopic meniscoplasty and strength restoration of quadriceps femoris could explain why the position of the patella relative to femoral trochlea at last follow-up returned to the preoperative position.

4.3. Progression in cartilage damage of tibiofemoral joint after meniscoplasty for torn DLM

Meniscus surgery is recognized as a high-risk factor of tibiofemoral arthritis,[32,33] while the impact of surgery on patellofemoral arthritis is not fully clear. Some studies have shown that meniscectomy (especially lateral meniscectomy), follow-up time, tibiofemoral arthritis, and obesity are risk factors for patellofemoral arthritis.[42–44] In our present study, upright MRI showed that the cartilage damage of the patellofemoral joint after DLM plasty was worsened over time. The damage of patellofemoral articular cartilage might be associated with the following factors. Firstly, the most important factor was that the stability of the patellofemoral joint was decreased in the early postoperative stage, in which the lateral shift of the patella caused high stress or abnormal distribution of stress.[45] Some reports have shown that partial meniscectomy results in sustained loss of quadriceps strength for 3 to 6 months or more.[39] Local stress concentration on the lateral articular surface can destroy the internal molecules and microstructure of cartilage collagen and matrix protein, resulting in cartilage surface damage and softening.[5] MRI showed that the cartilage of lateral patella and lateral trochlea was more susceptible to damage, which might be related to the lateral shift and tilt of the patella in the early postoperative stage. Wang has also verified that there is a direct correlation between the damage of articular cartilage and patellar instability through the animal model of patellar tilt.[46] Secondly, arthroscopic surgery itself might cause damage to the articular cartilage. Iatrogenic cartilage injury has been reported due to instrumentation.[47,48] Besides, excessive radiofrequency energy and inappropriate irrigation fluids could also exert a negative effect on cartilage.[49,50] Regretfully, there was no control group in our present study, which was a limitation, and we could not exclude that cartilage damage would be a natural degeneration process.

4.4. Inconsistence of clinical outcomes and imaging manifestation in patellofemoral joint

On the other hand, the physical examinations of the patellar grind test and patellar mobility at last follow-up were not significantly different from those examinations before the surgery. Kujala score, which was the most common evaluation for the function of the patellofemoral joint and included the incidence of anterior knee pain, pain when climbing stairs, and pain when squatting, was increased at the last follow-up compared with the score of the preoperation. Therefore, the obvious symptoms and signs concerning the patellofemoral joint were not observed in this mid-term study. Although cartilage damage was observed, cartilage damage was Grades 2 to 3 of ICRS in most patients, and the proportion of Grade II was 52% (13/25) at the last follow-up. Low- and mid-grade cartilage damage might not be always accompanied by clinical symptoms and signs. It might take more time to evaluate the effect of arthroscopic meniscoplasty of DLM on the patellofemoral joint.

There were also some limitations in our research. There was no control group in this prospective study. The group of nonsurgical patients with torn DLM might be suitable for the control group. However, the outcomes of nonsurgical treatment for the torn DLM generally remain poor, and it is unethical to deliberately guide patients with torn DLM to choose conservative treatment. Healthy individuals without DLM and without arthroscopic surgery are still inappropriate for the control group. Moreover, we could not judge whether the disease of DLM itself or surgery led to the changes of patellofemoral joint. As a prospective study, we calculated roughly the sample size for this mid-term follow-up based on some data of preoperation and 1 month after surgery. We also did power analysis and compared the data of the last follow-up with the data of preoperation, through which the sample size of 25 patients was enough to get relatively reliable results. In general, the sample size of this study was small, and we could not further explore the relationship of the outcomes and more factors, such as sex, age, and interval, between injury and surgery. Long-term and large-scale follow-up about the effects of meniscoplasty on the patellofemoral joint is still necessary for future studies.

5. Conclusions

In this mid-term study, arthroscopic meniscoplasty of DLM significantly improved the symptoms and function of patients'

knee at an average follow-up of 6.9 years. Weight-bearing MRI showed that the position of patella relative to femur at the last follow-up was similar to the preoperative position. The cartilage damage of the patellofemoral joint was worsened over time. Fortunately, most patients showed medium-grade cartilage damage by MRI, which did not develop clinical symptoms and signs of patellofemoral joint.

Author contributions

Conceptualization: Zaihang Zhang, Chang She, Wei Xu.
Formal analysis: Zaihang Zhang, Chang She, Yongtao Mao, Zhigao Jin, Qirong Dong, Haibin Zhou, Wei Xu.
Funding acquisition: Wei Xu.
Project administration: Wei Xu.
Software: Zaihang Zhang, Chang She, Liubing Li, Zhigao Jin, Zhiying Fan, Haibin Zhou.
Validation: Zaihang Zhang, Chang She, Liubing Li, Yongtao Mao, Zhigao Jin, Qirong Dong, Haibin Zhou, Wei Xu.
Writing—original draft: Zaihang Zhang, Zhiying Fan.
Writing—review and editing: Wei Xu.

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