

## Original Article

# Factors influencing clinical outcomes in patients with knee osteoarthritis undergoing arthroscopic treatment

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**Abstract:** Background: Knee osteoarthritis (KOA) is a prevalent degenerative joint disease characterized by pain and limited joint function. Arthroscopic debridement is a commonly used surgical intervention; however, its efficacy remains controversial. This study aimed to identify factors influencing the clinical outcomes of arthroscopic treatment for KOA. Methods: This retrospective cohort study included 169 patients with KOA treated between January 2019 and December 2023. Patients were divided into an observation group (arthroscopic debridement, n=85) and a control group (integrated traditional Chinese and Western medicine conservative treatment, n=84) according to the treatment modality. The visual analog scale (VAS) score, Lysholm knee score, range of motion (ROM), and Kellgren-Lawrence (K-L) grade were assessed preoperatively and at 1, 4, 7, and 24 months postoperatively. Multivariate logistic regression analysis was performed to identify predictors of treatment efficacy, and a nomogram model was constructed for outcome prediction. Results: The observation group exhibited significantly lower VAS scores and higher Lysholm scores at 1, 4, and 7 months postoperatively compared with the control group (all  $P < 0.05$ ). Improvements in ROM and K-L grade were also more pronounced in the observation group. Multivariate analysis identified body mass index (BMI)  $> 26 \text{ kg/m}^2$ , higher K-L grade, and higher Outerbridge grade as significant predictors of worse treatment outcomes. The nomogram demonstrated good predictive performance (concordance index = 0.82, area under the curve = 0.83). Conclusion: BMI, K-L grade, and Outerbridge grade are key determinants of clinical outcomes following arthroscopic treatment for KOA. The proposed nomogram offers a practical tool for preoperative prediction of surgical efficacy.

**Keywords:** Arthroscopy, knee osteoarthritis, clinical outcome, predictive factors

## Introduction

Knee osteoarthritis (KOA) is a chronic degenerative joint disorder characterized by recurrent or persistent knee pain, stiffness, and progressive functional impairment. It represents one of the most prevalent joint diseases worldwide and is a leading cause of disability, affecting approximately 355 million people globally. In Asia, about one in six individuals is affected by KOA, while in the United Kingdom, the number of patients has been estimated at 8.5 million among a total population of approximately 62 million [1]. The pathophysiology of KOA involves a multifactorial interplay of mechanical, biochemical, and biological processes that lead to the degeneration of hyaline cartilage, extracel-

lular matrix, and subchondral bone. The normal anabolic-catabolic balance of cartilage metabolism becomes disrupted, resulting in progressive structural deterioration. In addition, secondary pathological changes, such as synovial hyperplasia and osteophyte formation at the cartilage margins, may occur to varying degrees. As a chronic progressive disease, KOA causes irreversible degeneration of the affected joints, imposing substantial limitations on patients' daily activities and quality of life [2, 3].

Currently, the diagnosis of KOA is primarily based on clinical manifestations - including persistent knee pain, stiffness, and functional limitations - together with radiographic findings such as joint space narrowing and osteophyte

formation. The Kellgren-Lawrence (K-L) grading system is widely applied for disease staging: grade 0, no radiographic findings; grade I, doubtful; grade II, mild; grade III, moderate; and grade IV, severe. Treatment strategies are selected according to disease severity. Mild cases are mainly managed with conservative approaches such as physical therapy, nonsteroidal anti-inflammatory drugs, and intra-articular injections; moderate cases may benefit from arthroscopic intervention, whereas severe cases often require osteotomy or total knee arthroplasty [4]. As a minimally invasive surgical technique, arthroscopy offers several advantages, including reduced tissue trauma, less postoperative pain, lower treatment costs, and faster recovery. Arthroscopy was first introduced for the diagnosis and management of knee joint disorders in 1943 [5, 6]. In its early application, however, arthroscopy was limited in both visualization and meniscectomy, capability, restricting its clinical scope and posing numerous technical challenges. With the rapid advancement of medical technology, continuous improvement of arthroscopic equipment, and growing surgical expertise, the indications and types of arthroscopic procedures for knee disorders have expanded substantially. Among these, KOA has become one of the principal conditions treated arthroscopically [7]. Nevertheless, despite its advantages, the efficacy of arthroscopic surgery for KOA remains controversial, partly due to the inherent limitations of indirect visualization and variability in surgical technique.

Early arthroscopic techniques primarily included lavage and debridement, whereas modern approaches have evolved to encompass microfracture, mesenchymal stem cell stimulation, autologous chondrocyte implantation, and osteochondral autograft transplantation [8]. At the beginning of this century, approximately 12.5% of patients with KOA in the United States underwent arthroscopic surgery. However, a randomized controlled trial published in *The New England Journal of Medicine* by Moseley et al. reported no statistically significant difference in efficacy between arthroscopic debridement with lavage and conservative treatment [9]. Consequently, a growing consensus emerged that arthroscopic intervention for KOA provides limited therapeutic benefit and may function primarily as a placebo procedure. Reflecting this shift in perception, by 2008 only 6.3% of

KOA patients in the United States received arthroscopic treatment [10]. The clinical value of arthroscopy for KOA therefore remains controversial. A 10-year follow-up study in the United States further supported the earlier findings, showing no significant advantage of arthroscopic treatment over conservative management. Moreover, the American Academy of Orthopaedic Surgeons has recommended against the use of arthroscopic lavage or debridement for KOA, even in patients with early-stage disease [11]. Nonetheless, some studies have reported that under specific conditions, arthroscopic intervention can yield comparable or even favorable clinical outcomes [12]. The present study aimed to identify the key factors influencing the clinical efficacy of arthroscopic treatment in patients with KOA.

Building upon previous research, the present study further advanced the field by developing a predictive nomogram model incorporating body mass index (BMI), K-L grade, and Outerbridge grade to quantitatively estimate the likelihood of successful outcomes following arthroscopic debridement. This model is intended to assist clinicians in patient selection and the development of individualized treatment strategies.

### Materials and methods

#### *Study population*

This retrospective cohort study included patients with KOA who received treatment at the Affiliated Hospital of Guangdong Medical University between January 2019 and December 2023. A total of 320 cases were initially screened, and patients were further selected according to the following inclusion and exclusion criteria.

Inclusion criteria: (1) Diagnosis of KOA confirmed by clinical manifestations and imaging findings (e.g., joint space narrowing, cartilage degeneration, or osteophyte formation on radiography [X-ray] or magnetic resonance imaging); (2) Age between 50 and 75 years, regardless of sex; (3) Persistent or recurrent symptoms characterized by significant pain, joint stiffness, or functional limitations; (4) Knee pain or dysfunction interfering with daily activities, defined as a visual analog scale (VAS) score  $\geq 3$  or Lysholm score  $\leq 85$ ; (5) Physical condition suitable for surgery or conservative

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therapy, meeting anesthesia and surgical safety requirements (American Society of Anesthesiologists grade I-II).

Exclusion criteria: (1) Known allergy to study-related or anesthetic agents; (2) Severe systemic diseases, including but not limited to cardiopulmonary insufficiency, advanced hepatic or renal dysfunction, or coagulation disorders; (3) Active arthritis or other knee pathologies (e.g., rheumatoid arthritis, gouty arthritis, infectious arthritis, or post-traumatic arthritis); (4) Previous knee replacement or other major joint surgery; (5) Severe knee deformity (e.g., valgus or varus deformity > 15°) or significant ligament injury requiring concomitant surgical correction; (6) Psychological or cognitive impairment preventing compliance with preoperative rehabilitation or follow-up; (7) Pregnancy or lactation; (8) Incomplete clinical data or inability to obtain adequate follow-up information.

After applying these criteria, 169 patients (169 knees) were finally included and divided into two groups according to the treatment modality: the observation group (arthroscopic debridement, n=85) and the control group (integrated traditional Chinese and Western conservative therapy, n=84). In the observation group, there were 51 males and 34 females, aged 55-71 years (mean  $\pm$  standard deviation [SD], 61.19  $\pm$  7.37 years), with a disease duration of 1-7 years (mean  $\pm$  SD, 3.15  $\pm$  1.12 years). The affected side included 48 left and 37 right knees. In the control group, there were 52 males and 32 females, aged 56-72 years (mean  $\pm$  SD, 62.14  $\pm$  7.23 years), with a disease duration of 2-12 years (mean  $\pm$  SD, 3.45  $\pm$  1.16 years). The affected side included 50 left and 34 right knees. This study was reviewed and approved by the Medical Ethics Committee of Affiliated Hospital of Guangdong Medical University.

### *Treatment methods*

Treatment allocation for all patients was determined according to patient preference, clinical suitability, and the surgeon's recommendation following a comprehensive discussion of the risks and benefits associated with surgical and conservative management.

Patients in the observation group underwent arthroscopic debridement. Preoperatively, patients were positioned supine and administered continuous epidural anesthesia. A pneumatic

tourniquet was applied to the proximal thigh, maintaining an inflation pressure of 33-40 kPa to minimize intraoperative bleeding. Surgical draping and aseptic precautions were performed to ensure a sterile operative field. During the procedure, the knee joint was flexed to approximately 40°-50°. Arthroscopic portals were established about one finger's breadth above the tibial plateau and 1 cm medial and lateral to the patellar ligament. The joint cavity systematically inspected, and lesions were evaluated and addressed as required. Physiological saline was used to irrigate the cavity, and loose cartilage debris was removed. Cartilaginous lesions were smoothed or softened by scraping and shaving. Subchondral drilling and decompression were performed beneath areas of exposed cartilage, ensuring a depth sufficient to achieve marrow oozing. Hypertrophic, congested, and edematous synovial tissue was excised, osteophytes impeding knee motion were removed, and unstable meniscal fragments were trimmed. A drainage tube was placed at the end of the procedure. Postoperatively, the incision was cleansed and dressed appropriately. Rehabilitation began on postoperative day 2 with quadriceps isometric contraction and straight-leg-raising exercises. From one week after surgery, patients initiated active and passive knee flexion-extension exercises, gradually progressing to weight-bearing and ambulation according to limb recovery.

Patients in the control group received integrated traditional Chinese and Western conservative therapy. The regimen included oral nonsteroidal anti-inflammatory drugs, symptomatic relief agents such as diacerein (50 mg, Chemany, J20151187), glucosamine sulfate (0.26 g, Hubei Zexun Biological Technology Co., Ltd., H20043267), systemic glucocorticoids, and intra-articular sodium hyaluronate injections (3 mL: 22 mg, Ruiqi Biomedical Co., Ltd., F20040671). Additional interventions included administration of growth factors, traditional Chinese herbal medicine, topical Chinese patent medicine, acupuncture, hot compress therapy, and other local physical treatments. Each course lasted one week, and patients completed a total of four treatment courses.

### *Outcome measures*

All patients were followed up for seven months. The following evaluation indicators were recorded.

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1. Pain assessment: Pain intensity was evaluated before treatment and at 1, 4, and 7 months after treatment using the VAS. The VAS ranges from 0 to 10, where 0 indicates no pain and 10 indicates the most severe pain.

2. Knee function assessment: Knee function was assessed using the Lysholm knee scoring system before treatment and at 1, 4, and 7 months post-treatment. The Lysholm scale, with a maximum score of 100, evaluates eight domains: a. Pain (25 points): none (25), mild (20), moderate (15), severe (0); b. Limp (5 points): graded by walking stability; c. Support (5 points): evaluated according to the need for walking aids; d. Squatting (5 points): full (5), partial (2), or unable (0); e. Stability (25 points): assesses lateral and rotational stability during daily activities; f. Stairs (10 points): normal (10), requires assistance (5), unable (0); g. Walking (10 points): based on distance and endurance; h. Running (15 points): assesses the ability to jog, run, or perform strenuous activity. Scores are interpreted as follows: excellent, > 85; good, 76-85; fair, 60-75; and poor, ≤59. The clinical effectiveness rate was defined as the proportion of patients with Lysholm scores ≥76 (good or excellent), serving as a quantitative indicator for comparison of functional improvement between groups.

3. Range of motion (ROM): The maximum flexion and extension ROM of the knee joint were measured using a standard goniometer before surgery and at 1, 4, and 7 months postoperatively to assess improvement in joint flexibility.

4. Radiographic evaluation (K-L grading system): The K-L grading system was used to assess the radiographic severity and structural progression of KOA. The grades were defined as follows: a. Grade 0: no radiographic abnormalities; b. Grade I: doubtful osteophyte formation and possible joint space narrowing; c. Grade II: definite osteophyte formation with mild joint space narrowing; d. Grade III: multiple osteophytes, moderate joint space narrowing, and mild subchondral sclerosis; e. Grade IV: large osteophytes, severe joint space narrowing, and evident subchondral sclerosis. Standard weight-bearing radiographs obtained preoperatively and at 24 months postoperatively to evaluate joint structural changes. The deterioration rate of the K-L grade was recorded as an indicator of structural preservation.

Radiographs were independently evaluated by two experienced orthopedic surgeons, and any discrepancies were resolved by consensus.

5. Complications analysis: All postoperative adverse events, including joint swelling, infection, hematoma, mechanical catching, or adhesions, were documented. The incidence rate of complications was calculated to assess the safety of the treatment.

6. General information: Baseline clinical data, including age, sex, BMI, disease duration, occupation, preoperative K-L grade (I-IV), and intraoperative Outerbridge cartilage injury grade (I-IV) were collected for all patients.

### *Statistical analysis*

All statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as counts and percentages [n (%)], and comparisons between groups were conducted using the chi-square ( $\chi^2$ ) test. Continuous variables were presented as the mean  $\pm$  SD, and differences between groups were analyzed using the independent-samples *t* test. Repeated measures data were analyzed using repeated-measures analysis of variance. Multivariate logistic regression analysis was performed to identify independent factors influencing clinical efficacy. A two-tailed *P* value < 0.05 was considered statistically significant. A predictive nomogram model was constructed based on the results of multivariate logistic regression using the “rms” package in R (version 4.2.1; R Foundation for Statistical Computing, Vienna, Austria). Model performance was evaluated using the concordance index (C-index), calibration curve, and receiver operating characteristic (ROC) curve, with the area under the curve (AUC) calculated to assess discrimination. Internal validation was performed using the bootstrap method with 1,000 resamples. Decision curve analysis was conducted to evaluate the clinical utility of the model.

## **Results**

### *Baseline characteristics of patients*

In the observation group (n=85), the mean age was  $61.19 \pm 7.37$  years, comprising 51 males (60%) and 34 females (40%). The mean dis-

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**Table 1.** Baseline characteristics of patients

Variable	Observation Group (n=85)	Control Group (n=84)
Age (years), mean $\pm$ SD	61.19 $\pm$ 7.37	62.14 $\pm$ 7.23
Disease duration (years), mean $\pm$ SD	3.15 $\pm$ 1.12	3.45 $\pm$ 1.16
Sex, n (%)		
Male	51/60	52/61.9
Female	34/40	32/38.1
Affected side, n (%)		
Left knee	48/56.5	50/59.5
Right knee	37/43.5	34/40.5

Note: SD, standard deviation.

ease duration was 3.15  $\pm$  1.12 years. Regarding the affected side, 48 patients (56.5%) had left knee involvement and 37 (43.5%) had right knee involvement. In the control group (n=84), the mean age was 62.14  $\pm$  7.23 years, including 52 males (61.9%) and 32 females (38.1%). The mean disease duration was 3.45  $\pm$  1.16 years. In terms of disease laterality, 50 patients (59.5%) had left knee involvement and 34 (40.5%) had right knee involvement. There were no statistically significant differences in baseline characteristics between the two groups (all  $P > 0.05$ ) (**Table 1**).

### *Comparison of pain levels between groups*

Pre- and post-treatment pain intensity was evaluated using VAS. Before treatment, the mean VAS scores were 7.21  $\pm$  0.98 in the observation group and 7.22  $\pm$  0.99 in the control group, with no significant difference between the two groups ( $P > 0.05$ ). At 1, 4, and 7 months after treatment, the mean VAS scores in the observation group were 3.23  $\pm$  0.62, 3.86  $\pm$  0.54, and 3.95  $\pm$  0.57, respectively, whereas those in the control group were 4.37  $\pm$  1.22, 4.67  $\pm$  1.26, and 4.97  $\pm$  1.36, respectively. At all postoperative time points, the observation group exhibited significantly lower VAS scores compared with the control group (all  $P < 0.05$ ) (**Figure 1**).

### *Comparison of knee joint function between groups*

Pre- and post-treatment knee function was assessed using the Lysholm scoring system. Before treatment, the mean Lysholm scores were 72.21  $\pm$  10.90 in the observation group

and 71.22  $\pm$  10.99 in the control group, with no significant difference between the two groups ( $P > 0.05$ ). At 1, 4, and 7 months after treatment, the mean Lysholm scores in the observation group were 79.78  $\pm$  10.79, 77.51  $\pm$  10.72, and 68.42  $\pm$  10.73, respectively, whereas those in the control group were 68.37  $\pm$  10.26, 65.25  $\pm$  10.24, and 59.47  $\pm$  10.43, respectively. At all postoperative time points, the Lysholm scores of the observation group were significant-

ly higher than those of the control group (all  $P < 0.05$ ) (**Figure 2**).

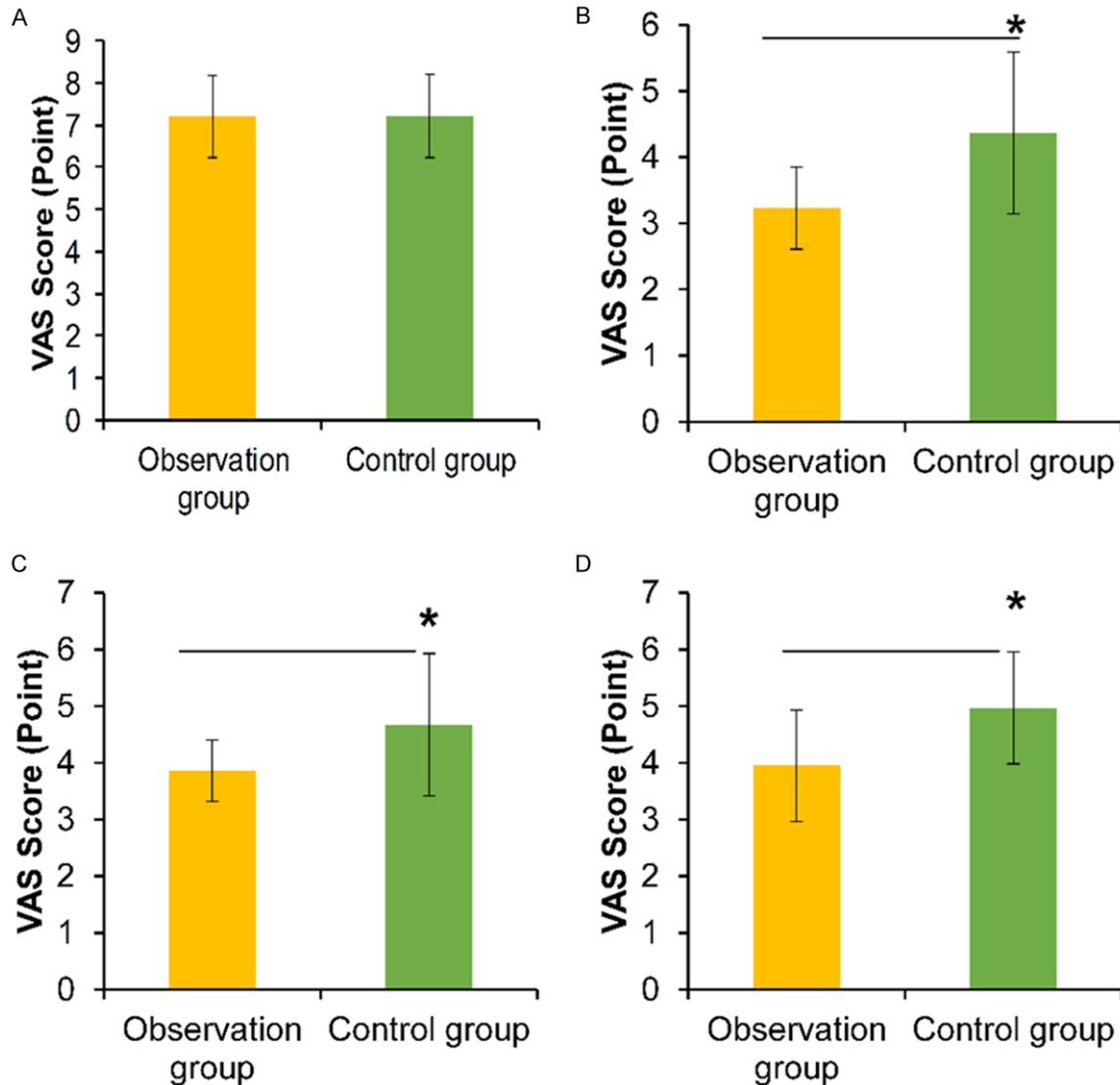
### *Comparison of overall clinical efficacy between groups*

In the observation group, 26 patients (30.6%) achieved excellent outcomes, 37 (43.5%) were rated as good, 16 (18.8%) as fair, and 6 (7.1%) as poor. In the control group, 21 patients (25%) were rated as excellent, 30 (35.7%) as good, 22 (26.2%) as fair, and 11 (13.1%) as poor. The proportion of patients with excellent or good outcomes was 74.1% (63/85) in the observation group and 60.7% (51/84) in the control group. The observation group demonstrated a significantly higher overall clinical efficacy rate compared with the control group ( $P < 0.05$ ) (**Figure 3**).

### *Comparison of improvement in knee joint ROM between groups*

The maximum flexion and extension ROM of the knee joint was assessed in both groups using a standard goniometer. The results showed a gradual postoperative improvement in joint mobility among patients in the observation group. The mean preoperative flexion angle was 104.31  $\pm$  11.20°, increasing to 113.62  $\pm$  10.11°, 120.47  $\pm$  9.30°, and 124.79  $\pm$  8.59° at 1, 4, and 7 months after surgery, respectively. In the control group, the corresponding values were 103.71  $\pm$  10.91°, 108.52  $\pm$  9.83°, 112.61  $\pm$  9.42°, and 115.22  $\pm$  9.04°, respectively. Compared with preoperative values, both groups exhibited significant improvements in joint mobility at 1, 4, and 7 months after treatment (all  $P < 0.05$ ). Furthermore, at each postoperative time point, the improvement in ROM

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**Figure 1.** Comparison of pain levels between groups (mean  $\pm$  SD, points). A. Before treatment; B. 1 month after treatment; C. 4 months after treatment; D. 7 months after treatment. Note: VAS, visual analog scale; SD, standard deviation. \* $P < 0.05$ , compared with the control group.

was significantly greater in the observation group than in the control group (all  $P < 0.05$ ) (Table 2).

### *Comparison of radiographic assessment of structural progression between groups*

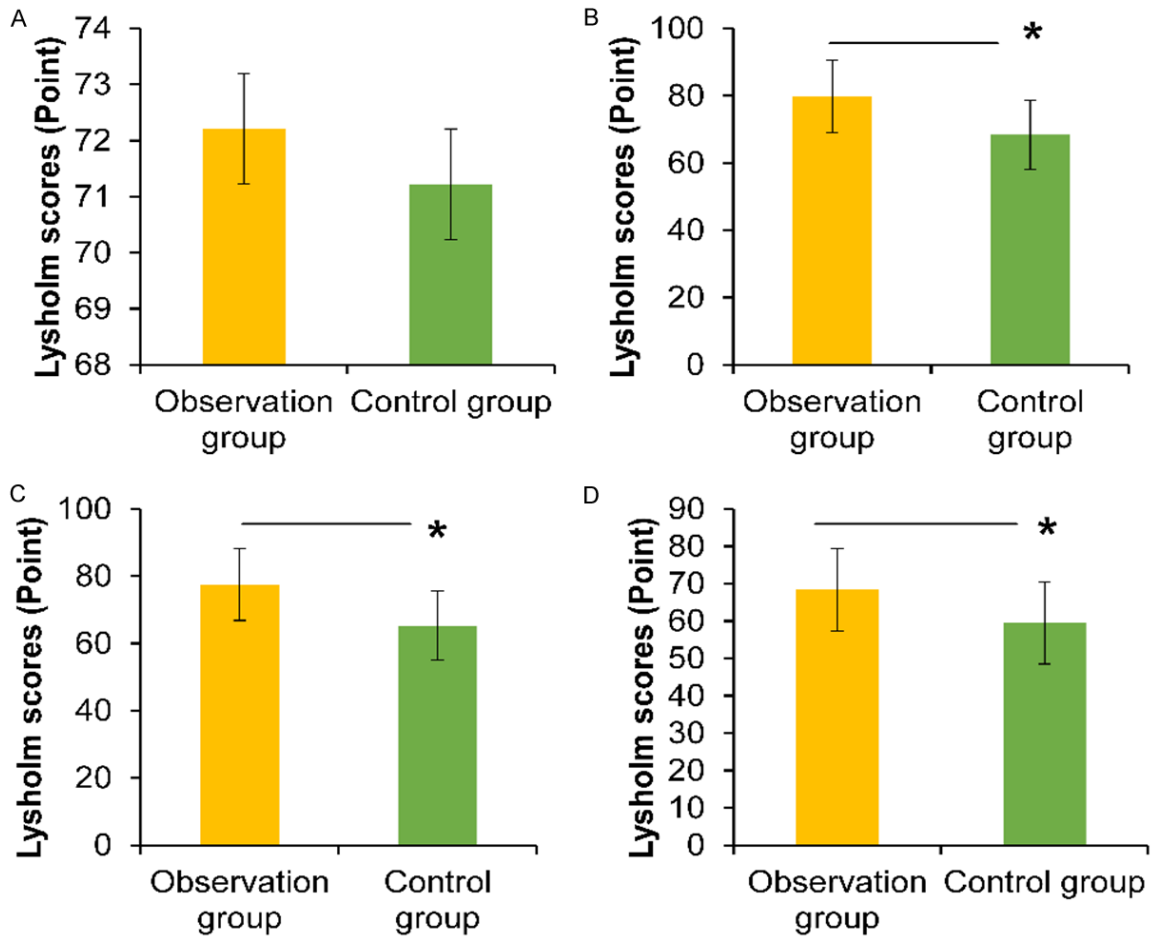
Standard weight-bearing knee X-rays obtained before surgery and at 24 months postoperatively were used to evaluate structural changes according to the K-L grading system. In the observation group, preoperative grading included 13 patients (15.3%) with grade I, 31 (36.5%) with grade II, 28 (32.9%) with grade III, and 13 (15.3%) with grade IV. At 24 months after surgery, 15 patients (17.6%) demonstrat-

ed a reduction in K-L grade. In the control group, preoperative K-L grades were as follows: grade I, 12 patients (14.3%); grade II, 32 (38.1%); grade III, 27 (32.1%); and grade IV, 13 (15.5%). After 24 months, only 5 patients (6.0%) exhibited an improvement in K-L grade. The rate of radiographic improvement in the observation group was significantly higher than that in the control group ( $P=0.021$ ) (Figure 4).

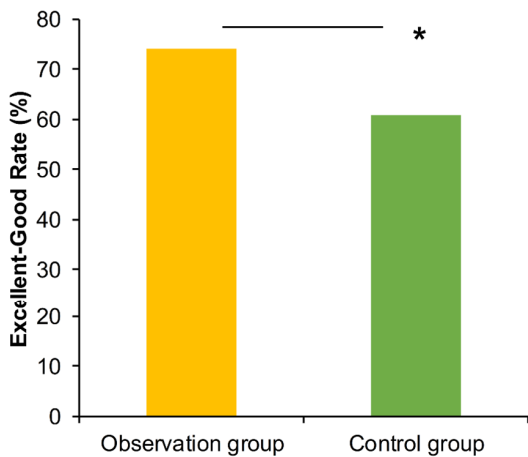
### *Univariate analysis of factors influencing arthroscopic outcomes*

In the observation group, 63 patients achieved excellent or good outcomes after arthroscopic treatment, while 22 were classified as fair

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**Figure 2.** Comparison of knee joint function between groups (mean  $\pm$  SD, points). A. Before treatment; B. 1 month after treatment; C. 4 months after treatment; D. 7 months after treatment. Note: SD, standard deviation. \* $P < 0.05$ , compared with the control group.



**Figure 3.** Comparison of overall clinical efficacy between groups [n (%)]. Note: \* $P < 0.05$ , compared with the control group.

or poor. To identify factors associated with treatment efficacy, baseline demographic and clinical characteristics were compared between the excellent/good and fair/poor subgroups. Significant differences (all  $P < 0.05$ ) were observed between the two groups in terms of sex, age, disease duration, BMI, preoperative K-L grade on knee radiographs, and intraoperative Outerbridge cartilage grade (Table 3).

### *Multivariate logistic regression analysis of prognostic factors*

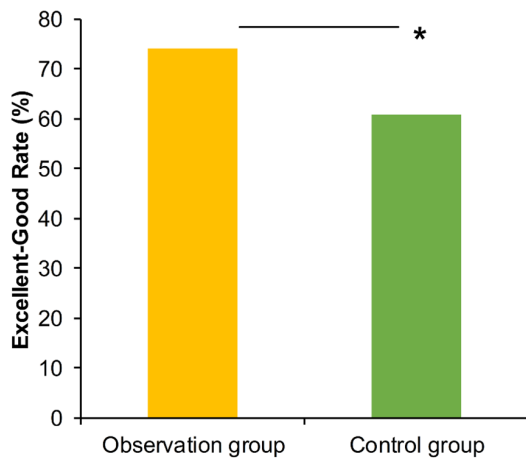
Multivariate logistic regression analysis identified several independent factors significantly associated with the outcomes of arthroscopic treatment for KOA. Specifically, BMI greater than 26 kg/m<sup>2</sup>, higher K-L grade, and higher

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**Table 2.** Comparison of maximum knee flexion angles at different postoperative time points between two groups (°)

Time Point	Observation Group (n=85)	Control Group (n=84)	t	P
Preoperative	104.31 ± 11.20	103.71 ± 10.91	0.41	0.682
1 month after surgery	113.62 ± 10.11	108.52 ± 9.83	3.03	0.003*
4 months after surgery	120.47 ± 9.30	112.61 ± 9.42	5.39	< 0.001*
7 months after surgery	124.79 ± 8.59	115.22 ± 9.04	6.73	< 0.001*

Note: \* $P < 0.05$ , compared with the control group.



**Figure 4.** Comparison of K-L grade improvement rates between groups [n (%)]. Note: K-L, Kellgren-Lawrence. \* $P < 0.05$ , compared with the control group.

Outerbridge grade were found to be significant predictors of worse clinical outcomes (all  $P < 0.05$ ) (Table 4).

### *Development and validation of the predictive nomogram model*

Based on multivariate logistic regression analysis, three independent predictors-BMI > 26 kg/m<sup>2</sup>, high K-L grade (≥ grade III), and high Outerbridge grade (≥ grade III)-were incorporated into a nomogram model to predict postoperative clinical outcomes. Internal validation demonstrated favorable model performance, with a C-index of 0.82 (95% confidence interval: 0.76-0.88), indicating good discriminative ability. The calibration curve showed excellent agreement between predicted and observed probabilities, further supported by a nonsignificant Hosmer-Lemeshow goodness-of-fit test ( $P=0.312$ ). ROC curve analysis revealed an AUC of 0.83 (95% confidence interval: 0.75-0.91). The optimal cutoff value was 64%, cor-

responding to a sensitivity of 76.2% and a specificity of 81.8% (Figure 5).

### **Discussion**

KOA is a prevalent degenerative joint disorder that profoundly affects patients' mobility and quality of life, particularly among the elderly. In this study, arthroscopic debridement significantly improved pain, knee joint function, ROM, and radiographic structural preservation compared with conservative treatment. Multivariate logistic regression analysis identified BMI > 26 kg/m<sup>2</sup>, higher K-L grade (≥III), and higher Outerbridge grade (≥III) as independent predictors of worse surgical outcomes. A predictive nomogram incorporating these variables demonstrated robust discriminative ability and calibration, suggesting that this model may serve as a valuable tool for predicting postoperative efficacy.

The superior short- and mid-term outcomes observed in the arthroscopy group align with previous evidence indicating that arthroscopic intervention can effectively relieve symptoms in appropriately selected KOA patients by removing intra-articular mechanical irritants and inflammatory debris [13]. Significant improvements in VAS and Lysholm scores were noted as early as one month after surgery, demonstrating that arthroscopic debridement provides rapid symptomatic relief. This therapeutic effect is likely attributed to the removal of loose cartilage fragments, fibrin deposits, and inflammatory mediators from the joint cavity, thereby disrupting the cycle of inflammation and mechanical degeneration. Consistent with the present findings, recent studies have confirmed that arthroscopic debridement can enhance knee function and yield significant short-term improvements in VAS and Lysholm scores, indicating favorable early efficacy [14, 15]. Moreover, the arthroscopy group exhibited a higher

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**Table 3.** Univariate analysis of factors influencing the outcome of arthroscopic treatment for KOA

Factor	Category	Excellent/Good (n=63)	Fair/Poor (n=22)	$\chi^2$	P
Sex	Male	41 (65.08%)	10 (45.45%)	4.263	0.03*
	Female	22 (34.92%)	12 (54.55%)		
Age (years)	≤60	47 (74.60%)	11 (50.00%)	4.118	0.042*
	> 60	16 (25.40%)	11 (50.00%)		
Disease duration (years)	< 1	11 (17.46%)	2 (9.09%)	9.382	0.009*
	1-3	39 (61.90%)	11 (50.00%)		
	> 3	13 (20.63%)	9 (40.91%)		
BMI (kg/m <sup>2</sup> )	≤26	44 (69.84%)	7 (31.82%)	10.527	0.001*
	> 26	19 (30.16%)	15 (68.18%)		
Kellgren-Lawrence grade	Grade I	8 (12.70%)	1 (4.55%)	9.846	0.020*
	Grade II	37 (58.73%)	9 (40.91%)		
	Grade III	14 (22.22%)	7 (31.82%)		
	Grade IV	4 (6.35%)	5 (22.73%)		
Outerbridge grade	Grade I	12 (19.05%)	2 (9.09%)	11.627	0.008*
	Grade II	42 (66.67%)	12 (54.55%)		
	Grade III	6 (9.52%)	6 (27.27%)		
	Grade IV	3 (4.76%)	2 (9.09%)		

Note: KOA, knee osteoarthritis; BMI, body mass index. \*P < 0.05, compared with fair/poor group.

**Table 4.** Multivariate logistic regression analysis of factors influencing the outcome of arthroscopic treatment for KOA

Variable	B	SE	P	OR (95% CI)
BMI > 26 kg/m <sup>2</sup>	2.417	0.168	0.009*	1.670 (0.142-3.464)
High Kellgren-Lawrence grade	1.339	0.326	0.018*	3.652 (1.890-6.152)
High Outerbridge grade	1.095	0.459	0.041*	3.271 (1.173-5.940)

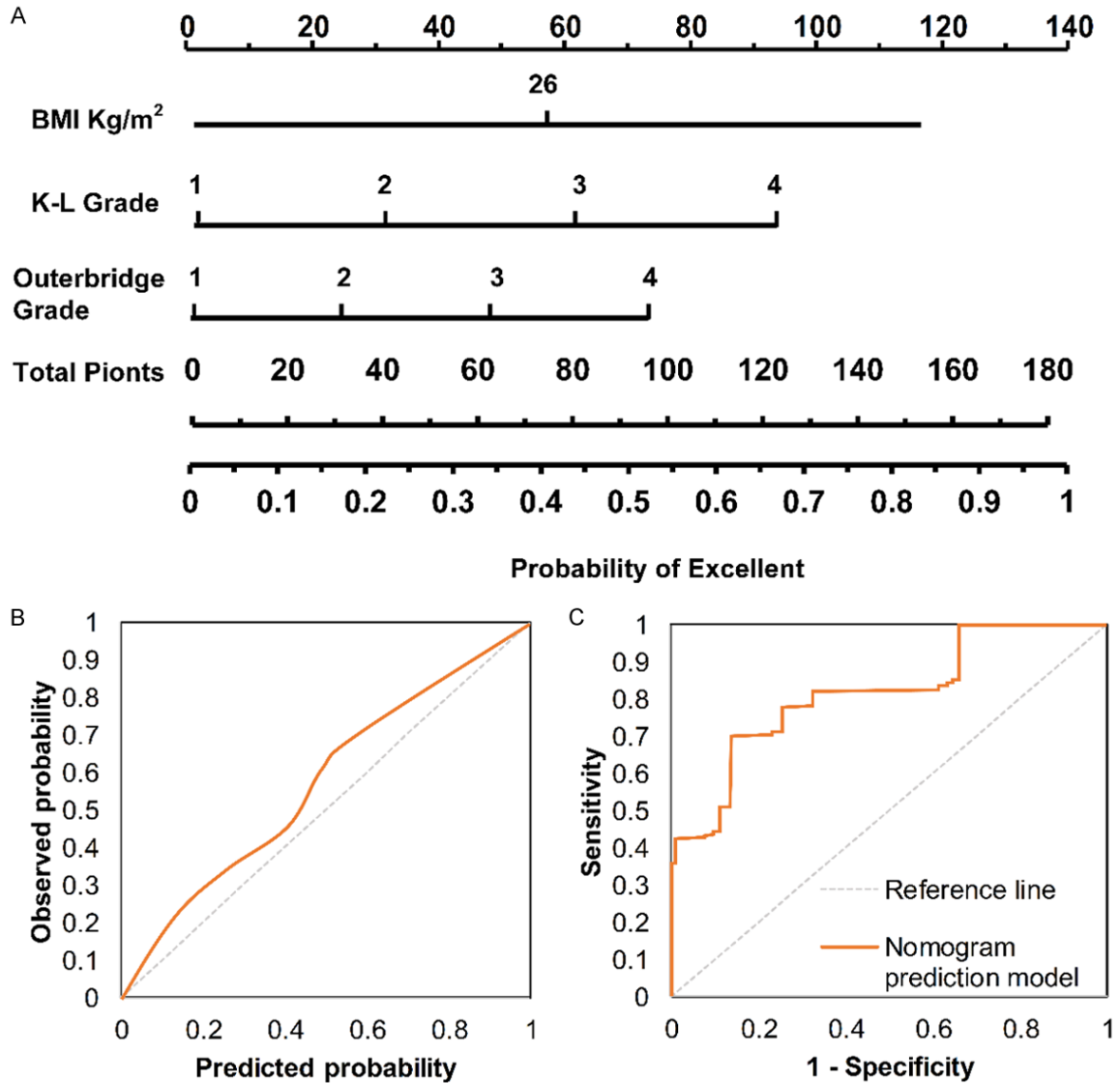
Note: KOA, knee osteoarthritis; OR, odds ratio; CI, confidence interval; BMI, body mass index; B, regression coefficient; SE, standard error. \*P < 0.05 indicates statistical significance.

rate of improvement in K-L grade at the 24-month follow-up. Several studies have also reported that the symptomatic and functional benefits of arthroscopic debridement can persist for approximately two years, suggesting a sustained mid-term advantage [16, 17]. With regard to radiographic outcomes, although the K-L grading system may be relatively insensitive to detecting subtle structural changes, recent investigations employing more sensitive parameters - such as joint space width - or incorporating cartilage repair techniques have indicated that arthroscopy may help delay radiographic progression in specific patient subgroups [18].

Multivariate analysis revealed that BMI > 26 kg/m<sup>2</sup>, high K-L grade (≥III), and high Outerbridge grade (≥III) were independent predictors

of unfavorable outcomes following arthroscopic surgery. This observation is consistent with findings from recent studies. Firstly, a higher BMI has been repeatedly confirmed by recent reviews and cohort studies to correlate with less favorable short- and mid-term outcomes after arthroscopic procedures. The underlying mechanism may involve not only the increased mechanical load on the knee joint but also the systemic pro-inflammatory state associated with obesity, which accelerates cartilage degeneration and impairs tissue repair capacity [19]. Secondly, a high K-L grade (≥III) represents advanced radiographic degeneration. In these patients, the benefits achievable by merely removing intra-articular debris and inflammatory mediators are limited, and the procedure is unlikely to prevent further structural deterioration over medium to long term time

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**Figure 5.** Predictive nomogram model and validation results. A. Nomogram prediction model; B. Calibration curve; C. ROC curve. Note: ROC curve, receiver operating characteristic curve. AUC, area under the curve; BMI, body mass index; K-L, Kellgren-Lawrence.

frames [20]. Furthermore, an Outerbridge grade  $\geq$ III typically indicates deep fissuring or exposure of subchondral bone under arthroscopic visualization. Such extensive and irreversible chondral damage exceeds the reparative capacity of arthroscopic debridement, often resulting in suboptimal postoperative symptom relief and functional recovery [21]. Interestingly, recent studies have reported that the K-L and Outerbridge grading systems are not entirely congruent: certain patients exhibit low radiographic grades but have severe chondral damage during arthroscopy, and vice versa. This

discrepancy suggests that these grading systems provide complementary information for assessing disease severity, which may explain why both emerged as independent predictors in the multivariate model [22]. Taken together, comprehensive evaluation incorporating BMI, K-L grade, and Outerbridge grade offers a more holistic assessment of mechanical loading, systemic metabolic stress, radiographic degeneration, and focal cartilage damage, thereby improving the accuracy of prognostic prediction. Similar perspectives have been supported by recent clinical follow-up studies [23].

Therefore, the nomogram developed based on BMI, K-L grade, and Outerbridge grade provides a quantitative approach for preoperative risk assessment, aligning with the current trend toward precision medicine in orthopedics. By integrating readily available clinical parameters (e.g., BMI), radiographic findings (K-L grade), and intraoperative cartilage evaluation (Outerbridge grade), the model enables individualized prediction of postoperative outcomes. This predictive tool supports shared decision-making between clinicians and patients, facilitates realistic expectation management, and contributes to more tailored treatment planning. The nomogram demonstrated strong discriminative ability (C-index = 0.82, AUC=0.83) reflecting substantial clinical utility comparable to that of predictive models recently proposed for other orthopedic interventions [24, 25]. Overall, the model may assist in identifying optimal candidates for arthroscopic surgery, improving the allocation of medical resources, and ultimately enhancing the overall quality and efficacy of patient care.

Despite the informative nature of the present findings, several limitations should be acknowledged. First, the retrospective study design inherently introduces the risk of selection bias and residual confounding, despite efforts to adjust for known variables through multivariate analysis. Second, although the sample size was adequate for preliminary model development, it remains relatively modest, which may limit the generalizability of the findings. Third, the follow-up period was restricted to 24 months, providing only mid-term radiographic data and preventing a comprehensive assessment of long-term efficacy for both arthroscopic treatment and the predictive model. Fourth, as a single-center study, the external validity of the nomogram remains to be confirmed, necessitating further validation in independent, multi-center, large-scale cohorts. In light of these limitations, future research should focus on several key areas. Prospective, multi-center studies with larger sample sizes are warranted to validate and refine the predictive nomogram. Longer follow-up durations (e.g., 5-10 years) are recommended to assess long-term outcomes and the need for subsequent surgical interventions such as total knee arthroplasty. Incorporating additional predictive variables-including genetic markers, advanced

imaging parameters (e.g., magnetic resonance imaging-based cartilage assessment), patient-reported outcome measures, and biomechanical indicators-may further enhance the model's predictive precision. Finally, future studies should evaluate the cost-effectiveness and real-world applicability of integrating this predictive tool into clinical decision-making across diverse healthcare systems.

### Conclusion

BMI > 26 kg/m<sup>2</sup>, higher K-L grade, and higher Outerbridge grade were identified as the primary factors influencing the clinical outcomes of arthroscopic treatment for KOA. The developed nomogram model (AUC=0.83) allows for quantitative prediction of postoperative outcomes, providing an evidence-based tool to assist in precise patient selection and individualized surgical decision-making. Nevertheless, this predictive model requires further validation in larger, prospective, multi-center cohorts to confirm its generalizability and clinical applicability. Future studies involving broader populations and extended follow-up periods are warranted to refine the model and further support its integration into clinical practice.

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### Disclosure of conflict of interest

None.

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