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RESEARCH

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The impact of anterior cruciate ligament deficiency severity on the outcomes of fixed-bearing unicompartmental knee arthroplasty: a retrospective study

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Abstract

Objective Anterior cruciate ligament deficiency (ACLD) has traditionally been regarded as a contraindication for unicompartmental knee arthroplasty (UKA). However, advancements in surgical techniques and improvements in prosthetic manufacturing have challenged this notion. Controversy persists regarding whether the anterior cruciate ligament (ACL) influences the postoperative outcomes of fixed-bearing (FB) UKA. This study aimed to evaluate the impact of varying severities of ACLD on the clinical outcomes of FB-UKA.

Methods This retrospective analysis included 81 patients (87 knees) who underwent FB-UKA for anteromedial osteoarthritis (AMOA). Patients were categorised into three groups on the basis of preoperative MRI and intraoperative findings: the intact ACL group (31 knees), the partial ACLD group (39 knees), and the complete ACLD group (17 knees). Patient demographics (age, body mass index [BMI]), preoperative hip-knee-ankle angle (HKA), follow-up duration, and preoperative and last follow-up data, collected more than one year postoperatively, were recorded, including the Hospital for Special Surgery knee score (HSS), Lysholm score, visual analogue scale (VAS) for pain, range of motion (ROM), postoperative X-ray assessment of the position of the femoral component relative to the tibial component, as well as evaluation of radiolucent lines on the postoperative X-rays. Statistical analyses were conducted to determine differences in clinical outcomes, including pre-and postoperative changes, among the three groups. Postoperative complications, such as infection, aseptic loosening, prosthetic dislocation, or periprosthetic fractures requiring revision surgery, were recorded.

Results There were no significant differences among the three groups in terms of age, BMI, follow-up duration, preoperative HKA, baseline Lysholm score, HSS knee score, VAS score, or ROM ($P > 0.05$). Postoperatively, all three groups showed significant improvements in the Lysholm score, HSS knee score, VAS score, and ROM ($P < 0.001$), with no significant differences in the extent of improvement among the groups ($P > 0.05$). The position of the

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femoral component relative to the tibial component did not differ significantly among the groups ($P > 0.05$), and no radiolucent lines were observed in any of the patients. No patients experienced complications such as infection, aseptic loosening, periprosthetic fractures, or prosthetic dislocations that required revision surgery at the latest follow-up.

Conclusion FB-UKA is a viable surgical option for the treatment of AMOA. For patients with AMOA and stable anteroposterior knee alignment, ACLD does not adversely affect short- to midterm outcomes following FB-UKA. Even in cases of partial or complete ACLD, careful patient selection and optimised surgical techniques can yield outcomes comparable to those in patients with intact ACLs.

Keywords Fixed-Bearing unicompartmental knee arthroplasty, Anterior cruciate ligament deficiency, Anteromedial osteoarthritis

Introduction

Unicompartmental knee arthroplasty (UKA) is an effective treatment for anteromedial osteoarthritis (AMOA) [1]. Compared with total knee arthroplasty (TKA), UKA offers several advantages, including less intraoperative blood loss, a shorter operative time, greater preservation of bone structure, improvement in gait, and a lower risk of postoperative complications [2–6].

Historically, anterior cruciate ligament deficiency (ACLD) was considered a contraindication for UKA [7]. However, advancements in prosthetic materials, notably the development of highly cross-linked polyethylene (HXLPE), have significantly enhanced the mechanical properties of UKA components, particularly their wear resistance and long-term durability. These improvements have expanded the applicability of UKA, making it a viable option for a broader spectrum of patients [8–12]. Recent studies suggest that, with appropriate surgical techniques, careful patient selection, and optimized rehabilitation protocols, patients with ACLD can achieve satisfactory clinical outcomes postoperatively [13].

To date, there has been limited research on the outcomes of fixed-bearing (FB) UKA in patients with combined ACLD and AMOA, and the severity of ACLD has not been clearly defined. This study is a retrospective analysis that aims to evaluate the impact of varying severities of ACLD on the postoperative outcomes of FB-UKA. The tested hypothesis was that complete ACLD may significantly affect clinical outcomes following FB-UKA, whereas patients with partial ACLD are expected to experience better postoperative clinical results.

Materials and methods

The inclusion criteria were as follows: (1) patients who underwent FB-UKA for AMOA at the Central Hospital Affiliated to Shenyang Medical College between September 2021 and September 2023; (2) patients with complete preoperative MRI, along with comprehensive preoperative and postoperative medical records and radiological data; (3) patients whose surgical records included intraoperative descriptions of anterior cruciate ligament (ACL) status; (4) patients whose preoperative lateral knee X-rays revealed cartilage damage confined to the anterior and central compartments, with negative Lachman and anterior drawer tests on physical examination; and (5) patients who participated in follow-up assessments. The exclusion criteria were as follows: (1) patients with inflammatory joint diseases, such as knee tuberculosis, gouty arthritis, or rheumatoid arthritis; (2) patients with incomplete medical or radiological records; (3) patients who refused participation or were lost to follow-up; and (4) patients with osteoarthritis involving other knee compartments.

All procedures were performed by the same experienced surgical team, who utilised a FB prosthesis design. The FB prosthesis was provided by the Chinese company Lidakang. In accordance with the inclusion and exclusion criteria, a total of 85 patients (91 knees) who underwent FB-UKA were enrolled. Four patients (4 knees) were lost to follow-up, resulting in a final cohort of 81 patients (87 knees) treated at our institution with FB-UKA. The patients were categorised into three groups according to the integrity of the ACL: the intact ACL group, the partial ACLD group, and the complete ACLD group. Intact ACL group: Patients with no ACLD on preoperative MRI and intraoperative findings confirming normal ACL morphology and function; 2. Partial ACLD group: Patients with MRI evidence of ACLD and intraoperative findings showing irregular ACL morphology but preserved function. 3. Complete ACLD group: Patients with MRI evidence of ACL rupture or intraoperative findings indicating a nonfunctional ACL (Fig. 1). Intraoperative assessment of the ACL was performed in two steps: direct visual inspection of the ACL morphology, followed by probing with a tendon hook. If the ACL ruptures, exhibits no tension, is easily elongated, or is prone to rupture, it is considered functionally incompetent.

The following data were recorded: patient age, body mass index(BMI), follow-up duration, preoperative hip-knee-ankle angle (HKA), postoperative X-ray assessment of the position of the femoral component relative to the tibial component (Fig. 2) [14], evaluation of radiolucent

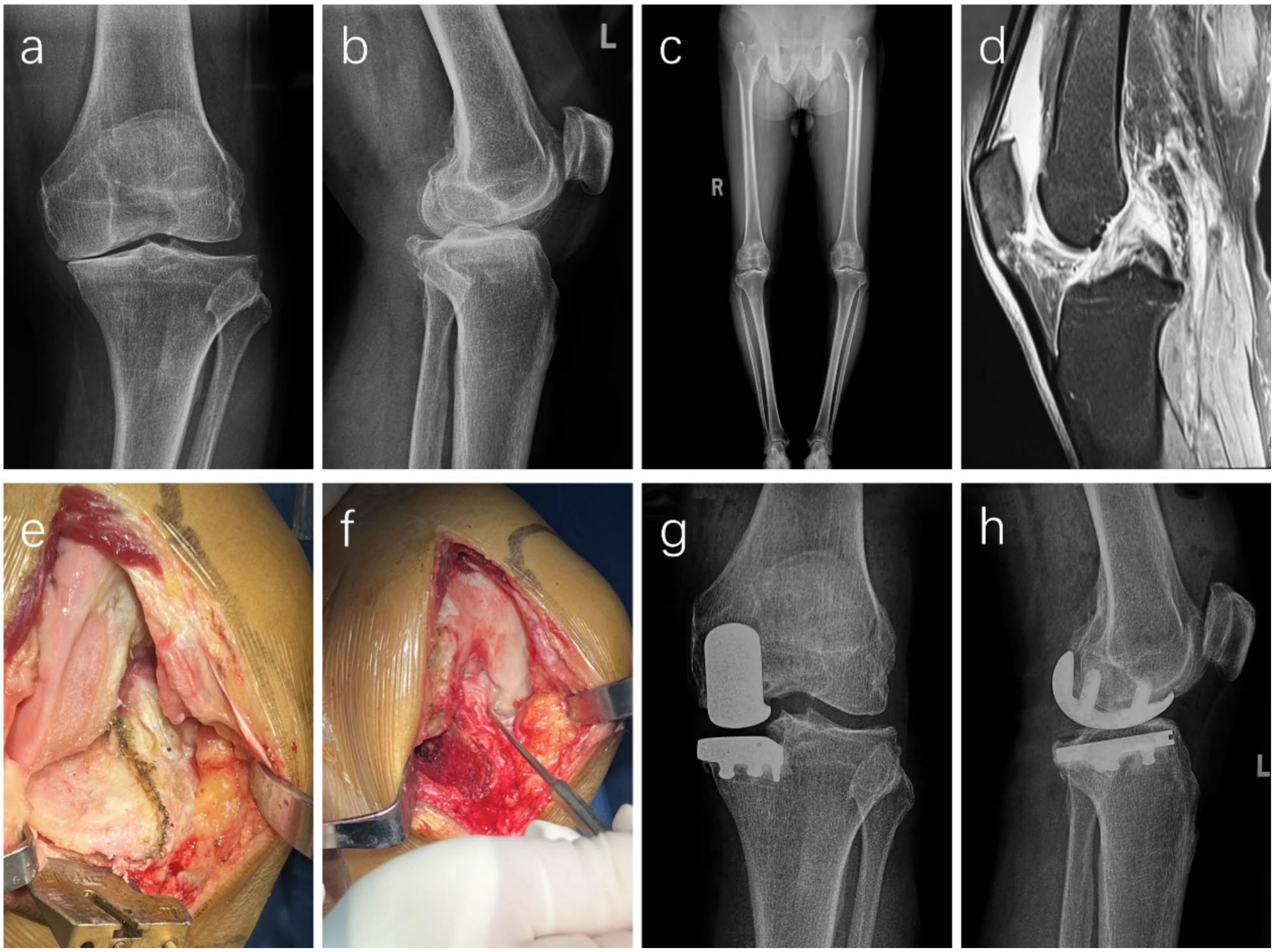

Fig. 1 A 74-year-old male patient with a 3-year history of left knee pain. Preoperative assessments, including the anterior drawer test and the Lachman test, were negative. (**a**, **b**, **c**) Preoperative X-ray imaging revealed medial compartment osteoarthritis of the left knee without posterior tibial plateau erosion. **(d)** Preoperative MRI revealed poor integrity of the ACL, indicating that it was wavy and lax. **(e)** Intraoperative exploration revealed a partial ACL tear. **(f)** Examination with a tendon retractor further confirmed that the ACL was lax and wavy. These findings indicated that the ACL was nonfunctional and that the patients were categorised into the complete ACLD group. (**g**, **h**) Postoperative anteroposterior and lateral X-rays of the left knee joint

lines on the postoperative X-rays, and clinical outcomes which were evaluated preoperatively and at follow-up exceeding one year postoperatively. These outcomes included the Lysholm score (≥ 95, excellent; 85–94, good; 65–84, fair; <65, poor) [15], Hospital for Special Surgery knee score (HSS) (85–100, excellent; 70–84, good; 60–69, fair; <60, poor) [16], visual analogue scale (VAS) score for pain (0, no pain; 10, worst pain) [17], and range of motion (ROM). Additionally, the occurrence of complications and the necessity for revision surgery were documented.

Data analyses

Statistical analyses were performed via SPSS version 27.0 (IBM Corp, Armonk, NY, USA). The normality of the distribution was assessed using the Shapiro-Wilk test for both normal and non-normal distributions. Continuous variables, including age, BMI, HKA, follow-up duration, Lysholm score, HSS knee score, VAS score, and ROM, are expressed as the mean ± standard deviation ($\overline{x} \pm s$) for normally distributed data, or as the median and interquartile range (M [P25, P75]) for non-normally distributed data. To evaluate the statistical significance of pre- and postoperative differences within groups, paired t-tests were used for variables that were normally distributed with homogeneity of variance, whereas nonparametric tests were applied for non-normal distributions. Intergroup differences in preoperative, postoperative, and change values were assessed via one-way analysis of variance (ANOVA) for data with a normal distribution and homogeneity of variance, and nonparametric tests were employed otherwise.

Categorical variables, such as the occurrence of complications, the need for revision surgery, and the postoperative position of the femoral component relative to the tibial component, were analysed via the chi-square test.

Fig. 2 **(a)** The distance from the lowest point of the femoral condyle prosthesis to the lateral wall of the tibial prosthesis. **(A)** The total distance between the medial and lateral walls of the tibial prosthesis. The positioning is classified as follows: Lateral: a/A < 0.4. Central: 0.4 ≤ a/A ≤ 0.6. Medial: a/A > 0.6

Table 1 Comparison of basic characteristics among the three patient groups ($\bar{x} \pm s$)

Group	Sample Size (*n*)	Age (years)	BMI (kg/m2)	Follow-up Time (months)	HKA (°)
Intact ACL group	31	64.74 ± 7.27	25.97 ± 3.34	14.58 ± 2.79	172.84 ± 3.00
Partial ACLD group	39	65.13 ± 6.70	26.85 ± 3.89	14.54 ± 2.67	173.74 ± 3.28
Complete ACLD group	17	68.88 ± 6.24	25.06 ± 3.73	14.53 ± 2.62	172.59 ± 3.02
P value		*P* = 0.108	*P* = 0.232	*P* = 0.978	*P* = 0.333

Table 2 Comparison of preoperative and postoperative Lysholm scores among the three patient groups ($\bar{x} \pm s$)

Group	Sample Size	PreoperativeLysholm	Postoperative Lysholm	Change in Lysholm	*P* value
Intact ACL group	31	63.65 ± 7.23	81.71 ± 6.00	18.06 ± 5.25	*P* < 0.001
Partial ACLD group	39	64.03 ± 6.19	81.64 ± 5.02	17.62 ± 4.60	*P* < 0.001
Complete ACLD group	17	64.00 ± 8.13	80.71 ± 7.32	16.71 ± 6.66	*P* < 0.001
P value		*P* = 0.972	*P* = 0.830	*P* = 0.696	

Table 3 Comparison of preoperative and postoperative HSS scores among the three patient groups ($\bar{x} \pm s$)

Group	Sample Size	Preoperative HSS	Postoperative HSS	Change in HSS	*P* value
Intact ACL group	31	57.61 ± 7.16	77.74 ± 6.54	20.13 ± 7.80	*P* < 0.001
Partial ACLD group	39	58.31 ± 6.39	77.56 ± 6.24	19.26 ± 4.99	*P* < 0.001
Complete ACLD group	17	56.82 ± 6.77	76.18 ± 6.41	19.35 ± 5.41	*P* < 0.001
P value		*P* = 0.742	*P* = 0.699	*P* = 0.831	

Table 4 Comparison of preoperative and postoperative ROM scores among the three patient groups ($\bar{x} \pm s$)

Group	Sample Size	Preoperative ROM	Postoperative ROM	Change in ROM	*P* value
Intact ACL group	31	94.48 ± 8.51	108.90 ± 8.15	14.42 ± 6.94	*P* < 0.001
Partial ACLD group	39	96.00 ± 6.70	109.31 ± 6.82	13.31 ± 6.74	*P* < 0.001
Complete ACLD group	17	95.35 ± 7.51	108.41 ± 8.56	13.06 ± 8.04	*P* < 0.001
P value		*P* = 0.707	*P* = 0.920	*P* = 0.750	

Table 5 Comparison of the preoperative and postoperative VAS scores [M (P25, P75)] among the three patient groups

Group	Sample Size	Preoperative VAS	Postoperative VAS	Change in VAS	*P* value
Intact ACL group	31	6(5, 6)	0(0, 1)	-5(-6, -5)	*P* < 0.001
Partial ACLD group	39	6(5, 6)	0(0, 1)	-5(-6, -5)	*P* < 0.001
Complete ACLD group	17	6(4.5, 7)	0(0, 0)	-6(-6.5, -4)	*P* < 0.001
P value		*P* = 0.828	*P* = 0.556	*P* = 0.783	

A significance level of $\alpha = 0.05$ was applied, with $P < 0.05$ indicating a statistically significant difference.

Results

A total of 81 patients (87 knees) were included in the study, with 4 patients (4 knees) lost to follow-up. The remaining patients completed the follow-up assessments. Among the included knees, 31 were classified into the intact ACL group, 39 into the partial ACLD group, and 17 into the complete ACLD group. No statistically significant differences were observed among the three groups in terms of age, BMI, follow-up duration, or HKA ($P > 0.05$), as detailed in Table 1.

Preoperatively, there were no significant differences among the three groups in the Lysholm score, HSS score, VAS score, or ROM ($P > 0.05$). Postoperatively, all groups demonstrated significant improvements in the Lysholm score, HSS score, VAS score, and ROM ($P < 0.001$). However, the changes observed between the preoperative and postoperative measurements were not significantly different ($P > 0.05$). Additionally, there were no significant differences in the postoperative position of the femoral component relative to the tibial component among the three groups ($P > 0.05$), and no radiolucent lines were observed in any of the patients. The detailed results are presented in Tables 2, 3, 4, 5, 6 and Fig. 3.

All postoperative incisions healed well in all patients, with no reported cases of infection, deep vein thrombosis, prosthetic loosening, periprosthetic fractures, or bearing dislocation. Patients were able to ambulate without reliance on walking aids, successfully performing level-ground walking and climbing stairs. Knee pain was significantly alleviated, joint function markedly

Table 6 Comparison of position of the femoral component relative to the tibial component (%) among the three patient groups postoperatively

Group	Sample Size	Medial(%)	Central(%)	Lateral(%)	*P* value
Intact ACL group	31	7(22.6)	20(64.5)	4(12.9)	
Partial ACLD group	39	11(28.2)	16(41)	12(30.8)	
Complete ACLD group	17	5(29.4)	6(35.3)	6(35.3)	
P value					χ^2=6.006 *P*=0.199

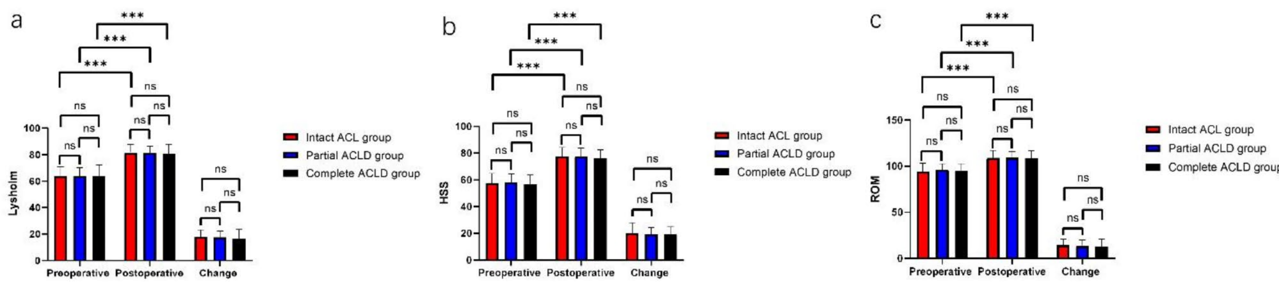

Fig. 3 Comparison of the Lysholm scores, HSS scores, and ROM among the three patient groups, as well as the preoperative and postoperative assessments

improved, and overall quality of life greatly increased. Notably, no patients required revision surgery.

Discussion

This study revealed that the postoperative Lysholm score, HSS score, VAS score, and ROM significantly improved compared with the preoperative values in the intact ACL group, the partial ACLD group, and the complete ACLD group. Furthermore, there were no significant differences in postoperative clinical outcomes between the groups. These findings suggest that ACLD is not a determinant of postoperative outcomes in FB-UKA patients.

For patients with medial KOA, UKA is increasingly regarded as an ideal alternative to TKA, offering an effective treatment option [2–6]. By preserving the ACL and posterior cruciate ligament (PCL) as well as the bone stock in other compartments, UKA maintains knee kinematics closely resembling normal biomechanics, with postoperative proprioception and functional outcomes approaching those of a native knee. However, the long-term revision rate of UKA is approximately three times higher than that of TKA. Among younger patients, the most common causes of revision are unexplained pain, joint instability, and aseptic loosening of the prosthesis, whereas in elderly patients, aseptic loosening and disease progression are the primary reasons for revision [18]. Therefore, careful preoperative assessment of surgical indications and contraindications, along with meticulous intraoperative management, is crucial for ensuring the success of the procedure.

Patients with KOA combined with ACLD are common, and the mechanisms of injury primarily fall into two categories: (1) secondary ACLD caused by femoral intercondylar notch osteophytes associated with primary KOA, which results in wear and damage to the ACL [19]; and (2) secondary KOA induced by acute ACLD, which leads to knee instability and tibial subluxation [20]. Preoperative physical examination and MRI are standard methods for diagnosing ACLD; however, these techniques may overestimate or underestimate the extent of ACLD [21]. Thus, intraoperative exploration remains the "gold standard" for accurate diagnosis. In this study, we classified patients on the basis of preoperative MRI findings and intraoperative exploration to ensure accuracy in grouping.

In 1989, Scott et al. proposed that an intact ACL was a prerequisite for UKA [7]. Furthermore, in 1992, Goodfellow et al. followed 301 UKA patients for nine years and reported that the survival rate of knees with an intact ACL at 6 years was 95%, whereas the equivalent survival rate for patients with ACLD was 81% [22]. Consequently, ACLD has long been considered a contraindication for UKA. However, recent studies have challenged this notion, suggesting that even in the presence of ACLD, if the knee is stable and other factors are appropriate, the prosthesis can maintain a good survival rate and clinical outcomes. For example, Plancher et al. reported that in a study of 114 patients with KOA who underwent UKA, the 10-year survival rate was 97% for both the ACLD group and the intact ACL group, with over 85% of patients achieving the Patient Acceptable Symptom State (PASS). There are no significant clinical differences between ACLD knees and intact ACL knees [23]. A meta-analysis comparing 1,287 cases of FB-UKA with 1,229 cases of mobile-bearing (MB) UKA also demonstrated that ACLD patients who underwent UKA achieved similar survival rates and clinical outcomes to those with intact ACLs [24]. Ou et al. conducted a finite element analysis and concluded that ACLD, in the absence of other structural damage and with maintained anterior-posterior knee stability, should not be considered a contraindication for UKA [25]. On the basis of the findings of this study and the relevant literature, ACLD is not an absolute contraindication for UKA. This trend may be attributed to improvements in prosthetic materials, surgical techniques, and patient selection. However, caution is advised when selecting MB prostheses for patients with ACLD. Owing to their distinct design, MB prostheses feature fully mobile inserts, which, when combined with ACLD, may lead to altered stress distributions, thereby increasing the risk of wear and even inserting dislocations [22].

This study included patients who underwent UKA and who exhibited anterior-posterior knee stability preoperatively. For unstable knees, TKA is recommended. This anterior-posterior stability may be associated with the formation of femoral intercondylar osteophytes, capsular contracture, and compensatory mechanisms from other ligaments [26, 27]. Therefore, during surgery, in addition to removing osteophytes that may wear on the ACL or interfere with prosthesis motion, it is important to minimise the removal of other osteophytes and cautiously release the medial collateral ligament and joint capsule to maintain knee stability. Concerning the adjustment of the tibial slope, some studies have suggested that increasing the tibial slope reduces collateral ligament tension, which, in turn, increases tibial anterior translation in ACLD knees. Conversely, decreasing the tibial slope increases collateral ligament tension, reducing tibial anterior translation and thereby enhancing knee stability [28]. Plancher et al. followed 241 patients who underwent UKA (both intact ACL and ACLD) for an average of 8 years and reported that those with a tibial slope > 7° experienced significantly worse postoperative pain, whereas the survival rate of FB-UKA at 10 years was 96% [29]. Adulkasem et al. used 3D-printed tibial inserts with a posterior slope of 3°-12° in 15 fresh cadaveric specimens and performed computer-assisted navigation for FB-UKA. Their study revealed that a 1° change in the tibial slope nearly doubled the degree of knee translation, and the optimal tibial posterior slopes for FB-UKA in patients with partial and complete ACL tears were 5–7° and 5–6°, respectively [30]. Zumbrunn et al. studied the kinematics of UKA in ACLD patients and reported that ACLD caused posterior femoral translation; however, reducing the tibial slope resulted in kinematic patterns similar to those of intact ACL knees, with a reduction in the tibial posterior slope partially compensating for ACL function [31]. For patients with AMOA combined with ACLD, intraoperative strategies may involve a deliberate reduction in the tibial slope to compensate for the compromised function of the ACL.

For younger patients with anteroposterior knee instability, UKA combined with anterior cruciate ligament reconstruction (ACLR) represents a feasible treatment option, with the advantages of reducing surgical morbidity and recovery time, and ultimately improving joint kinematics and clinical outcomes [32]. Volpin et al. (2018) [33] conducted a meta-analysis incorporating eight studies, comprising a total of 186 patients who underwent UKA combined with ACLR, with a mean follow-up period of 37.6 months. The results demonstrated a significant improvement in clinical outcomes, as reflected by the Oxford Knee score, which increased from a preoperative mean of 27.5 to 36.8 postoperatively. However, several postoperative complications were noted, including three cases of tibial insert dislocation, one case of infection, one case of deep vein thrombosis, two cases requiring revision surgery due to infection, one case of conversion to TKA, one case requiring manipulation under anaesthesia, and one case necessitating arthroscopic release. Similarly, Ayham et al. reported consistent findings in their 10-year follow-up of 23 patients who underwent UKA combined with ACLR [34]. The implant survival rate was 91.4%, and significant improvements were observed in patient-reported outcomes, including VAS, Lysholm, Tegner, and University of California, Los Angeles (UCLA) activity scores. Additionally, the rate of return to sports was notably high. The authors emphasised that the integrity of the medial collateral ligament (MCL) is a fundamental prerequisite for surgical success, as it dictates the depth of tibial resection. Following UKA, the insertion of an autologous ACL graft requires the implantation of a tibial bearing to prevent excessive varus stress and optimise the load distribution within the joint. In a study of 24 patients who underwent simultaneous combined ACL reconstruction and UKA, significant improvements were observed in the Lysholm, Tegner, OKS, and VAS pain scores, with all patients returning to sports and no revisions required [35]. Legnani et al. conducted a study on patients with medial KOA and ACLD and reported that, after 10 years, UKA combined with ACLR provided clinical and radiographic results comparable to those of TKA, with significant improvements in the KOOS, OKS, and WOMAC scores [36]. While UKA combined with ACLR is an effective strategy for managing ACLD associated with AMOA, it demands advanced surgical expertise and carries potential risks. These include postoperative stiffness, graft impingement, stress concentration, and aseptic loosening of the tibial prosthesis. In the MB-UKA, the failure of ACLR can further heighten these risks. Therefore, meticulous surgical planning and postoperative management are essential to achieve optimal outcomes.

On the basis of the findings of this study and other studies, we conclude that for patients with AMOA and ACLD, knee stability in the anterior-posterior direction is critical for successful UKA. Preoperative clinical assessments (e.g., drawer tests and Lachman tests) are essential for screening appropriate candidates for UKA. For knees with anterior-posterior stability, older patients with lower activity levels may be considered for FB-UKA, whereas younger, more active patients with higher functional demands may benefit from a combined approach of FB-UKA and ACLR. For patients with anterior-posterior knee instability, TKA remains the treatment of choice.

This study has several limitations. First, as a single-centre retrospective study, its findings rely on patient-reported outcomes, introducing potential bias. Second, the relatively small sample size may limit the generalisability of the conclusions. Finally, the short follow-up period necessitates longer-term studies to validate the durability and effectiveness of the observed outcomes.

Conclusions

ACLD is not an absolute contraindication for FB-UKA. In patients with AMOA and partial or complete ACLD, short- to midterm outcomes comparable to those of patients with intact ACLs can be achieved, provided that preoperative anteroposterior knee stability is ensured through meticulous surgical planning and intraoperative management. This finding supports the potential expansion of UKA indications in the future, although further research is necessary to validate its long-term outcomes.

Abbreviations

UKA	Unicompartmental knee arthroplasty
ACL	Anterior cruciate ligament
ACLD	Anterior cruciate ligament deficiency
BMI	Body mass index
HSS	Hospital for Special Surgery knee score
VAS	Visual analogue scale
ROM	Range of motion
KOA	Knee osteoarthritis
TKA	Total knee arthroplasty
HKA	Hip-knee-ankle
ACLR	Anterior cruciate ligament reconstruction
PASS	Patient acceptable symptom state
FB	Fixed-bearing
AMOA	Anteromedial osteoarthritis
HXLPE	Highly cross-linked polyethylene
ANOVA	One-way analysis of variance
PCL	Posterior cruciate ligament
MB	Mobile-bearing
UCLA	University of California, Los Angeles
MCL	Medial collateral ligament

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None.

Author contributions

SHJ wrote the first draft of the manuscript and reviewed related literature. DL, BZ, MYS, FJL, YXJ, and GAW collected the data, analysed the data, and created visualisations. BZ provided technical expertise, revised the manuscript, and ensured the accuracy of the technical details. All the authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the Ethics Committee of Shenyang Medical College (Approval Number: EC-2024-091(02)) and was exempt from obtaining informed consent in accordance with relevant regulations.

Competing interests

The authors declare no competing interests.

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