Zhang et al.
Journal of Orthopaedic Surgery and Research (2025) 20:344
https://doi.org/10.1186/s13018-025-05728-w

Journal of Orthopaedic Surgery and Research

RESEARCH

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A controlled study of personalized versus standard osteotomy in medial unicompartmental knee osteoarthritis

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Abstract

Purpose To compare the efficacy of personalized osteotomies with that of standard osteotomies in treating medial unicompartmental knee osteoarthritis.

Methods The clinical data of 96 patients who were diagnosed with unicompartmental knee osteoarthritis in our group between 2019 and 2023 were retrospectively analysed on the basis of preoperative and postoperative radiological measurements. The knee injury and osteoarthritis outcome score (KOOS), forgotten joint score (FJS), and Lysholm knee score scale (Lysholm) were used to assess the clinical outcome, and complications were observed and recorded.

Results According to the relevant criteria, 84 of 96 patients were included in this study. All patients were followed for a mean of 31 (range 22–55) months. Fifty-one patients underwent personalized osteotomy procedures, and thirty-three underwent standard osteotomy procedures. The postoperative KOOS Pain ($P < 0.0001$), KOOS Symptoms ($P < 0.0001$), KOOS ADL ($P < 0.0001$), KOOS Sport ($P = 0.0023$), KOOS QoL ($P < 0.0001$), Lysholm ($P < 0.0001$) and FJS ($P < 0.0001$) scores were higher than those in the standard osteotomy group. Nevertheless, postoperative extension ($P = 0.2636$) and postoperative flexion ($P = 0.3554$) were not significantly different.

Conclusion This was a single-centre, retrospective, short follow-up study with several limitations. However, on the basis of the results of the present study, we believe that the function of the knee after medial unicompartmental knee arthroplasty (mUKA) is affected by the direction of tibial osteotomy. We believe that better clinical results may be obtained when the tibial implant is placed near the preoperative tibial deformity.

***Level of evidence*:** Level IV; retrospective case series.

Keywords Unicompartmental knee arthroplasty, Kinematic alignment, Mechanical alignment, Implant positioning

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Introduction

Unicompartmental knee osteoarthritis is a degenerative joint disease [1] characterized by knee pain, limited mobility, and deformity. Its incidence is increasing due to obesity and the ageing of the population [2]. Early treatment is mainly focused on relieving pain and slowing wear and tear of the joint, and unicompartmental knee arthroplasty (UKA) is currently the mainstay of treatment for advanced unicompartmental knee osteoarthritis [3]. Compared with those of total knee replacement, the advantages of UKA include faster postoperative recovery, fewer complications, and better knee mobility [4, 5]. Since the UKA prosthesis was designed, many controversies have been reported [6]; for example, obesity was once considered a contraindication to UKA, but in more recent studies, the outcomes of UKA have been satisfactory in patients with a BMI > 30 kg/m^2 [7]. Current debates focus on the optimal alignment strategy for UKA tibial prostheses. Mechanical alignment (tibial prosthesis perpendicular to the mechanical axis of the tibia) remains the gold standard for unicompartmental knee arthroplasty (UKA) procedures [8, 9]. However, currently, scholars believe that kinematic alignment (placement of the tibial prosthesis in the vicinity of the preoperative tibial deformity) allows for restoration closer to the patient's natural anatomy, with potentially better clinical outcomes [10–12].

The aim of this study was to compare the effects of personalized osteotomy for kinematic alignment with those of standard osteotomy for mechanical alignment on functional recovery of the knee after UKA via retrospective analysis.

Materials and methods

This study was approved by the Ethics Committee of Yichang Central People's Hospital and was performed in accordance with the Declaration of Helsinki (2024–519-01).

Inclusion and exclusion criteria

The inclusion criteria were as follows: ① The diagnosis was medial unicompartmental knee osteoarthritis. ② The anterior cruciate ligament is functionally intact. ③ Knee varus alignment < 15°.

The exclusion criteria were as follows: ① Fixed-bearing prosthesis placement. ② Total knee arthroplasty was performed. ③ Overweight (BMI>30 kg/m^2). ④ Death during the follow-up period or incomplete information.

Clinical data

From 2019 to 2023, 96 patients were diagnosed with unicompartmental knee osteoarthritis. Among them, 84 patients who met the above inclusion criteria were enrolled in the current study (Fig. 1). The patients' demographics and radiological characteristics were comprehensively reviewed. The demographic data included age, sex, and BMI. The radiologic features included the hip–knee–ankle (HKA), medial proximal tibial angle (MPTA), lateral distal femoral angle (LDFA), and arithmetic HKA (aHKA). All long-leg radiographs were taken in a standardized, weight-bearing, upright position with the patella facing forwards and the knee fully extended to limit the risk of error in the projected coronal plane alignment measurements [13]. Postoperative knee function data, including postoperative knee range of motion, the Knee Injury and Osteoarthritis Outcome (KOOS) score, the Lysholm knee score scale, and the forgotten joint score (FJS), were collected from the patients. Long-term complications and reoperation rates were recorded. All patients completed the questionnaire independently.

Arithmetic hip–knee–ankle

The arithmetic hip-knee-ankle (aHKA) angle was obtained using the MPTA-LDFA in the standard weight-bearing upright position, as assessed via X-ray imaging to evaluate kinematic alignment[14]. Patients were deemed to exhibit kinematic alignment if their postoperative HKA angle was situated within one standard deviation (± 3°) of the aHKA[14, 15].

Knee range of motion

A knee range of motion assessment was employed to evaluate knee mobility and impairment status. During the assessment, patients were seated with their legs in a suspended position. The maximum angle was documented as the patient performed slow and controlled flexion and extension of the knee.

Knee injury and osteoarthritis outcome scores

The Knee Injury and Osteoarthritis Outcome (KOOS) score is a comprehensive evaluation tool that assesses

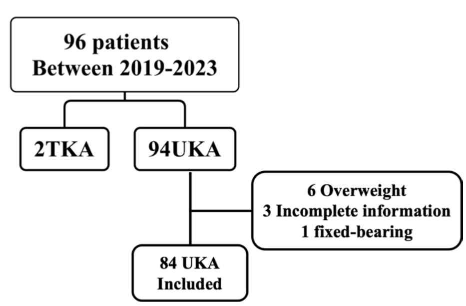

Fig. 1 Flow chart showing patient cohort inclusion

five key domains: pain, symptoms, activities of daily living, sport, and quality of life. These components provide a detailed assessment of the knee joint's functionality, with percentile scores ranging from 0 (indicating severe dysfunction) to 100 (representing optimal function) [16].

Lysholm score scale

In 1982, Lysholm and Gillqui proposed the Lysholm knee score scale as an improvement over the Larson scoring system. The scale is questionnaire-based and focuses on daily symptoms and mobility, with an emphasis on knee stability [17].

Forgotten joint score

The forgotten joint score (FJS) is a scoring system utilized to assess the extent of awareness of the artificial joint in patients who have undergone hip or knee replacement surgery. A higher score on the FJS indicates a greater level of forgetfulness regarding the artificial joint [18].

Statistical analysis

The statistical analysis was conducted via SPSS 25.0 software (SPSS Inc., Chicago, USA). Categorical variables are expressed as frequencies and percentages. Comparisons between groups were conducted using the chi-square test. Continuous variables are expressed as the means ± standard deviations. The Kolmogorov–Smirnov test was employed to ascertain the normality of the distribution. Levene's test was used to assess the equality of variance among the groups. Independent samples *t* tests were utilized for between-group comparisons, and Welch's corrected *t* tests were employed when the variance was not homogeneous. In instances where the data were not normally distributed, the Mann–Whitney U test was employed. A P value < 0.05 indicated statistical significance.

Surgical techniques

A tourniquet should be applied to the thigh. The leg should then be suspended with a lower limb brace. The hip joint should be flexed by 30° and mildly abducted. The leg should then be lowered naturally, and the knee joint should be flexed by 135°. A medial parapatellar incision should be made, with the superior end commencing at the medial superior border of the patella, the distal end situated 3 cm distal to the joint line, and ending at the medial border of the tibial tuberosity. The surgical procedure in the standard osteotomy group was conducted with a third-generation Oxford unicondylar prosthesis(The tibial osteotomy surface is perpendicular to the mechanical axis of the tibia).

Personalized osteotomy involves inserting a spoon gauge into the medial condyle of the femur to represent the inclination of the joint line. A custom-made side-slidable ankle yoke was connected to an extramedullary (EM) rod, replacing the original ankle yoke [19]. The EM rod was then aligned parallel to the anterior tibial cortex. The cutting block was subsequently positioned immediately below the spoon. In most cases, the spoon is not parallel to the cutting block but rather varus. The custom-made yoke was then carefully slid laterally until the cutting block and the spoon were positioned parallel (the degree of movement needed to be referenced to the preoperative MPTA, but the postoperative MPTA should be at least 80°) (Fig. 2 A, B). The spoon and the cutting block are fixed using the G-clamp, and the cutting block is fixed using a headless pin. Subsequent osteotomies were performed according to the design of the third-generation Oxford unicondylar prosthesis. After completion of the osteotomy, the patients in both groups were fitted with a cemented Oxford mobile-bearing Medial UKA prosthesis (JUST®, Mobile-bearing unicompartmental knee prosthesis system, Tianjin, China) after osteotomy was complete (Fig. 2 C, F).

Results

A total of 96 individuals were diagnosed with unicompartmental knee osteoarthritis from 2019 to 2023. A total of 84 patients (62 females and 22 males) met the inclusion criteria and were included in the study (Fig. 1). All patients were followed for a mean period of 31 months (range 22–55), during which time no patient developed prosthesis infection or required revision. Among the patients, 51 underwent personalized osteotomy, while the remaining 33 underwent standard osteotomy. The two datasets were homogeneous in terms of age, body mass index (BMI), LDFA and HKA angle. No significant differences in age, sex distribution, BMI, MPTA, LDFA, HKA angle, or aHKA angle were detected between the two groups ($P > 0.05$), indicating that the characteristics of the two groups were comparable (Table 1).

The differences in the KOOS Pain ($P < 0.0001$), KOOS Symptoms ($P < 0.0001$), KOOS ADL ($P < 0.0001$), KOOS Sport ($P = 0.0023$), and KOOS QoL ($P < 0.0001$) scores between the two groups of patients were statistically significant. These findings suggest that, in comparison with the standard osteotomy group, the personalized osteotomy group experienced greater pain and symptom relief and exhibited a greater ability to perform activities of daily living and sports. This finding is identical to that of the Lysholm score ($P < 0.0001$) (Table 2, Fig. 3). Furthermore, the personalized osteotomy group had a higher FJS ($P < 0.0001$), indicating that, in terms of prosthesis perception, the patients in this group demonstrated a greater level of prosthesis acceptance (Table 2, Fig. 3). Nevertheless, no statistically significant

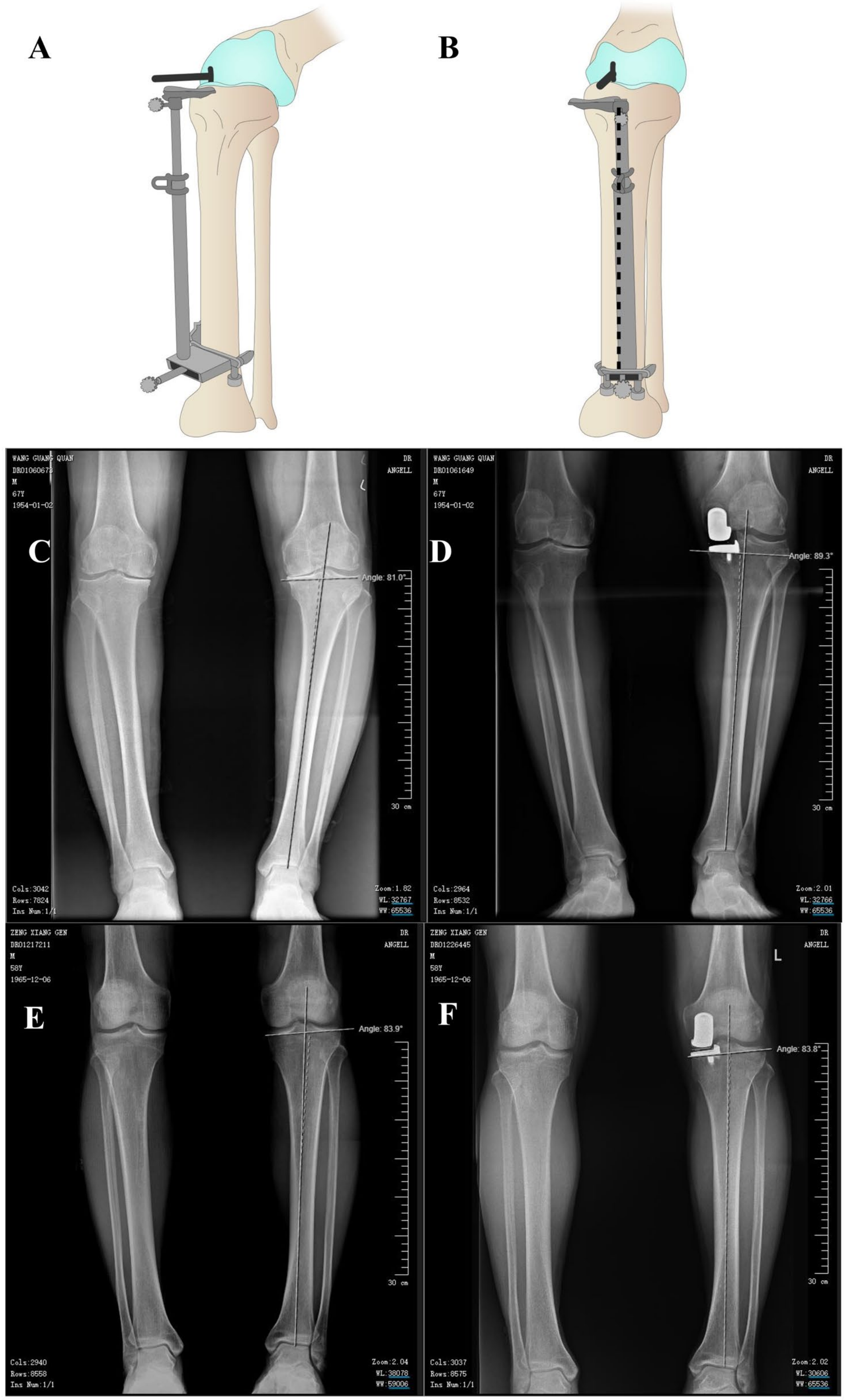

Fig. 2 Schematic of personalized osteotomy and long-leg preoperative and postoperative radiographs in both groups of patients. **A** and **B** Schematic of personalized osteotomy. **C** and **D** Preoperative and postoperative aspects of standard osteotomies. **E** and **F**, Preoperative and postoperative personalized osteotomies. Prosthetic Information: JUST®, Mobile-bearing unicompartmental knee prosthesis system, Tianjin, China

Table 1 Patient demographics and imaging characteristics

Variables	Personalized Osteotomy(n = 51)	Standard Osteotomy(n = 33)	Homogeneous or not	*P* Value
Age (years)	66.08 ± 6.86	66.33 ± 6.28	Yes	0.8641
Sex (M/F)	13(25.49%)/38(74.51%)	9(27.27%)/24(72.73%)	–	0.8560
BMI (kg/m^2)	24.32 ± 3.10	24.39 ± 2.73	Yes	0.9124
Left/Right	22(43.14%)/29(56.86%)	12(36.37%)/21(63.63%)	–	0.5368
MPTA	88(85.6–89.45)	87.1(85.9–87.7)	–	0.0970
LDFA	88.49 ± 2.77	88.38 ± 2.55	Yes	0.8468
HKA angle	4.86 ± 3.49	5.59 ± 3.41	Yes	0.3416
aHKA	− 1.1(−3.05–1.2)	− 1.7(−3.4–0.3)	–	0.2471

BMI, body mass index; *MPTA,* medial proximal tibial angle; *LDFA,* lateral distal femoral angle; *HKA*, hip–knee–ankle; *aHKA,* arithmetic hip–knee–ankle. Sex and left/right were categorical variables that were tested using chi-square tests and did not require ANOVA. The mPTA and aHKA angle were not normally distributed so the Mann–Whitney U test was performed, and ANOVA was not required

Table 2 Postoperative patient-reported outcome scores

Variables	Personalized Osteotomy(n = 51)	Standard Osteotomy(n = 33)	Homogeneous or not	*P* Value
KOOS Pain	83.71 ± 11.25	67.67 ± 17.58	No	< 0.0001
KOOS Symptoms	77.27 ± 10.81	64.64 ± 12.54	Yes	< 0.0001
KOOS ADL	87.43 ± 9.54	72.06 ± 14.44	No	< 0.0001
KOOS Sport	76.57 ± 12.55	61.06 ± 25.49	No	0.0023
KOOS QoL	79.86 ± 11.16	52.06 ± 20.80	No	< 0.0001
Lysholm	83.31 ± 10.21	63.52 ± 21.97	No	< 0.0001
FJS	72.16 ± 2.85	50.39 ± 6.03	No	< 0.0001
Postoperative extension	1.94 ± 1.86	1.46 ± 2.03	Yes	0.2636
Postoperative flexion	120(114–141)	128(108–143)	—	0.3554

KOOS, Knee Injury and Osteoarthritis Outcome Score; *ADL,* Activities of Daily Living; *QoL,* Quality of Life. *FJS* For the joint score, postoperative flexion did not follow a normal distribution and was analysed using the Mann–Whitney U test without ANOVA chi-square analysis

difference was observed between the two groups in terms of postoperative degrees of knee flexion or extension activation ($P > 0.05$) (Table 2, Fig. 4).

Discussion

Knee osteoarthritis (KOA) is a chronic disease that affects the joints and their surrounding tissues. The disease primarily causes progressive damage to the articular cartilage, which subsequently leads to damage to the subchondral bone and surrounding synovial structures[20]. The prevalence of KOA varies across different countries and regions. A meta-analysis conducted in China[21] revealed that the overall prevalence of KOA was 14.6% in studies conducted between 2012 and 2016. Additionally, the analysis revealed a higher prevalence in women than in men (19.1% and 10.9%, respectively). The prevalence of this condition is increasing due to concomitant increases in both the prevalence of obesity and the proportion of aging adults in the population [2].

If the patient's arthritis is limited to the unicompartmental compartment, UKA appears to be a superior alternative to total knee arthroplasty (TKA). A meta-analysis of 60 studies [22] revealed that, compared with TKA, UKA resulted in shorter postoperative hospital stays, higher functional scores, and lower postoperative mortality rates. However, no significant difference was observed between the two groups in terms of pain relief. Notably, the 5-year revision rate was significantly higher in the UKA group than in the TKA group. In a study analysing the high revision rate of UKA, the predominant cause was aseptic loosening, which constituted approximately 36% of cases [23]. The highest incidence of loosening was observed on the tibial side [24]. UKA is also more effective than high tibial osteotomy (HTO) is [25]. The traditional mechanical alignment method requires tibial osteotomy to be performed perpendicular to the mechanical axis of the tibia [8]. This is a viable approach for patients with a varus deformity of 2–3°, but many patients present with varus deformities exceeding 3° [9]. If mechanical alignment is pursued for these patients without consideration of other factors,

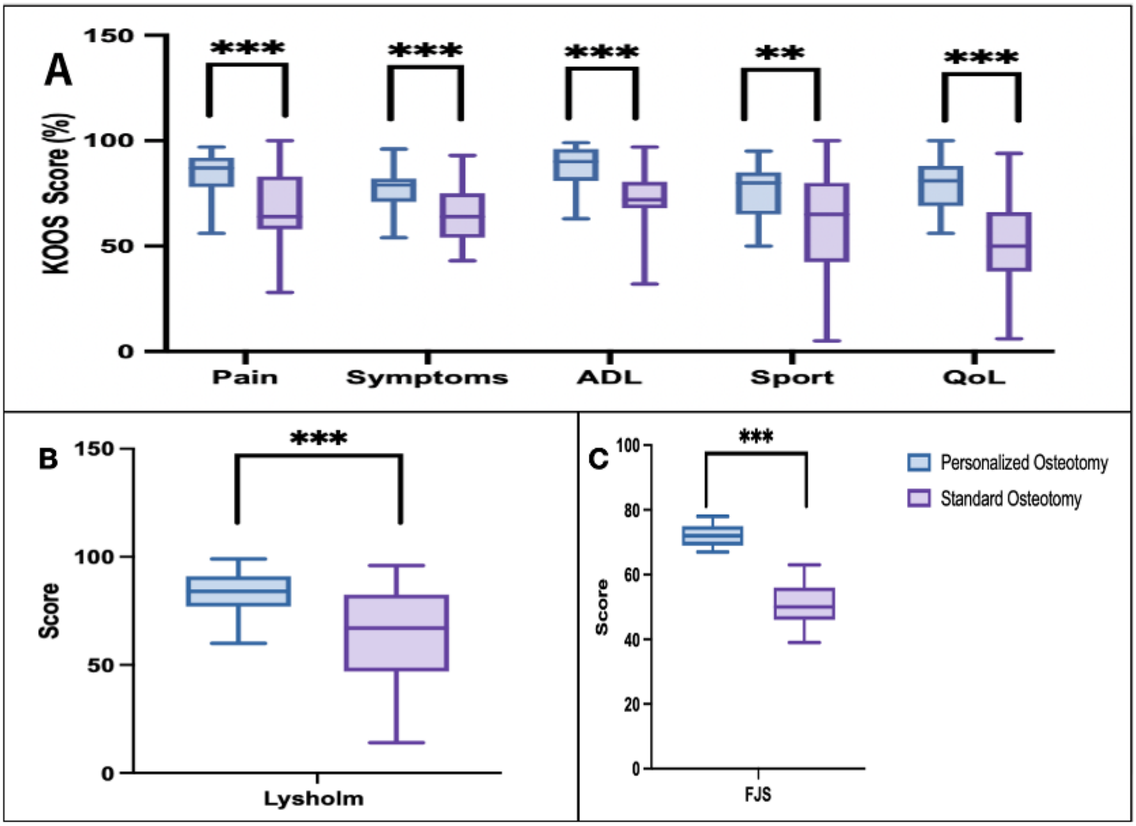

Fig. 3 Comparison of the postoperative KOOS, Lysholm score and FJS between the two groups. **A** Comparison of the postoperative KOOS. **B** Comparison of the postoperative Lysholm score. **C** Comparison of the postoperative FJS. *KOOS,* Knee Injury and Osteoarthritis Outcome Score; *ADL,* Activities of Daily Living; *QoL,* Quality of Life. *FJS* Forgotten Joint Score. (** $P < 0.01$. *** $P < 0.001$.)

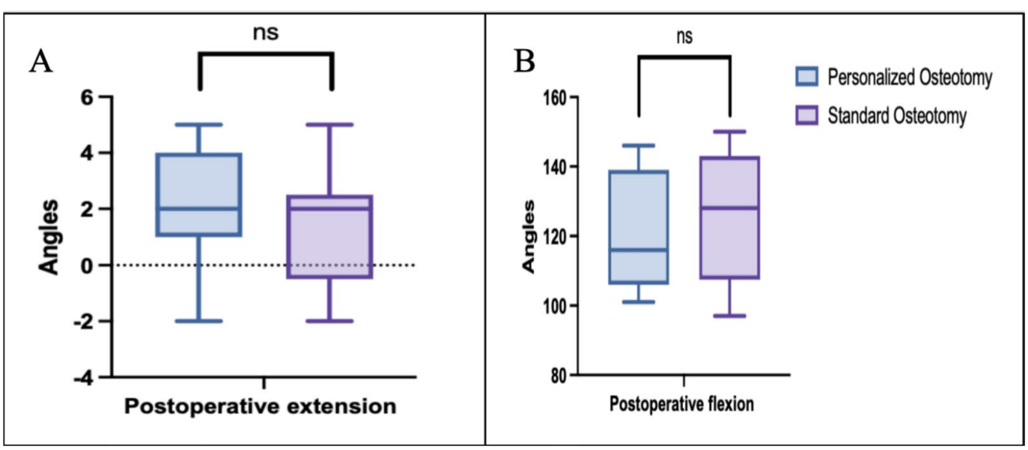

Fig. 4 Postoperative comparison of knee flexion and extension range of motion between the two groups. **A** Postoperative knee extension comparison. **B** Postoperative knee flexion comparison. (ns: no significance.)

the result may be unsatisfactory, and early loosening may occur. In light of these findings, some scholars have upheld the principles of tibial kinematic alignment [26], suggesting that UKA is, in many ways, the ultimate operation for achieving kinematic alignment as the express aim is to resurface the diseased side of the joint and restore alignment to its pre-arthritic status, joint line obliquity, and balance while maintaining the integrity of both cruciate ligaments [10]. Research revealed that patients exhibiting kinematic alignment of the fixed-bearing medial UKA prosthesis experienced better postoperative recovery and prosthesis longevity than those with kinematic alignment in the standard osteotomy group [12]. Despite the absence of substantial disparities in clinical outcomes between fixed-bearing and mobile-bearing designs in medial UKA [27], as evidenced by previous research, further investigation is necessary to ascertain the applicability of the aforementioned theory to mobile-bearing Medial UKA prostheses.

The follow-up period was characterized by the absence of significant complications, including infection, prosthesis failure, or prosthesis dislocation. In this study, we performed personalized osteotomy and used the Oxford prosthesis. Patients experienced more pain and symptom relief, as well as better recovery, when we performed personalized osteotomy. These observations were made during the postoperative follow-up. The results of this study indicate that kinematic alignment is equally achievable for patients with mobile-bearing medial unicompartmental knee arthroplasty (UKA) prostheses. Micicoi et al. [11] reported a modest improvement in clinical outcomes when tibial implants were positioned in proximity to the preoperative tibial deformity rather than when the Cartier angle was restored. This finding suggests that more individualized tibial osteotomy may be advantageous for patients whose knee valgus angles exceed 3°. However, they were not controlled against standard osteotomies, and the reliability and validity of the results could be questioned; thus, our study fills this gap. Plancher et al. [12] similarly reported the benefits of kinematic alignment at the 10-year follow-up. On the basis of the results of our study and those of previous studies, we believe that personalized osteotomy leading to kinematic alignment effectively treated medial knee osteoarthritis. This treatment is particularly effective in patients with knee valgus > 3°. In addition, the short- and long-term follow-up results support this conclusion. The applicability of kinesiological alignment theory to younger patients warrants further investigation, as our study, in conjunction with prior research, has yet to incorporate these demographic cohorts.

The shortcomings of this study include the following:

1. The relatively short follow-up period in this study, with an average duration of 31 months, did not permit a comparison of the impact of the two alignment techniques on prosthesis longevity. Thus, follow-up and analyses will continue to determine whether the two alignment methods affect the longevity of the prosthesis and the incidence of postoperative aseptic loosening.
2. The present study was conducted at a single centre, which may limit the generalizability of the findings to other centres or surgeons. To increase the generalizability of the results, we intend to expand the study to multiple centres in the future.
3. This was a retrospective study with low level of evidence. In the future, we intend to design and refine prospective studies to facilitate a comparison of the differences.

Conclusion

The results of this study suggest that the use of personalized osteotomies to achieve kinematic alignment of the tibial prosthesis has potential advantages over standard osteotomies in the treatment of medial knee osteoarthritis. These benefits include pain and symptom relief, restoration of activity and motor function, and reduced prosthetic awareness.

Author contribution

ZZ: Manuscript writing and data collection， WL: Data collection, BS: Performer of surgery， SW: Post-operative rehabilitation of all patients. KS: Supervision of the research process and revision of the manuscript.

Funding

There is no funding source.

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval

This study was approved by the Ethics Committee of Yichang Central People's Hospital and performed in accordance with the Declaration of Helsinki (2024–519-01).

Informed consent

Informed consent was obtained from all individual participants included in the study.

Consent for publication

Written informed consent for publication was obtained from all participants.

Competing interests

The authors declare no competing interests.

Received: 23 December 2024 Accepted: 17 March 2025
Published online: 06 April 2025

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