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Simultaneous bilateral and staged total knee arthroplasty combined with unicompartmental knee arthroplasty in the treatment of bilateral knee osteoarthritis: comparison of early clinical outcomes, complications, and prosthesis survival

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Abstract

Objective Knee osteoarthritis (KOA) is usually bilateral. In many patients, the degree of bilateral knee degeneration varies, with one side involving multiple compartments and the other a single compartment degeneration. Therefore, the objective of this study was to compare the early clinical efficacy of simultaneous bilateral and staged total knee arthroplasty (TKA) combined with unicompartmental knee arthroplasty (UKA) in the treatment of bilateral KOA with different degrees.

Methods We compared clinical data from 71 simultaneous bilateral TKA/UKA (SB-TKA/UKA) patients with 52 Staged TKA/UKA (Staged-TKA/UKA) patients. Staged-TKA/UKA is defined as TKA on one knee followed by UKA on the other knee. The comparison included Hospital for Special Surgery (HSS) score, range of motion(ROM), complication rate and prosthetic survival rate at the last follow-up between the two groups.

Results The follow-up time of SB-TKA/UKA group was (69.08 ± 14.35) months, and that of Staged-TKA/UKA group was (73.25 ± 18.39) months. Staged-KA/UKA group had a shorter hospital stays, less hospitalization costs and shorter operating time ($p < 0.001$ for hospital stay, $p < 0.001$ for hospitalization costs and $p < 0.001$ for operating time). There

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were no significant differences in HSS and ROM between the two groups at the last follow-up ($p > 0.05$). There was no significant difference in complication rate between the two groups ($\chi2 = 0.56$, $p = 0.454$). For the TKA-side knee joint, there was no significant difference in the prosthetic survival rate ($\chi2 = 0.05$, $p = 0.824$) and the prosthetic survival curve ($\chi2 = 0.052$, $p = 0.82$) between the two groups. For UKA-side knee joint, there was no significant difference in prosthetic survival rate ($\chi2 = 0.08$, $p = 0.777$) and prosthetic survival curve ($\chi2 = 0.074$, $p = 0.786$) between the two groups.

Conclusions Compared to Staged-TKA/UKA, SB-TKA/UKA has the same early clinical efficacy, shorter operating time and hospital stays, less hospitalization costs, and no increased postoperative complications and prosthesis revision rates. Therefore, SB-TKA/UKA may be recommended for patients who can tolerate simultaneous bilateral surgery as assessed before surgery.

Keywords Simultaneous bilateral, Staged, Total knee arthroplasty, Unicompartmental knee arthroplasty, Knee osteoarthritis

Introduction

Knee osteoarthritis (KOA) is a common disease in the elderly. The main symptom of the patient is joint pain and limited activity, and the main cause of this manifestation is cartilage wear and bone hyperplasia around the joint, which ultimately seriously affects the quality of life of the patient [1]. Previous studies have found that 30% of patients with KOA have only a single compartment, while the incidence of medial compartment is much higher than that of lateral compartment, and patients with end-stage knee osteoarthritis often have bilateral compartment wear. The main surgical methods for KOA patients include high tibial osteotomy (HTO), unicompartmental knee arthroplasty (UKA), and total knee arthroplasty (TKA) [2, 3]. With the maturity of surgical techniques and the continuous improvement of prostheses, UKA has developed rapidly. Compared with TKA, UKA has many advantages, including less surgical trauma, less bleeding, less bone amputation, shorter operation time, shorter hospital stay, faster postoperative recovery, good proprioception, and greater knee motion [4]. Interestingly, most pronation alignments do not occur in isolation. Bilateral medial osteoarthritis with varus alignment is a common condition. With an aging population and increasing indications for surgery, it is expected that the demand for bilateral knee replacement in KOA patients will increase exponentially over the next few decades.

Studies have shown that at least 20% of patients undergoing knee replacement are affected by bilateral KOA and require surgery on the contralateral knee within a few years of the initial surgery [5]. In addition, many patients who require knee replacement have bilateral pain and require surgery on both knees. Bilateral KOA patients who require surgery may opt for phased bilateral surgery, which means a period of time between operations. Alternatively, bilateral surgery may be performed at the same time, that is, simultaneous bilateral knee replacement. The safety of concurrent bilateral joint replacement remains a controversial issue. In previous literature, there were many reports comparing the safety of simultaneous bilateral TKA (SBTKA) with that of staged bilateral TKA [6, 7]. At the same time, there are many reports comparing the safety of bilateral UKA (SBUKA) with that of staged bilateral UKA [8, 9]. For patients who need bilateral joint replacement, some scholars believe that simultaneous replacement can shorten the time of anesthesia, operation and hospitalization, as well as speed of recovery and cost less [6]. However, it is also believed that the risk of deep vein thrombosis, infection and death after simultaneous replacement is significantly higher than that of staged replacement [10]. Although stage replacement has advantages in reducing complications and improving safety, the recovery period is prolonged, resulting in increased hospital stay and cost.

With the maturity of individualized treatment system, joint preservation therapy and joint replacement therapy should be taken into account, and the ladder treatment program that is truly suitable for patients should be selected. For patients with osteoarthritis with different degrees of degeneration of both knees, it is an effective measure to choose TKA and UKA for non-homogenous surgery according to the degree of lesion. To date, there have been few reports comparing SB-TKA/UKA and Staged-TKA/UKA. In this study, patients with different degrees of KOA in both knees were enrolled for TKA in one knee and UKA in the other knee. By comparing the clinical data of SB-TKA/UKA and Staged-TKA/UKA patients to investigate the clinical course and outcome of the operation, the results may provide lessons and guidance for surgeons to choose the surgical method.

Materials and methods

Inclusion and exclusion criteria

Inclusion criteria: ① The same patient was diagnosed with different degrees of degenerative osteoarthritis on both sides of the knee, one side had multiple compartments degeneration and reached TKA indication, and the other side had simple medial compartment degeneration and reached UKA indication; ② From January 2015 to December 2022, he received SBHTO or SBUKA

treatment in the Affiliated Hospital of Qingdao University. Exclusion criteria: ① Serious destruction of medial compartment bone caused by rheumatoid arthritis; ② Infectious arthritis; ③ With severe osteoporosis; ④ History of severe myocardial infarction, cerebral infarction and other serious diseases; ⑤ Performing other operations in conjunction with SB-TKA/UKA or Staged-TKA/UKA; ⑥ Patients with missing follow-up or missing clinical data. We compared clinical data from 71 SB-TKA/UKA and 52 Staged-TKA/UKA patients according to inclusion and exclusion criteria. The study was approved by the Ethics committee of the Affiliated Hospital of Qingdao University(Approval No.: QYFYWZLL28296), and all patients signed informed consent forms.

Surgical procedures

For TKA, the TKA group received prosthetic implants following the traditional protocols for full knee replacement surgery. After the patella was cut, the knee was fexed 70°–90°, and the patella was laterally subluxated but not everted. The femur and tibia were cut with minimally invasive instruments that cut from medial to lateral. The distal femur was cut with 5° of valgus from its anatomical axis. The femoral component was set for 3° of external rotation using the posterior femoral condyle as a reference. The proximal tibia was cut 2 mm below the deepest part of the medial tibial plateau, perpendicular to the mechanical axis. The tibial saw guide was set parallel to the long axis of the tibia to create a tibial slope of 7°. The range of motion and stability of the knee joint were checked after the mold was installed, and a suitable tibial pad was selected. After the test was satisfied, pulse irrigation was used, prosthesis was installed and fixed with bone cement, and patelloplasty was performed. After the bone cement hardened, the drainage tube was placed, and the incision was sutured layer by layer and then pressurized.

For UKA, a midline incision was made, followed by a small medial parapatellar incision. The patella was not subluxed to avoid damage to the synovial reflections of the suprapatellar pouch. The margins of the medial tibial condyle were exposed and cleared ensuring that too much soft tissue is released. The medial meniscus was removed. Osteophytes were removed from the tibia, femur, and intercondylar notch. A routine inspection of the patellofemoral and lateral compartments was conducted to ensure that each patient had isolated medial knee OA. The anterior cruciate ligament (ACL) was also intact in all patients. First, the tibial cut was made sagittally as close to the ACL insertion as possible. However, precautions were taken not to cut the ACL fibers. The saw was placed parallel to the anatomical axis of the tibia and not tilted medially, laterally, anteriorly, or posteriorly. Then, the femoral cuts were made using the intramedullary guide. The femoral end was osteotomy and file grinding by intramedullary positioning method, and the balance of flexion and extension space was achieved. All test models were placed, and the knee joint was fully moved. After it was confirmed that the knee joint was stable and without impact, prostheses were formally installed and fixed with bone cement.

Perioperative management

Both groups were treated with cotton pad and elastic bandage after operation, and drainage was removed within 24 h to relieve pressure. Rivaroxaban 5 mg, qd, was taken in the postoperative 24 h to prevent DVT. Antibiotics were routinely given to prevent infection after the two stages, and antibiotics were stopped 24 h after the operation. The two groups of patients began rehabilitation training under the same guidance of rehabilitation doctors on the first day after surgery. The quadriceps isometric contraction exercise was performed on the first day after surgery, active knee flexion and extension exercise was performed on the second day, and walking with a walker began on the third day.

Outcomes

Review hospital records to obtain information on patient length of stay, operation time and cost. Clinical outcomes were evaluated by 2 senior surgeons (TRW and XZ), and clinical outcomes were evaluated at the last postoperative follow-up using the Hospital for Special Surgery (HSS) score and range of motion(ROM). The postoperative complications and prosthesis revision of all patients were obtained by outpatient review and telephone follow-up at the last follow-up. A revision was defined as the removal, exchange, or addition of an implant component, including bearing exchange for bearing dislocation, or conversion to TKA.

Statistical analysis

SPSS25.0 statistical software was used for analysis. The measurement data corresponded to normal distribution and were expressed as mean±standard deviation. The normality of continuous variables was determined by the Kolmogorov-Smirnov test or the Shapiro-Wilk test in SPSS. Paired T-test was used for comparison between groups. The qualitative data of the two groups were compared by chi-square test or Fisher's Exact Test. The revision was evaluated using Kaplan–Meier survival analysis. Significance was set at $P<0.05$.

Results

General results

All patients were followed up for 9–12 months, and complete imaging data and medical records could be collected, meeting the requirements of the study. A total of

123 patients were included and divided into two groups (SB-TKA/UKA group (n=71) and Staged-TKA/UKA group (n=52) according to surgical methods (Figs. 1 and 2). There were 17 men and 51 women in the SB-TKA/UKA group; The mean age was (63.58±6.57) years, the mean BMI was (27.81±3.81) Kg/m^2, the mean follow-up time was (69.08±14.35) months, the mean operation time was (114.1±27) minutes, and the mean hospital stay was (8.35±2.67) days. The average hospitalization cost was (11920.05±1801.01) $. The Staged-TKA/UKA group consisted of 12 men and 40 women; The mean age was (62.35±7.22) years, the mean BMI was (26.69±3.97) Kg/m^2, the mean follow-up time was (73.25±18.39) months, the mean operation time was (161.25±21.99) minutes, and the mean hospital stay was (17.29±3.92) days. The average hospitalization cost was (19084.33±3137.83) $. There were no differences in age, BMI, gender and follow-up time between the two groups (p>0.05). However, Staged-TKA/UKA group had a shorter hospital stays, less hospitalization costs and shorter operating time (p<0.001 for hospital stay, p<0.001 for hospitalization costs and p<0.001 for operating time). The two sets of basic data are shown in Table 1.

Functional evaluation

In the knee joint of the TKA side, the HSS of the SB-TKA/UKA group and the Staged-TKA/UKA group were (89.42±4.58) and (89.69±3.83) at the last follow-up. In the knee joint of the UKA side, the HSS of the SB-TKA/UKA group and the Staged-TKA/UKA group were (89.17±3.53) and (89.54±4) at the last follow-up. There was no significant difference in HSS scores between SB-TKA/UKA group and Staged-TKA/UKA group at last follow-up (p>0.05). In the knee joint of the TKA side, the ROM in the SB-TKA/UKA group was (123.52±3.04) ° at the last follow-up, and that in the Staged-TKA/UKA group was (124.06±3.04) °. The ROM in the SB-TKA/UKA group was (124.51±2.82) ° at last follow-up, and

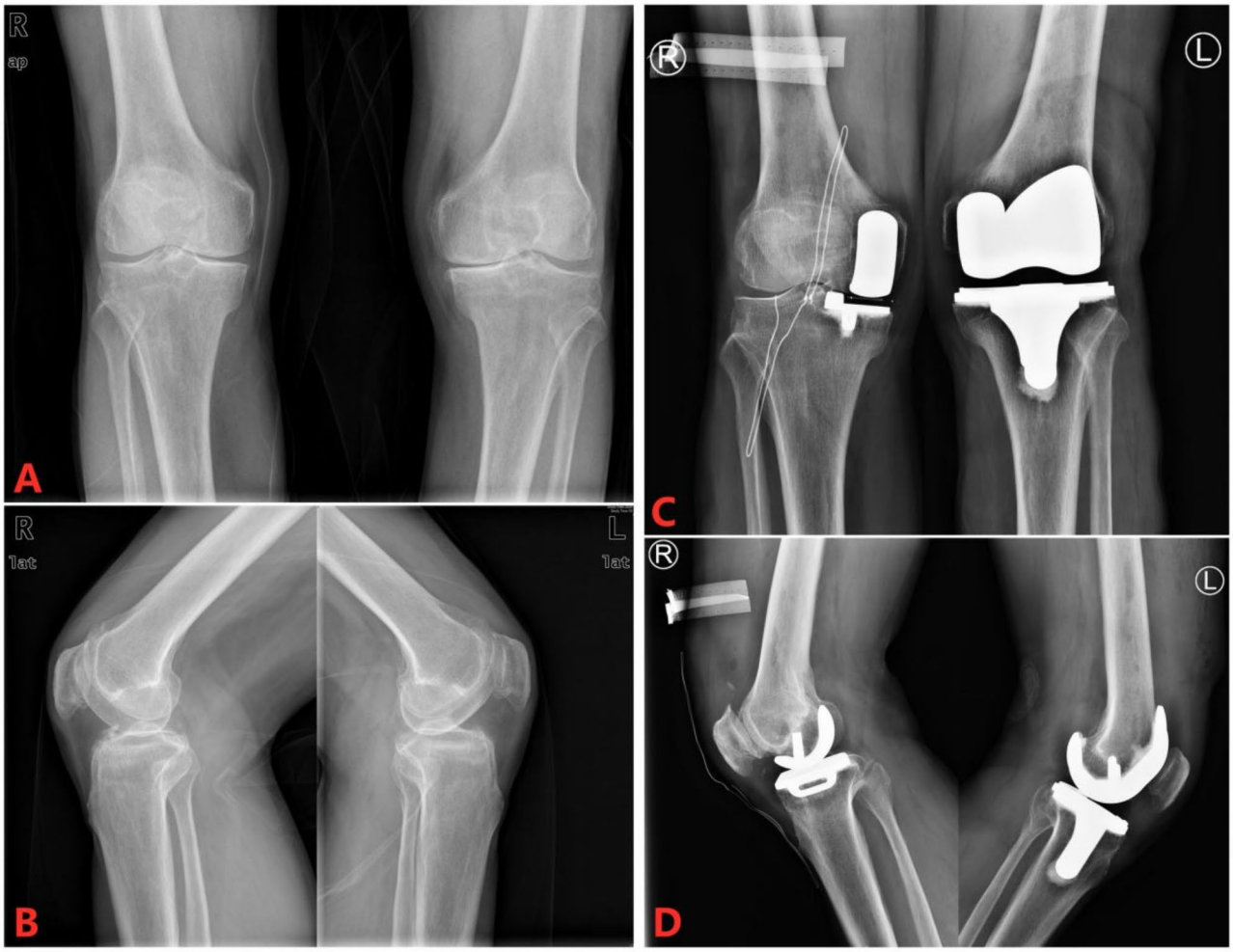

Fig. 1 Typical case of SB-TKA/UKA. Pre-operative radiographs showed varying degrees of osteoarthritis in both knees. (**A**) Anteroposterior View; (**B**) Lateral View. Post-operative radiographs following SB-TKA/UKA. (**C**) Anteroposterior View; (**D**) Lateral View

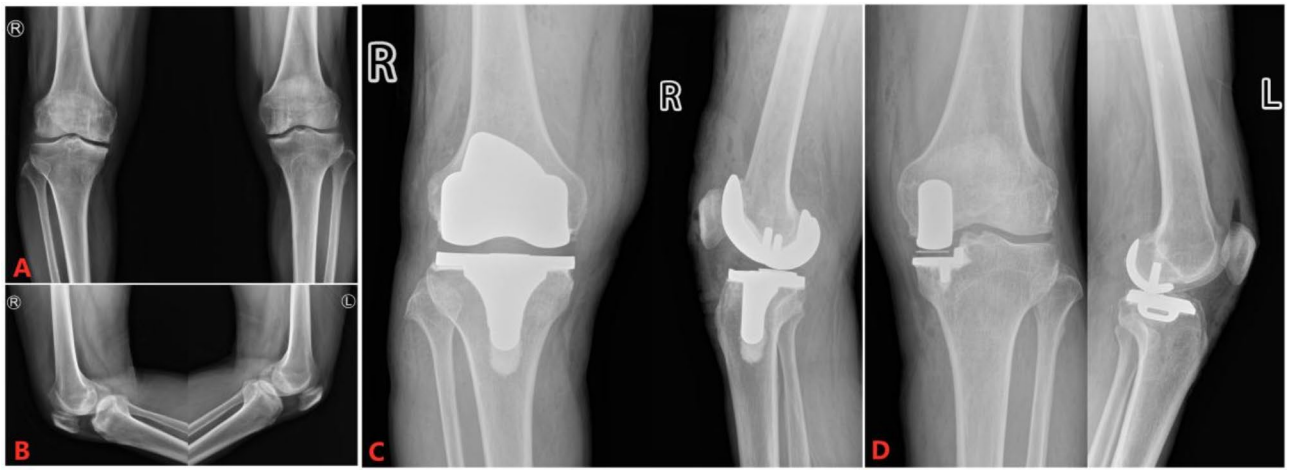

Fig. 2 Typical case of Staged-TKA/UKA. Pre-operative radiographs showed varying degrees of osteoarthritis in both knees. (**A**) Anteroposterior View; (**B**) Lateral View. (**C**) Post-operative radiographs following TKA; (**D**) Post-operative radiographs following UKA

Table 1 Comparison of baseline data in two groups

Variables	SB-TKA/UKA (*N* = 71)	Staged-TKA/UKA (*N* = 52)	T/χ2	*p* value
Sex(M/F)	17/54	12/40	0.013	0.911
Age (years, mean ± SD)	63.58 ± 6.57	62.35 ± 7.22	0.984	0.327
BMI (kg/m^2, mean ± SD)	27.81 ± 3.81	26.69 ± 3.97	1.578	0.117
Mean follow-up(months, mean ± SD)	69.08 ± 14.35	73.25 ± 18.39	-1.358	0.178
Hospital stay (days, mean ± SD)	8.35 ± 2.67	17.29 ± 3.92	-14.212	<0.001
Hospitalization costs ($, mean ± SD)	11920.05 ± 1801.01	19084.33 ± 3137.83	-15.989	<0.001
Time of operation (mins, mean ± SD)	114.1 ± 27	161.25 ± 21.99	-10.659	<0.001

N = number of patients; M = male; F = female; SD = standard deviation; BMI = body mass index

Table 2 Comparison of the HSS among the two groups before the operation and at the last follow-up (x ± s)

Variables	SB-TKA/UKA (*N* = 71)	Staged-TKA/UKA (*N* = 52)	T value	*P* value
TKA side				
Preop	41.72 ± 5.85	41.46 ± 6.81	0.224	0.823
Last follow-up	89.42 ± 4.58	89.69 ± 3.83	-0.345	0.73
UKA side				
Preop	42.2 ± 6.2	44.21 ± 7.39	-1.597	0.114
Last follow-up	89.17 ± 3.53	89.54 ± 4	-0.52	0.589

N = number of patients; HSS = Hospital for Special Surgery; TKA = total knee arthroplasty; UKA = unicompartmental knee arthroplasty

that in the Staged-TKA/UKA group was (124.65 ± 2.92) °. There was no significant difference in ROM between Staged-TKA/UKA group and SB-TKA/UKA group at last follow-up ($p > 0.05$). Detailed data are shown in Tables 2 and 3.

Complications

Postoperative complications occurred in 10 cases in the SB-TKA/UKA group, including 1 case of prosthetic joint infection, 3 cases of gasket dislocation, 1 case of blood transfusion within 72 h after surgery, 2 cases of aseptic loosening, 2 cases of deep vein thrombosis, and 1 case of surgical incision infection. The complication rate was 14.08%. There were 5 postoperative complications in Staged-TKA/UKA group, including 1 case of joint infection,2 cases of gasket dislocation, 1 case of aseptic loosening, and 1 case of surgical incision infection. The complication rate was 9.62%. The incidence of post-operative complications in SB-TKA/UKA group was higher than that in Staged-TKA/UKA group (14.08% vs. 9.62%), but the difference was not statistically significant ($\chi 2 = 0.56$, $p = 0.454$). Detailed data are shown in Table 4.

Implant revision status and implant survival rate

In the UKA side knee joint, 5 cases of revision surgery occurred in the SB-TKA/UKA group, and the survival rate of prosthesis was 92.96%. Staged-TKA/UKA group underwent revision surgery in 3 cases, and the survival

Table 3 Comparison of the ROM among the two groups before the operation and at the last follow-up (°, x ± s)

Variables	SB-TKA/UKA (*N* = 71)	Staged-TKA/UKA (*N* = 52)	T value	*P* value
TKA side				
Preop	119.03 ± 3.08	119.13 ± 3.13	-0.188	0.851
Last follow-up	123.52 ± 3.04	124.06 ± 3.04	-0.968	0.335
UKA side				
Preop	119.17 ± 2.97	118.33 ± 3.11	1.524	0.13
Last follow-up	124.51 ± 2.82	124.65 ± 2.92	-0.281	0.779

N = number of patients; ROM = range of motion; TKA = total knee arthroplasty; UKA = unicompartmental knee arthroplasty

Table 4 Complication rates in two groups

Variables	SB-TKA/UKA (*N* = 71)	Staged-TKA/UKA (*N* = 52)	χ2	*P* value
Prosthetic joint infection	1	1		
Gasket dislocation	3	2		
Aseptic loosening	2	1		
Transfusions within 72 h of surgery	1	0		
Deep vein thrombosis	2	0		
SSI	1	1		
Any complication	10	5	0.56	0.454

N = number of patients; SSI = surgical site infection; TKA = total knee arthroplasty; UKA = unicompartmental knee arthroplasty

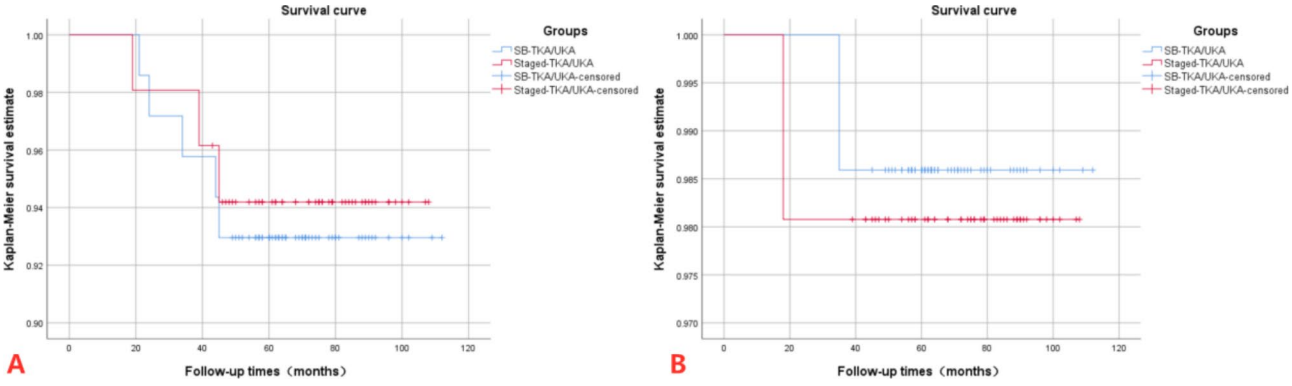

Fig. 3 The revision was evaluated using Kaplan-Meier survival analysis. (**A**) Kaplan-Meier survival curve after UKA. (**B**) Kaplan-Meier survival curve after TKA. No difference in the prosthesis survival curve was found among the two groups (χ2 = 0.074, *P* = 0.786; χ2 = 0.052, *P* = 0.82)

rate was 94.23%. The survival rate of prostheses in SB-TKA/UKA group was lower than that in Staged-TKA/UKA group (92.96% vs. 94.23%), but the difference was not statistically significant (χ2 = 0.08, *p* = 0.777). As can be observed from Kaplan-Meier prosthesis survival curves of the two groups (Fig. 3A), the prosthesis retention rate of the two groups gradually decreased with the increase of follow-up time. At the last follow-up, the retention rate of prostheses was similar in all groups (χ2 = 0.074, *p* = 0.786). In the TKA side knee joint, revision surgery occurred in 1 case in the SB-TKA/UKA group, and the prosthesis survival rate was 98.59%. Staged-TKA/UKA group underwent revision surgery in 1 case, and the survival rate was 98.08%. The survival rate of prostheses in SB-TKA/UKA group was higher than that in Staged-TKA/UKA group (98.59% vs. 98.08%), but the difference was not statistically significant (*χ2* = 0.05, *p* = 0.824). As can be observed from Kaplan-Meier prosthesis survival curves of the two groups (Fig. 3B), the prosthesis retention rate of the two groups gradually decreased with the increase of follow-up time. At the last follow-up, the retention rate of prostheses was similar in all groups (*χ2* = 0.052, *p* = 0.82). Detailed data are shown in Table 5.

Discussion

According to statistics, 1/3 of the patients with knee osteoarthritis are affected by both knees, and about 10% of the patients will undergo contralateral knee replacement within 1 year after one knee replacement [11]. Among patients who have had one knee replaced, about 20% of them will need joint replacement due to aggravation of symptoms of contralateral knee osteoarthritis [12]. With the maturity of the individualized treatment system, KOA patients of different degrees will adopt

Table 5 Survival rate of the implant in two groups

Group	*N* knees	Number of revision	Survival rate
TKA side			
SB-TKA/UKA	71	1	98.59%
Staged-TKA/UKA	52	1	98.08%
At the last follow-up	$\chi2=0.05$, $P=0.824$		
Survival curve comparison	$\chi2=0.052$, $P=0.82$		
UKA side			
SB-TKA/UKA	71	5	92.96%
Staged-TKA/UKA	52	3	94.23%
At the last follow-up	$\chi2=0.08$, $P=0.777$		
Survival curve comparison	$\chi2=0.074$, $P=0.786$		

TKA = total knee arthroplasty; UKA = unicompartmental knee arthroplasty

different treatment methods, and the ladder treatment plan that is truly suitable for patients will be selected according to the ladder treatment concept [4]. The surgical methods mainly include TKA, UKA and HTO. TKA is a kind of surgery with high safety and mature technology. However, for patients with single-compartment knee osteoarthritis, the normal compartment is also replaced when the surgery is completed, which expands the original localized lesions and changes a physiological knee joint into a mechanical knee joint, which is prone to knee instability after surgery. Complications such as prosthesis loosening and infection may also occur over time [1, 2]. UKA has gradually matured after technical improvement and replacement of prosthesis design after clinical application, and has good long-term survival and patient prognosis [13, 14]. Compared with TKA, UKA also showed great advantages, mainly including less bleeding during and after surgery, more bone retention, no damage to cruciate ligament, postoperative knee joint mobility close to normal, rapid recovery of postoperative patients, and short duration of pain [2]. Previous studies have confirmed the safety and efficacy of SB-TKA/UKA for KOA patients with varying degrees of degeneration of both knees [15]. At present, it has not been reported whether simultaneous or staged non-homogeneous surgical protocols affect clinical efficacy. Therefore, in this study, patients with different degrees of KOA in both knees were collected, and TKA was performed on one knee and UKA was performed on the other knee. By comparing the clinical data and clinical outcomes of SB-TKA/UKA and Staged-TKA/UKA patients, the most important finding of this study is that compared to Staged-TKA/UKA, SB-TKA/UKA has the same early clinical efficacy, shorter operating time and hospital stays, less hospitalization costs, and no increased postoperative complications and prosthesis revision rates. Therefore, SB-TKA/UKA may be recommended for patients who can tolerate simultaneous bilateral surgery as assessed before surgery.

A number of studies have compared whether there is a difference in the recovery of bilateral knee joints after TKA combined with UKA in the treatment of bilateral knee arthritis. Although these studies have confirmed the safety and efficacy of SB-TKA/UKA, the comparison of clinical efficacy between the two remains controversial. In 1991, Laurencin et al. [16] reported a study on patients with different degrees of degeneration of both knee joints. In this study, UKA or TKA treatment was selected according to the degree of knee joint degeneration. Follow-up results showed that 50% of patients believed that the UKA side was better than TKA side,21% were more satisfied with TKA side, and 29% believed that there was no significant difference between the two sides. In 2009, Dalury et al. [17] also conducted a similar comparative study, and the results showed that except for hospitalization and recovery time and patients' own psychological acceptance, there was almost no difference in the efficacy of UKA+TKA and TKA in the treatment of patients with different degrees of degeneration of both knees, and patients were satisfied with the therapeutic effect in the short term. No negative effects of non-homogenous surgical protocols (UKA+TKA) were found during follow-up. Costa et al. [18] also conducted a prospective study, and there was no significant difference in the relevant scores, which showed good performance in the near and middle postoperative period. Meanwhile, no obvious prosthesis abnormalities were found in the follow-up imaging examination, especially no obvious arthritic progression in the lateral ventricle of the UKA side, and no adverse confrontation between the UKA side and the TKA side. Later, a retrospective study with a larger sample size by Longo et al. [19] also reached a similar conclusion. This work builds on previous studies to discuss differences in clinical efficacy, complications, and prosthesis survival between SB-TKA/UKA and Staged-TKA/UKA.

The results of this study suggest that for KOA patients with different degrees of knee degeneration, selecting SB-TKA/UKA for non-homogeneous surgery according to the degree of lesion, the early and middle curative effect is similar to that of staging surgery. In previous literature,

there were many reports comparing the clinical efficacy of bilateral TKA at the same period and bilateral TKA at different stages [6, 7]. At the same time, there are many reports comparing the safety of bilateral UKA (SBUKA) with that of staged bilateral UKA [8, 9]. In terms of surgical safety, scholars have conducted a large number of studies and believe that the surgical risks of simultaneous and staged operations are the same, and the surgical costs and hospital stay can be reduced by simultaneous operations [20–22]. In this study, the operation time and hospital stay in the concurrent group were significantly shorter than those in the stage group, and the operation cost was significantly reduced, which was consistent with the above conclusions. We believe that in the same group, anesthesia preparation, position placement, disinfection towel and other surgical preparations were performed only once, so the operation time was shorter and the utilization rate of the operating room was improved. Because only one anesthesia was performed and the operation time was short, the risk of related anesthesia accidents was reduced and the surgical safety was improved. In addition, shorter hospital stay can reduce the psychological stress of patients and reduce the risk of hospital-resistant bacterial infections.

Some scholars believe that SBTKA has advantages in knee functional recovery. Symmetrical movement is considered to be the best biomechanical outcome for rehabilitation after TKA. When elective bilateral TKA is used, untreated contralateral knee pain and gait abnormalities sometimes hinder the recovery process [23, 24]. However, SBTKA results have been reported to be similar to elective bilateral TKA in terms of KSS and WOMAC [25]. Nicholas et al. found that SBTKA did not increase the readmission rate [26]. At the same time, compared with staged surgery, SBUKA is more favorable in terms of cumulative hospital stay and total surgical time, with similar clinical outcomes and complications [27]. The study of Berend et al. [20] showed that the knee function score of patients in the same period group was significantly higher than that in the stage group at the last follow-up, suggesting that the operation in the same period had better results and had potential benefits for the functional rehabilitation of patients. We analyzed that the reason for this result may be that both sides of the knee joints of patients in the same period of postoperative rehabilitation can be mutual references, which can promote functional exercise. Meanwhile, through symmetric rehabilitation exercise, the function of both lower limbs can be synchronously recovered, which is conducive to the recovery of postoperative gait, motor mechanics and functional status of patients. However, patients in the stage group still had pain in the knee joint of the unoperated side after the first operation, which affected the functional exercise and recovery of the operative side, and some patients resisted the functional rehabilitation training accompanied by pain after the second operation.

Uncertainty regarding the relative complication rate of SBTKA versus staging bilateral TKA remains unresolved. Most scholars believe that SBTKA has a high risk of serious complications, especially for elderly patients with underlying diseases such as hypertension, heart disease and obesity [28, 29]. Ellen et al. found that patients undergoing surgery at the same time had a higher incidence of mortality, cardiac events and thromboembolic events [30]. The incidence of complications such as pulmonary embolism, stroke and blood transfusion is increased [10]. In addition, patients with SBTKA have increased hospitalization costs and an increased risk of developing important postoperative complications and mortality [31]. However, a meta-analysis by Liu et al. found no significant differences between SBTKA and sequential BTKA in revision, cardiac complications, and neurological complications [32]. Similarly, in this study, the incidence of postoperative complications was higher in the SB-TKA/UKA group than in the Staged-TKA/UKA group (14.08% vs. 9.62%), but the difference was not statistically significant. In the study of Berend et al. [20], the incidence of perioperative complications during simultaneous operations was lower than that of staged operations, but this result may be related to the younger age and fewer underlying diseases of patients in the same period group in the study. The study of Chen et al. [33] showed that the complication rate in the same period group was 8.2%, which was significantly higher than that in the stage group, but the incidence of lower extremity deep vein thrombosis and pulmonary embolism were 1.9% and 3.8%, respectively, which were related to the absence of preventive use of low molecular weight heparin sodium or other anticoagulation measures after surgery. Therefore, we suggest that no matter simultaneous or staged surgery, low molecular weight heparin sodium or rivaroxaban should be used in the early postoperative period, combined with iso-length contraction exercise of both lower limb muscles and walking down to prevent thrombosis.

This study has certain limitations: First, due to the limited number of patients suitable for simultaneous bilateral knee replacement surgery, the number of patients is relatively small, and there are relatively few reports of similar cases for reference. It is necessary to further increase the sample size for research in the future. Second, only HSS and ROM were compared in this study, and other clinical scores should also be considered. Third, non-homogenous surgical plan means asymmetrical rehabilitation exercise, and asynchronous recovery of lower limb function may affect the recovery of postoperative functional state. Fourth, the surgeons who performed the surgery in this study were different, because the amount of surgery

performed by one doctor could hardly meet the sample size requirements of this study. Finally, this study was a single-center retrospective clinical trial, and similar investigations should be conducted at other institutions to confirm the current results. Therefore, longer follow-up and prospective studies are also necessary.

Conclusions

Compared to Staged-TKA/UKA, SB-TKA/UKA has the same early clinical efficacy, shorter operating time and hospital stays, less hospitalization costs, and no increased postoperative complications and prosthesis revision rates. Therefore, SB-TKA/UKA may be recommended for patients who can tolerate simultaneous bilateral surgery as assessed before surgery.

Abbreviations

KOA	Knee osteoarthritis
UKA	Unicompartmental knee arthroplasty
TKA	Total knee arthroplasty
HTO	High tibial osteotomy
SBTKA	Simultaneous bilateral total knee arthroplasty
SBUKA	Simultaneous bilateral unicompartmental knee arthroplasty
BMI	Body mass index
HSS	Hospital for Special Surgery
ROM	Range of motion

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Author contributions

KSX, LZ and TBY designed this study; KSX and XL wrote the manuscript; MYY, XZ and TRW collected and analyzed the data; KSX and XZ revised the manuscript; LZ and YZZ approved the final version of the manuscript. All authors reviewed the 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 study was approved by the medical ethics committee of the Affiliated Hospital of Qingdao University according to the Declaration of Helsinki, and informed consent was obtained from all individual participants included in the study. All methods were carried out in accordance with the Declaration of Helsinki.

Consent for publication

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Competing interests

The authors declare no competing interests.

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