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ORIGINAL ARTICLE

Effects of preoperative valgus deformity in patients undergoing neutrally aligned total knee arthroplasty: A retrospective cohort study with a minimum five-year follow-up

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ABSTRACT

Objectives: This study aimed to investigate the relationship between the severity of preoperative valgus deformity and clinical outcomes of neutrally aligned total knee arthroplasty (TKA).

Patients and methods: A total of 376 knees with valgus deformity who underwent TKA from January 2006 to March 2014 were retrospectively screened, and 287 knees (242 patients; 32 males, 210 females; mean age: 64.5±8.8 years; range, 35 to 83 years) aligned neutrally after the operation were included. Patients were divided into four groups based on the preoperative hip-knee-ankle (HKA): mild (0°< HKA ≤5°, n=94), moderate (5°< HKA ≤10°, n=74), severe (10°< HKA ≤15°, n=75), and very severe (HKA >15°, n=44) groups. Range of motion (ROM), Knee Society Score (KSS), Visual Analog Scale (VAS) dynamic pain scores, and Forgotten Joint Score (FJS) were evaluated. Mechanical failures were recorded to assess prosthesis survival. A survival rate analysis was performed using Kaplan-Meier survival analysis.

Results: The degree of preoperative valgus deformity did not have a significant impact on the postoperative ROM, KSS, VAS dynamic pain scores, or FJS at the last follow-up. There were no significant differences in cumulative survival rates of neutrally aligned TKAs at 10 years between the four groups (p=0.513).

Conclusion: The severity of preoperative valgus deformity did not affect the clinical outcomes of neutrally aligned TKAs in the minimum five-year follow-up. Additionally, it did not impact the survival rates of neutrally aligned TKAs over 10 years.

Keywords: Alignment, follow-up, total knee arthroplasty, valgus deformity.

Among several alignment principles,[1] achieving postoperative neutral alignment remains the optimal guide to successful total knee arthroplasty (TKA),[2] as it presents improved stability, higher clinical assessment scores,[3] and long-term survival.[4] However, even when postoperative alignment is correctly achieved, there is still a possibility of requiring revision surgery, and preoperative valgus deformity may be one contributing factor.[5] The severity of preoperative valgus malalignment brings forward several unique surgical challenges for surgeons performing TKA.[6-8] Specifically, achieving a neutrally aligned TKA in patients with severe preoperative valgus alignment necessitates increased distal femoral osteotomy and more extensive lateral soft tissue release.[9]

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In addition, patients accustomed to valgus alignment for an extended period may not readily adapt to neutral alignment.[10,11] Therefore, the relationship between preoperative valgus severity and clinical outcomes following neutrally aligned TKA remains inconclusive.

To date, there has been no analysis conducted on the survival of TKAs based on the severity of preoperative valgus deformity in a large cohort of patients with a mean follow-up exceeding five years. The present study assessed whether the severity of preoperative valgus deformity affected the longevity of postoperative neutrally aligned TKAs. Patients were categorized into groups based on the mechanical hip-knee-ankle (HKA) angle, and the survival of TKAs and clinical functional scores in each group were analyzed. We hypothesized that in patients with very severe valgus deformity, the survival rate of neutrally aligned TKAs might be reduced.

PATIENTS AND METHODS

This retrospective cohort study was conducted at the Orthopaedic Department of the West China Hospital between January 2006 and March 2014. The inclusion criteria were patients with end-stage osteoarthritis or rheumatoid arthritis presenting with valgus deformity (HKA >0°) and scheduled for primary TKA. The exclusion criteria were as follows: *(i)* patients with preoperative varus or neutral alignment (HKA ≤0°); *(ii)* patients with postoperative valgus or varus alignment (postoperative HKA <–3° or HKA >3°);[12] *(iii)* patients with a history of hip arthroplasty or extra-articular deformity that could affect ipsilateral limb alignment; *(iv)* patients lost to follow-up before a minimum of five years or deceased during follow-up due to other diseases.

During the specified period, we performed 2,305 cemented TKAs in 1,951 patients, 321 of whom (376 knees) were diagnosed with valgus deformity. We excluded patients (n=20) who had a history of hip arthroplasty or extra-articular deformity that could affect their ipsilateral limb alignment and patients with postoperative valgus-aligned or varus-aligned TKAs (n=43). Patients (n=26) who were lost to follow-up before a minimum of five years were also excluded. Finally, 287 neutrally aligned (postoperative HKA between –3° and 3°)[2] valgus-type knees (242 patients; 32 males, 210 females; mean age: 64.5±8.8 years; range, 35 to 83 years) were enrolled into this study. Patients were divided into four groups based on the preoperative HKA: mild valgus (0°< HKA ≤5°, n=94), moderate valgus (5°< HKA ≤10°, n=74), severe valgus (10°< HKA ≤15°, n=75), and very severe valgus (HKA >15°, n=44) groups (Figure 1).[12-15] Demographical

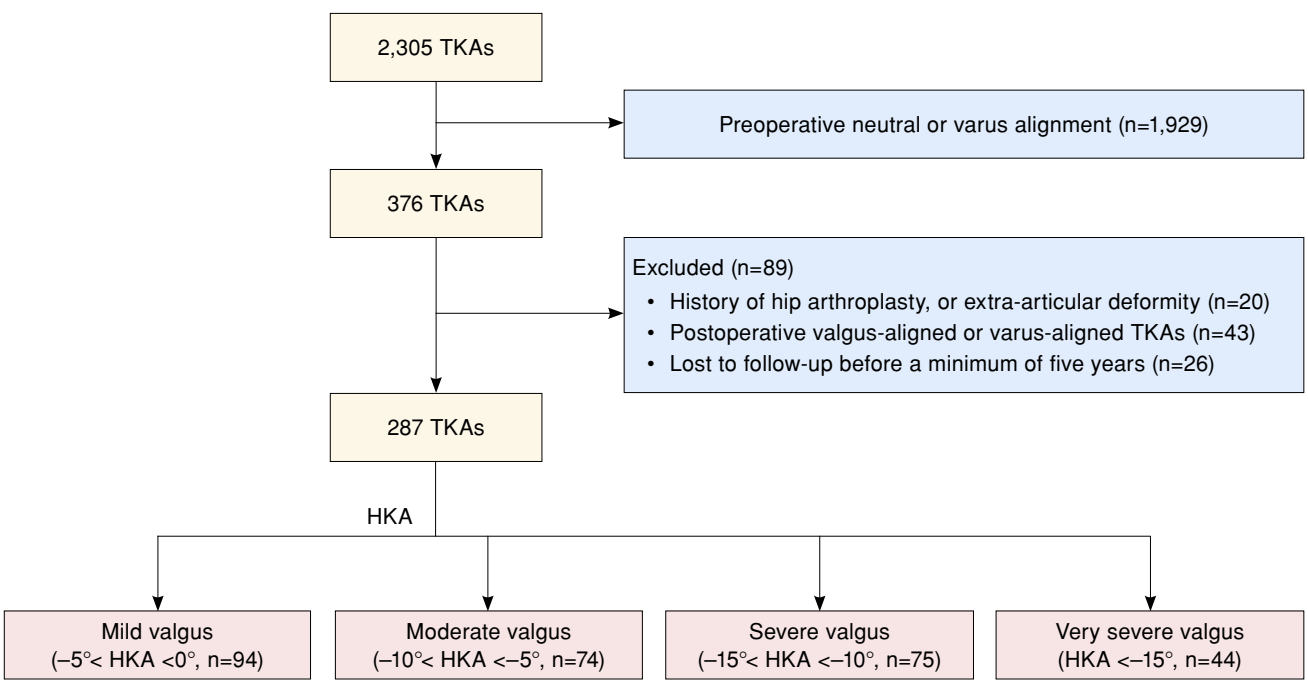

FIGURE 1. Participant flow diagram illustrating the study design.
TKA: Total knee arthroplasty; HKA: Hip-knee-ankle angle.

and radiological parameters were comparable among the four groups according to preoperative valgus deformity degrees (Table I).

Surgical procedure

All the operations were performed by two senior surgeons with the patients under general anesthesia in the same laminar air flow operation room. A standard midline skin incision through the medial parapatellar approach was made. After retracing the patella, the anterior cruciate ligaments and meniscus were completely resected. Intramedullary guides were utilized for the femur and extramedullary guides for the tibia during the surgical procedures. The femoral valgus correction angle was determined according to the preoperative full-length radiographs to achieve neutral alignment and was used for distal femoral resection. The consistency of the actual and planned valgus correction angle was judged by an intraoperative intramedullary guide. The entry point of the femoral intramedullary alignment rod was also determined according to the preoperative measurement. The femoral intramedullary alignment rod was inserted in the center of the femoral intercondylar notch, 10 mm anterior to the femoral insertion of the posterior cruciate ligament. After tibial cutting, the posterior cruciate ligament was resected. Soft tissue release was performed based on the extent of preoperative flexion contracture. Depending on the patient's degree of valgus, polyethylene inserts of different thicknesses were inserted, or additional soft tissue release was conducted. Cemented, posterior-stabilized TKAs were conducted for all subjects, and a Sigma fixed-bearing or rotating-platform, posterior-stabilized total knee prosthesis (P.F.C.; Johnson & Johnson/DePuy, Warsaw, IN, USA) was implanted. All patients underwent patelloplasty without patellar resurfacing.

Radiological assessment

Using a standardized radiographic technique,[16] preoperative and postoperative full-length, long-standing radiographs were taken with patients in a standing position and the patella oriented forward. The mechanical HKA was assessed in all patients one week before and one year after TKA using full-length radiography to measure preoperative and postoperative overall mechanical alignment, respectively. Valgus and varus angles were represented as positive and negative values, respectively. Preoperatively, knees with HKA >0° were categorized as having valgus-type knee deformity. Postoperatively, knee alignment was

TABLE I
Baseline demographic and clinical characteristics

Characteristics	Mild (HKA 0-5°)			Moderate (HKA 5-10°)			Severe (HKA 10-15°)			Very severe (HKA >15°)			*p*
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	
Knee (%)	94	32.8		74	25.8		75	26.1		44	15.3		
Age (year)			64.1±8.8			64.0±8.8			65.8±8.9			64.0±8.8	0.623
Operated side													0.293
Left	45			40			32			26			
Right	49			34			43			18			
Sex													0.068
Male	7			6			17			5			
Female	87			68			58			39			
Height (m)			1.57±0.06			1.56±0.06			1.58±0.07			1.57±0.07	0.244
Weight (kg)			63.6±9.4			61.2±9.3			61.1±9.4			59.8±9.4	0.102
Body mass index (kg/m^2)			25.9±3.6			25.1±3.6			24.4±3.6			24.2±3.6	**0.026***
Patient's blood volume (mL)			2873.0±367.3			2793.5±364.1			2852.6±369.5			2764.2±367.2	0.298
Disease course (year)			10.8±9.7			12.6±9.8			12.6±9.6			17.1±9.9	**0.006***
Follow-up (year)			8.1±1.6			8.1±1.6			7.9±1.6			8.0±1.7	0.872

SD: Standard deviation; HKA: Hip-knee-ankle angle.

considered neutral within the range of –3° to 3° HKA. Two investigators independently determined the angles. To ensure the reliability of the measurements, 50 patients were randomly selected, and HKA angles were measured twice at two-week intervals by the two investigators. The intraclass correlation coefficient of interobserver reliability was >0.90.

Outcome measurements

Patients were followed up by outpatient visits. At follow-up, range of motion (ROM) and Knee Society Score (KSS) were evaluated. Dynamic pain scores were assessed by the Visual Analog Scale (VAS) and Forgotten Joint Score (FJS). Mechanical failures, including polyethylene wear, aseptic prosthesis loosening, and instability requiring revision surgery, were recorded to assess prosthesis survival. Perioperative hemoglobin and hematocrit, the volume of transfusion, and the length of stay were recorded at discharge. The three-month readmission rate and the three-month mortality rate were recorded.

Statistical analysis

The power analysis was calculated using PASS 2021 software (NCSS, LLC, Kaysville, UT, USA). The overall survival rate of knees in neutral alignment preoperatively was previously calculated to be 99.3%.[5] While the survival rate of the severe valgus knee deformity was calculated as 92.4%.[17] Power calculation for an alpha failure of α=0.05 and an aimed power (1–β) of 80% required a sample size of 41 knees per group. Means and standard deviations were calculated for quantitative data, and the frequencies and constituent ratios were determined for qualitative data. One-way analysis of variance and the least significant difference post hoc test was performed to compare continuous variables. Kaplan-Meier survival analysis was performed using revisional TKA for mechanical failure as an endpoint. The Mantel-Cox log-rank test was used to compare the survival rates. A p-value <0.05 indicated statistical significance.

RESULTS

Ninety-four (32.8%) TKAs were in the mild valgus group, 74 (25.8%) TKAs were in the moderate valgus group, 75 (26.1%) were in the severe valgus group, and 44 (15.3%) were in the very severe group (Figure 1). There were no significant differences among the four

TABLE II
Range of motion and patient-reported outcome measures

Characteristics	Mild (HKA 0-5°) Mean±SD	Moderate (HKA 5-10°) Mean±SD	Severe (HKA 10-15°) Mean±SD	Very severe (HKA >15°) Mean±SD	*p*
Range of motion (°)					
Preoperative	96.9±20.8	94.2±20.9	90.5±20.5	91.3±20.4	0.197
Postoperative	102.5±15.5	107.6±15.3	105.6±14.0	102.3±15.4	0.112
Improvement	5.6±28.0	13.5±26.5	15.1±24.7	11.0±25.7	0.089
Knee society score					
Knee score					
Preoperative	53.3±15.4	53.4±14.3	51.6±16.1	45.3±14.7	**0.021***
Postoperative	90.0±12.2	91.0±10.4	92.2±9.7	90.1±11.7	0.603
Improvement	36.7±19.7	37.6±16.1	40.6±19.0	44.8±18.1	0.083
Functional score					
Preoperative	32.8±18.9	31.8±18.7	34.3±20.2	32.7±17.4	0.882
Postoperative	79.9±24.8	79.3±26.9	77.7±27.5	73.9±26.8	0.626
Improvement	47.1±29.7	47.5±30.1	43.4±32.4	41.1±33.3	0.624
VAS dynamic pain score					
Preoperative	4.8±0.9	4.9±0.9	4.7±0.8	4.8±0.9	0.823
Postoperative	0.4±0.5	0.4±0.5	0.4±0.5	0.4±0.5	0.866
Improvement	4.5±1.1	4.5±1.1	4.3±0.9	4.5±1.0	0.702
Forgotten joint score-12	78.4±20.7	76.4±21.1	78.8±18.6	77.3±22.9	0.888

SD: Standard deviation; HKA: Hip-knee-ankle angle; VAS: Visual Analog Scale; * p<0.05.

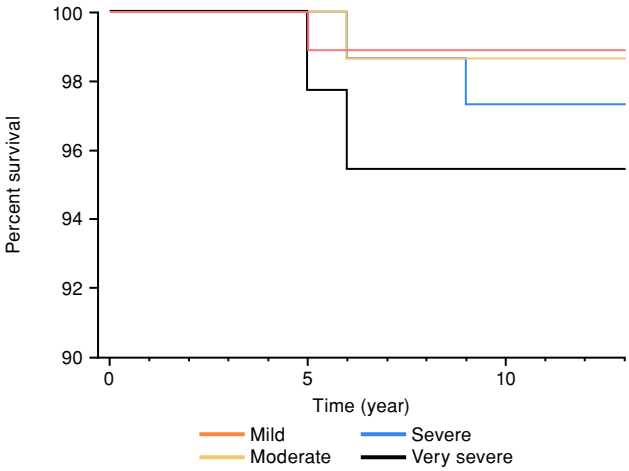

FIGURE 2. Kaplan-Meier survival curve shows the influence of preoperative valgus severity on implant survival rates in patients with neutral-aligned total knee arthroplasties.

groups in terms of age, side, sex, height, weight, blood volume, and follow-up duration. The body mass index differed between mild and severe groups (p=0.012), as well as between mild and very severe groups (p=0.012). The disease course differed between mild and very severe groups (p=0.020; Table I). The mean follow-up time was 8.03±1.69 years.

The mean preoperative HKAs were 2.5°±1.3° in the mild group, 7.6°±1.4° in the moderate group, 12.1°±1.8° in the severe group, and 18.8°±4.1° in the very severe group, which differed between any two group (p<0.001). The postoperative HKAs were −0.1°±1.6° in the mild group, −0.5°±1.6° in the moderate group, −0.2°±1.8°) in the severe group, and −0.5°±1.7° in the very severe group, which were similar among the four groups (p>0.05) and within the range of −3° to 3°, indicating that neutral alignment was achieved in all groups. We compared the knee functions in four groups. Patients among the four groups had similar postoperative ROM, while patients in the severe group had greater improvement compared to the mild group (p=0.031; Table II). Patients did not differ significantly in postoperative KSS, functional scores, VAS dynamic pain scores, or FJS (Table II).

The overall failure rate was 2.09% (6 of 287 prostheses). In the mild group, one patient underwent revision for prosthesis loosening at five years; In the moderate group, one patient underwent revision for instability at six years. Two patients withdrew in the severe group; these patients underwent revision for prosthesis loosening at six and nine years. Two patients underwent revision for prosthesis loosening at five and six years in the very severe group. Kaplan-Meier survival estimated at 10 years was 98.94% (95% CI: 92.69~99.85%) in the mild group, 98.46% (95% CI: 89.58~99.78%) in the moderate group, 94.65% (95% CI: 78.03~98.79%) in the severe group, and 94.94% (95% CI: 81.08~98.72%) in the very

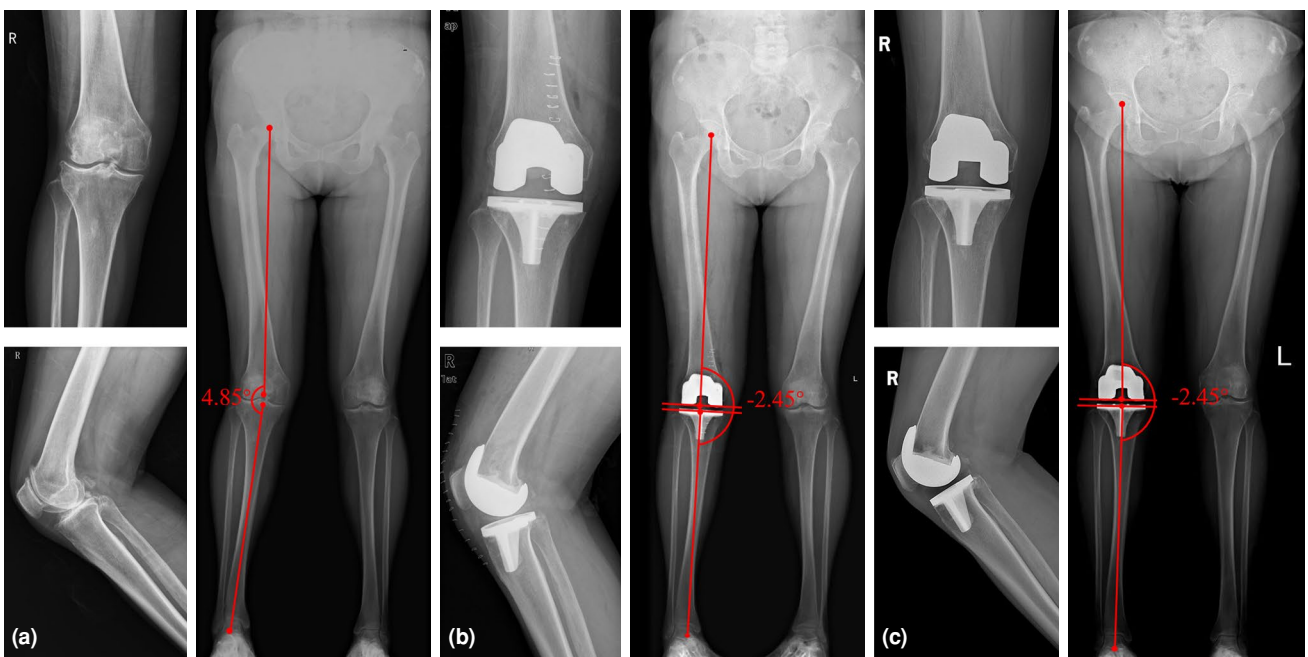

FIGURE 3. Radiographs of a 71-year-old woman with 10-year osteoarthritis who underwent total knee arthroplasty for right knee. **(a)** Preoperative radiographs show uniform joint space narrowing and mild valgus right knee (Hip-knee-ankle angle 4.85°). **(b)** Early postoperative radiographs. **(c)** Postoperative radiographs were taken at the 121 months, showing components to be stable.

severe group. There were no significant differences between the four groups by the Mantel-Cox log-rank test (chi-square=2.296, p=0.513; Figure 2). Figures 3 and 4 demonstrate the radiographically stable knees at the last follow-up in the neutrally aligned position of patients with mild valgus knees and very severe valgus knees. No infection occurred in any of the 287 TKAs.

The four groups showed no differences in hemoglobin and hematocrit preoperatively and postoperatively (Table III). During hospital stay, the total blood loss was also similar between the four groups. One (1.1%) patient in the mild group, three (4.1%) in the moderate group, two (2.7%) in the severe group, and three (6.8%) in the very severe group received transfusion. However, the proportion of transfusion, the blood volume received, or length of stay had no significant differences among the four groups. No three-month readmission or three-month death occurred in any group (Table III).

DISCUSSION

This study suggested that the severity of preoperative valgus knee deformity had no influence on the longevity of postoperative neutrally aligned TKA or any clinical outcomes. Specifically, the severity of preoperative valgus deformity did not affect KSS knee and functional scores, ROM, or VAS dynamic pain scores at the last follow-up. Furthermore, it did not impact the FJS. Additionally, the degree of valgus deformity did not influence the 10-year expected survivorship of neutrally aligned TKAs. Moreover, during the perioperative period, the severity of valgus deformity did not affect total blood loss.

Among the postoperative alignment strategies, such as kinematic alignment, mechanical alignment, and anatomic alignment, neutral alignment continues to be an important alignment in TKAs for increased implant survivorship and functional improvement.[2,18,19] However, whether the severity of preoperative valgus knee deformity influences the longevity of postoperative neutrally aligned TKA is unclear. Moreover, there remain concerns that the surgeons performing TKAs in patients with valgus knee deformity may encounter more difficulty as greater soft tissue release and osteotomy are required.[20,21] Ritter et al.[5] reported that patients who had a valgus deformity of ≥11° had a higher failure rate compared to patients who had neutral knees preoperatively. Mazzotti et al.[22] reported that patients with valgus deformity had a 2.1-fold higher risk for revision compared to patients who had varus deformity. Parratte et al.[23] reported that in a cohort of 280 patients (398 knees), the preoperative valgus deformity did

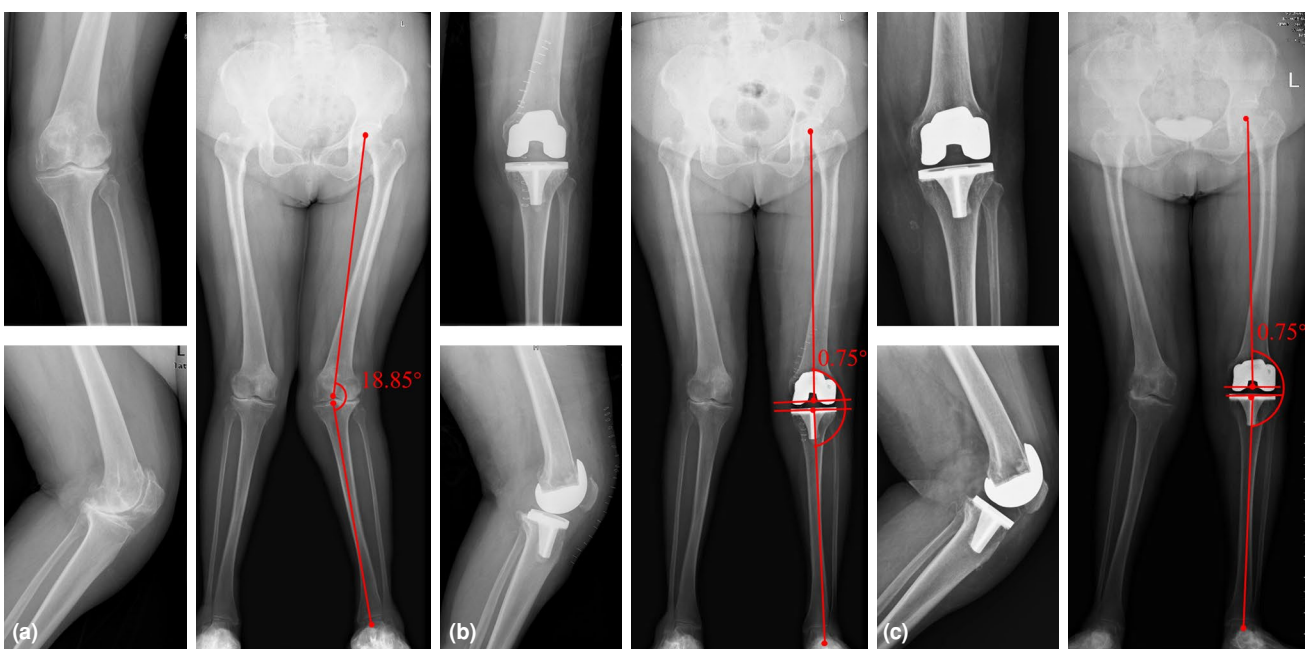

FIGURE 4. Radiographs of a 69-year-old woman with 15-year osteoarthritis who underwent total knee arthroplasty for right knee. **(a)** Preoperative radiographs show uniform joint space narrowing and very severe valgus right knee (Hip-knee-ankle angle 18.85°). **(b)** Early postoperative radiographs. **(c)** Postoperative radiographs were taken at the 72 months, showing components to be stable.

not significantly impact the 15-year Kaplan-Meier survival rate. Ren et al.[24] reported good clinical results in a long-term follow-up in 65 patients with valgus deformity >20°.

Recent studies also discussed whether the severity of valgus knee deformity affected postoperative outcomes after TKA. Rueckl et al.[15] reported that in 133 patients with valgus knees, no difference in clinical outcomes among patients with different degrees of valgus deformities (<5°, 5~9.9°, 10~14.9°, and ≥15°). Putman et al.[25] compared 53 patients in >20° valgus with a series of 53 cases of 10° to 20° valgus and found that the incidence of complications was low, and the survival rate was comparable to that of the control group with less pronounced deformity. In a matched cohort study including 162 patients with valgus knees conducted by Kahlenberg et al.,[14] no significant differences were discovered in clinical outcomes among patients with different degrees of preoperative valgus deformity (7~9.9°, 10~14.9°, ≥15°) within the first year after TKA. Consistent with the other studies, we observed that the severity of preoperative valgus deformity does not predict lower 10-year survival of TKAs in patients with valgus-type deformity corrected to neutral alignment, underscoring the efficacy of achieving postoperative neutral alignment in patients with preoperative valgus deformity.

Although several studies have raised doubts about the necessity of achieving neutral alignment for optimal outcomes after TKA,[23,26] neutral alignment continues to be considered the most effective in TKAs in valgus knees.[27] Sterneder et al.[20] suggested that preserving valgus alignment in patients with valgus osteoarthritis does not offer any functional advantage. Instead, due to the presence of medial collateral ligament injury in a large proportion of these patients, residual valgus deformity may increase the risk of secondary instability. Lee et al.[28] reported that in a cohort of 93 patients who had valgus knee deformity, patients with a postoperative valgus degree >6° could undergo patellar maltracking. Zhou et al.[10] also stated that when the residual valgus angle was >6°, the postoperative scores were significantly reduced, and the risk of poor patellar tracking could increase as well. Therefore, according to these studies, we consider that neutral alignment should remain a goal of TKA in patients with valgus knees.

Our findings should be interpreted with caution considering several limitations. First, the study was retrospective in design. Second, the absence of a significant difference in prosthesis survival

TABLE III
Perioperative outcomes

Characteristics	Mild (HKA 0-5°)			Moderate (HKA 5-10°)			Severe (HKA 10-15°)			Very severe (HKA >15°)			*p*
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	
Hemoglobin (g/dL)													
Preoperative			127.5±16.9			126.6±13.3			129.7±13.8			126.7±12.4	0.556
Postoperative			110.7±17.7			111.2±15.0			113.3±12.0			108.1±13.8	0.336
Drop			16.8±12.9			15.4±11.8			16.4±11.7			18.6±13.8	0.592
Hematocrit (mL/mL)													
Preoperative			0.39±0.05			0.39±0.03			0.40±0.04			0.39±0.04	0.708
Postoperative			0.33±0.05			0.34±0.04			0.34±0.03			0.33±0.04	0.451
Drop			0.06±0.03			0.06±0.03			0.06±0.03			0.06±0.04	0.704
Total blood loss (mL)			496.7±313.3			488.7±379.2			479.4±290.5			594.9±682.7	0.449
Transfusion													
No. (%)	1/93	1.1		3/71	4.1		2/73	2.7		3/41	6.8		0.314
Volume (mL)			6.4±57.0			16.2±62.0			14.7±69.2			25.0±74.2	0.171
Length of stay (day)			6.3±3.4			6.0±2.9			5.5±2.5			6.2±3.1	0.411
Three months-readmission (%)	0/94	0		0/94	0		0/94	0		0/94	0		1.000
Three months-death (%)	0/94	0		0/74	0		0/75	0		0/44	0		1.000

HKA: Hip-knee-ankle angle.

warrants further confirmation through larger sample sizes and extended follow-up periods. Third, the influence of preoperative valgus deformity may vary in TKAs with residual valgus alignment, a factor we did not analyze as we focused solely on knees corrected to postoperative neutral alignment. Fourth, the preoperative sex differences between groups may have introduced bias due to the slightly lower proportion of male patients in the severe valgus group. Moreover, several factors may influence the severity of valgus deformity, such as the body mass index. Whether the factors influenced the longevity in patients with valgus knees could be addressed in future studies.

In conclusion, in patients with valgus-type osteoarthritis, the severity of valgus deformity did not impact the survival rates of neutral-aligned TKA over a 10-year period. Additionally, these patients can anticipate good clinical outcomes at the 10-year follow-up.

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Ethics Committee Approval: The study protocol was approved by the West China Hospital Ethics Committee (date: 26.09.2022, no: 2022-1564). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed: X.M.C., Q.P.Y., W.N.Z., Z.K.Z.; The first draft of the manuscript was written: X.Y.L., Q.P.Y. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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