

# Residual Mild Varus Alignment and Neutral Mechanical Alignment Have Similar Outcome after Total Knee Arthroplasty for Varus Osteoarthritis in Five-Year Follow-Up

Zhiqi Zhang, MD, PhD<sup>1</sup> Can Liu, MD<sup>1</sup> Zhiwen Li, MD<sup>1</sup> Peihui Wu, MD, PhD<sup>1</sup> Shu Hu, MD<sup>1</sup>  
Weiming Liao, MD, PhD<sup>1</sup>

<sup>1</sup>Department of Joint Surgery, The First Affiliated Hospital, Sun Yat-sen University, Guangzhou, Guangdong, China

Address for correspondence Weiming Liao, MD, PhD, Department of Orthopaedic Surgery, The First Affiliated Hospital, Sun Yat-sen University, Guangzhou 510080, China  
(e-mail: liaowmsysu@163.com).

J Knee Surg 2020;33:200–205.

## Abstract

The effect of residual varus on survival rate and function in patients with varus knee osteoarthritis (OA) was considered an important issue for successful primary total knee arthroplasty (TKA). In this study, we compared the midterm clinical and functional outcomes in patients with different residual varus. A retrospective review of 175 patients (219 knees) with varus OA was  $> 3^\circ$  for the hip-knee-ankle (HKA) who underwent primary TKA after exclusions and loss to follow-up from 237 patients (281 knees). The mean follow-up period was  $5.2 (\pm 1.1)$  years. Patients were divided into four groups according to the first postoperative HKA angle from weight-bearing full-leg radiographs: “valgus” group (HKA angle  $> 0^\circ$ ,  $n = 44$ ), “neutral” group ( $-3^\circ \leq$  HKA angle  $< 0^\circ$ ,  $n = 86$ ), “mild varus” group ( $-6^\circ \leq$  HKA angle  $< -3^\circ$ ,  $n = 62$ ), and “severe varus” group (HKA angle  $< -6^\circ$ ,  $n = 27$ ). Survival analysis, Knee Society Score (KSS, including knee score and functional score), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) were compared among the four groups. No knee required revision surgery during follow-up. For the KSS knee score and functional score at the last follow-up, the neutral and mild varus groups were better compared with the valgus and severe varus groups ( $p < 0.05$ ), and there were no significant differences between the neutral and mild varus groups ( $p > 0.05$ ). WOMAC scores of the neutral and mild varus groups were also better compared with the valgus and severe varus groups ( $p < 0.05$ ), and there were no significant differences between the neutral and mild varus groups at the last follow-up. The postoperative HKA angle was significantly changed in valgus group between first and at the last follow-up when compared with the other three groups ( $p < 0.05$ ). Leaving an HKA angle at  $< 6^\circ$  varus had the same excellent functional outcome as neutral mechanical alignment after TKA for varus-type OA in the 5-year follow-up, using mechanically aligned technique. Caution is advised when leaving valgus or leaving severe varus after TKA.

## Keywords

- ▶ TKA
- ▶ varus alignment
- ▶ osteoarthritis

The neutral mechanical alignment (MA) is regarded as the gold standard in total knee arthroplasty (TKA), as it guarantees postoperative clinical efficacy and long-term prosthesis

survival. However, 7.5 to 26.8% of patients with a neutral MA after TKA still were dissatisfaction.<sup>1–3</sup> In recent years, because of advances in prosthetics, studies have found that

received

April 20, 2018

accepted after revision

November 22, 2018

published online

January 16, 2019

Copyright © 2020 by Thieme Medical Publishers, Inc., 333 Seventh Avenue, New York, NY 10001, USA.  
Tel: +1(212) 760-0888.

DOI <https://doi.org/10.1055/s-0038-1677497>.  
ISSN 1538-8506.

slight lower extremity alignment deviations do not reduce the postoperative clinical efficacy of TKA and prosthesis survival.<sup>4-8</sup> It was reported that a neutral alignment did not increase prosthesis survival rate in the 15-year survival rate of 398 knees, and the researchers believed that a neutral alignment does not significantly affect the prognosis of prosthesis survival with modern prostheses.<sup>6</sup> The improvements in prostheses, especially in the design of polyethylene inserts and materials, greatly reduce wear on joint surfaces and decrease implant failures because of component malalignment.<sup>9</sup> In addition, it was found that the complete correction of the lower extremity alignment in patients with preoperative varus deformities may lead to an abnormally large Q angle and subsequently result in knee instability.<sup>10</sup> Therefore, better clinical efficacy of TKA in patients with varus knee osteoarthritis may be achieved by leaving appropriate residual varus.

Therefore, some researchers have begun the search of new alignment strategies that can enhance the clinical efficacy of TKA. For instance, kinematic alignment (KA) is a method that aims to restore the physiological kinematic axes of knee joints and has currently achieved good 10-year follow-up and clinical outcomes.<sup>11</sup> The concept of KA could be used in all deformities as reference during TKA, and the knee may be left in mild varus so as to preserve the original lower extremity alignment and reduce the extent of soft tissue release. Such a method may possibly enhance patient satisfaction after TKA. Moreover, it was reported that a higher rate of varus limb alignment after MA than with KA with both patient specific instrumentation as well as manual instruments, and using conventional instrumentation had the greatest varus mean MA and most varus outliers.<sup>12</sup>

The purpose of the present study was to conduct a retrospective analysis of the relationship between postoperative lower extremity alignment and patient outcome, and specifically evaluate the correlation between the different residual deformity and neutral alignment after TKA in varus-type OA patients.

## Methods

### Patient Information

The study was approved by institutional review board of our hospital (IRB No. 2011-011). Patients with varus-type knee osteoarthritis who underwent primary TKA between January 1, 2010 and December 31, 2013 were selected for follow-up.

The exclusion criteria were preoperative valgus or neutral lower extremity alignment (hip-knee-ankle [HKA] angle  $< -3^\circ$ ), a history of knee surgery, other forms of knee arthritis (traumatic knee arthritis, rheumatoid arthritis, septic arthritis), severe preoperative flexion deformity (over  $20^\circ$ ), concomitant severe chronic disease (liver or kidney disease, malignant tumor, cerebral stroke, severe heart disease), use of constrained or hinged prostheses, a history of mental or psychiatric disorders, and poor cooperation due to cultural, language, or cognitive differences.

A total of 237 patients (281 knees) fulfilled the criteria for this study. Of these, 175 patients (219 knees, with 116 left knees and 103 knees) underwent follow-up, including 31 males (38 knees) and 144 females (181 knees), and the mean age at surgery was  $69.9 \pm 7.2$  years (51-85 years). Thirty-one patients had concomitant diabetes, and 67 patients had concomitant hypertension. The follow-up rate was 73.8%, and the mean follow-up time was  $5.2 \pm 1.1$  years (4-7 years).

### Surgical Information

In all knees, a medial parapatellar approach after a standard midline skin incision was performed. The patella was retracted, and the anterior cruciate ligament and the menisci were completely resected. The femoral notch was cleared from osteophytes, and the posterior cruciate ligament was also resected. By means of a gouge, the entry point of intramedullary guides for the femur was marked mediolaterally and ventrodorsally with  $5^\circ$  or  $6^\circ$  valgus angle for general patients according to the preoperative radiological planning. For the appropriate rotational alignment of the femoral component, including the posterior condylar axis, the anteroposterior axis (Whiteside's line) and the anatomical transepicondylar axis were used as landmarks. Extramedullary guides for the tibia with the center of the tibial intercondylar eminence and the true center of the ankle were as the proximal and distal landmarks. All TKA patients were implanted with a cemented posterior-stabilized total knee prosthesis. One of the patients underwent patella replacement because of postoperative malunion of a patellar fracture, whereas the other patient did not undergo patella replacement but treated with removal of peripatellar osteophytes, adequate shaping of the patellar articular surface, and patellar denervation.

Patients were rehabilitated and discharged from hospital after TKA according to a uniform protocol; each patient had a clean dry wound and could walk satisfactorily with at least  $90^\circ$  of flexion before discharge. All patients underwent an objective and independent clinical and radiological assessment pre- and postoperatively.

### Follow-Up and Observation Indices

Before and after TKA and during follow-up, the Knee Society Score (KSS) (Knee Score and Functional Score) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scales were reported by the patient and the score form was filled by the doctor (Drs. Z.Z. and C.L.), and both KSS and WOMAC score systems were used to assess clinical efficacy and knee function. Postoperative complications were identified and recorded.

Anteroposterior and lateral radiographs of the operated knee and weight-bearing full-leg radiographs were taken preoperatively, postoperatively, and during the last follow-up. The HKA angle was defined as the included angle formed between the mechanical femoral axis and the mechanical tibial axis<sup>13-15</sup>; the angle was expressed as a deviation from  $180^\circ$  with a positive value for valgus and negative value for varus alignment. In addition, periprosthetic radiolucent lines were calculated to assess the risk of loosening.

### Statistical Analysis

All data were expressed as the mean standard deviation and analyzed with Statistical Package for the Social Sciences (SPSS) version 17.0 (Chicago, IL). All continuous variables were evaluated using the Student's t-test or the Mann-Whitney U test, depending on the distribution characteristics of the data. In all comparisons, a  $p$  value  $< 0.05$  was considered significant.

### Results

Patients were divided into four groups according to the first postoperative HKA angle from weight-bearing full-leg radiographs: "valgus" group (HKA angle  $> 0^\circ$ ,  $1.79^\circ \pm 1.59^\circ$ ,  $n = 44$ ), "neutral" group ( $-3^\circ \leq$  HKA angle  $< 0^\circ$ ,  $-1.6^\circ \pm 0.9^\circ$ ,  $n = 86$ ), "mild varus" group ( $-6^\circ \leq$  HKA angle  $< -3^\circ$ ,  $-4.2^\circ \pm 0.9^\circ$ ,  $n = 62$ ), and "severe varus" group (HKA angle  $< -6^\circ$ ,  $-7.1^\circ \pm 1.0^\circ$ ,  $n = 27$ ).

There were no statistically significant differences in patient age, body mass index, KSS, and WOMAC scores among the groups before surgery. Periprosthetic joint infection or prosthetic loosening did not find in all groups. No knee required revision surgery during follow-up. The final follow-up KSS and WOMAC scores for the various groups were significantly higher compared with the preoperative scores (**Table 1**).

For the last follow-up KSS Knee Score, the neutral ( $92.1 \pm 6.5$ ) and mild varus ( $92.0 \pm 5.9$ ) groups were better compared with the valgus ( $88.2 \pm 12.6$ ) and severe varus ( $87.6 \pm 9.8$ ) groups ( $p < 0.05$ ), and for the Functional Score, the neutral ( $79.7 \pm 16.4$ ) and mild varus ( $81.5 \pm 18.2$ ) groups were better compared with the valgus ( $71.6 \pm 19.0$ ) and severe varus ( $71.5 \pm 21.1$ ) groups ( $p < 0.05$ ). WOMAC scores of the neutral ( $8.1 \pm 7.2$ ) and mild varus ( $7.6 \pm 5.2$ ) groups were also better compared with the valgus ( $13.3 \pm 13.3$ ) and severe varus ( $12.9 \pm 12.3$ ) groups ( $p < 0.05$ ), and there were no significant differences between the neutral and mild varus groups at the last follow-up (**Table 2** and **Fig. 1**).

For each patient, the HKA angle measured first postoperatively (HKA<sub>1</sub>) was subtracted from the last follow-up HKA angle (HKA<sub>2</sub>) to obtain the difference in lower extremity alignment, dHKA (difference of HKA) = HKA<sub>2</sub> - HKA<sub>1</sub> (**Fig. 2**). The differences in dHKA of valgus group ( $2.5 \pm 2.5$ )

was statistically higher than neutral ( $1.3 \pm 0.8$ ), mild varus ( $0.9 \pm 0.8$ ), and severe varus ( $1.0 \pm 0.6$ ) groups ( $p < 0.05$ ).

### Discussion

In this study of varus-type OA patients, we analyzed patients who underwent primary TKA treatment at our hospital between 2010 and 2013. Postoperative KSS values were clearly increased, and the WOMAC score was clearly decreased and both statistically significant, indicating a satisfactory level of treatment efficacy. Moreover, there were no significant differences between the neutral and mild varus ( $< 6^\circ$ ) groups at the 5-year follow-up. However, the postoperative HKA angle was significant changed in valgus group when compared with other three groups. Therefore, leaving an HKA angle at  $< 6^\circ$  varus had the same excellent outcome as a neutral MA after TKA, using mechanically aligned technique.

As we know, the neutral MA has been the long-standing gold standard in TKA, because malalignment in the lower extremity coronal plane may result in an imbalance of forces between the medial and lateral tibial plateau, accelerated wear of the polyethylene insert, and increased risk of osteolysis and prosthesis loosening. Prosthesis malalignment was a high risk factor for revisions, and this was proven through results from a large number of successive studies.<sup>16</sup> In certain studies, it was reported that deviations of  $\pm 3^\circ$  and above from neutral alignment were associated with poorer clinical scores (especially in patients with a varus MA), and long-term survival was also adversely affected.<sup>4,17,18</sup> It was also reported that a non-neutral alignment increased aseptic loosening and subsidence, ultimately resulting in revision.<sup>19,20</sup>

However, in recent years, different opinions have emerged from many clinical studies. Many researchers found that mild malalignment in modern prostheses did not result in an increase in revision rate.<sup>4,6,8,13-15,21</sup> Patients with a postoperative mild varus malalignment and those with a neutral alignment obtained similarly good clinical scores.<sup>5</sup> In our 5-year follow-up study, it was found that among patients with varus knee osteoarthritis who underwent TKA, the neutral and residual mild varus groups obtained better KSS and WOMAC scores.

Furthermore, as we mentioned in the introduction, KA in TKA could achieve good 10-year outcomes.<sup>11</sup> Although

**Table 1** General characteristics and evaluation

	Preoperation ( $n = 219$ knees)	Last follow-up ( $n = 219$ knees)	$p$ -Value <sup>a</sup>
KSS score			
Knee score <sup>b</sup>	$45.1 \pm 11.5$	$90.7 \pm 8.5$	$< 0.001$
Functional score <sup>b</sup>	$36.2 \pm 11.8$	$77.6 \pm 18.5$	$< 0.001$
WOMAC score <sup>b</sup>	$46.1 \pm 6.5$	$9.68 \pm 9.3$	$< 0.001$
HKA <sup>b</sup> ( $^\circ$ )	$-8.1 \pm 6.7$	$-2.9 \pm 3.7$	$< 0.001$

Abbreviations: HKA, hip-knee-ankle; KSS, Knee Society Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

<sup>a</sup>The  $p$ -values are for the difference between the two groups.

<sup>b</sup>The values are given as the mean and standard deviation.

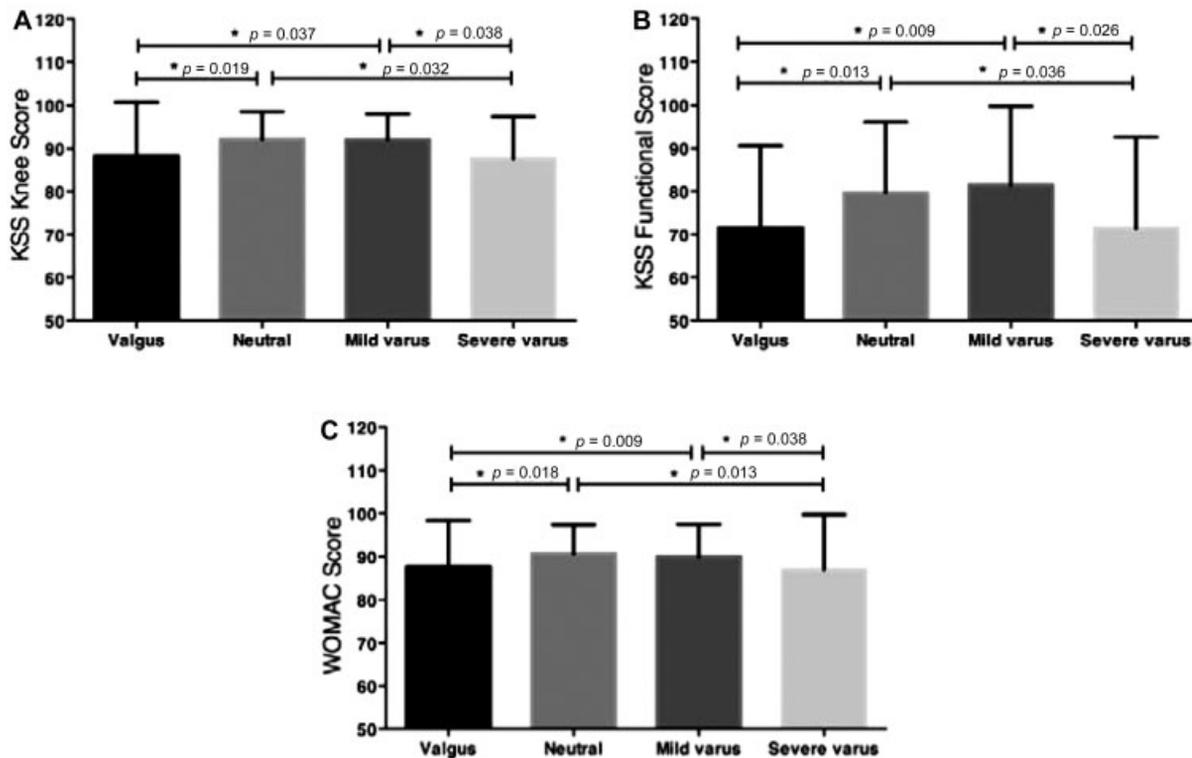
**Table 2** The pre- and postoperative index in different groups

	Valgus (n = 44)	Neutral (n = 86)	Mild varus (n = 62)	Severe varus (n = 27)
Age <sup>a</sup> (y)	66.2 ± 7.5	68.0 ± 6.7	67.2 ± 7.1	63.9 ± 7.4
BMI <sup>a</sup> (kg/m <sup>2</sup> ) <sup>a</sup>	25.4 ± 3.8	25.3 ± 3.2	26.2 ± 3.6	26.0 ± 3.4
Sex (M/F)	6/38	17/69	12/50	3/24
Side (L/R)	20/24	45/41	37/25	14/13
Follow-up time <sup>a</sup> (y)	4.3 ± 0.5	5.4 ± 1.3	5.4 ± 0.5	5.0 ± 1.7
<b>Knee score</b>				
Pre-op <sup>a</sup>	42.9 ± 8.8	45.8 ± 9.5	44.6 ± 15.4	46.6 ± 9.2
Last follow-up <sup>a</sup>	88.2 ± 12.6	91.1 ± 6.5	92.0 ± 5.9	87.6 ± 9.8
p-Value <sup>b</sup>	< 0.01	< 0.01	< 0.01	< 0.01
<b>Functional score</b>				
Pre-op <sup>a</sup>	38.6 ± 10.8	35.6 ± 11.3	36.6 ± 13.1	34.7 ± 11.6
Last follow-up <sup>a</sup>	71.6 ± 19.0	79.7 ± 16.4	81.5 ± 18.2	71.5 ± 21.1
p-Value <sup>b</sup>	< 0.01	< 0.01	< 0.01	< 0.01
<b>WOMAC score</b>				
Pre-op <sup>a</sup>	47.6 ± 6.7	45.9 ± 6.0	45.8 ± 7.5	45.9 ± 5.9
Last follow-up <sup>a</sup>	13.3 ± 13.3	8.1 ± 7.2	7.6 ± 5.2	12.9 ± 12.3
p-Value <sup>b</sup>	< 0.01	< 0.01	< 0.01	< 0.01

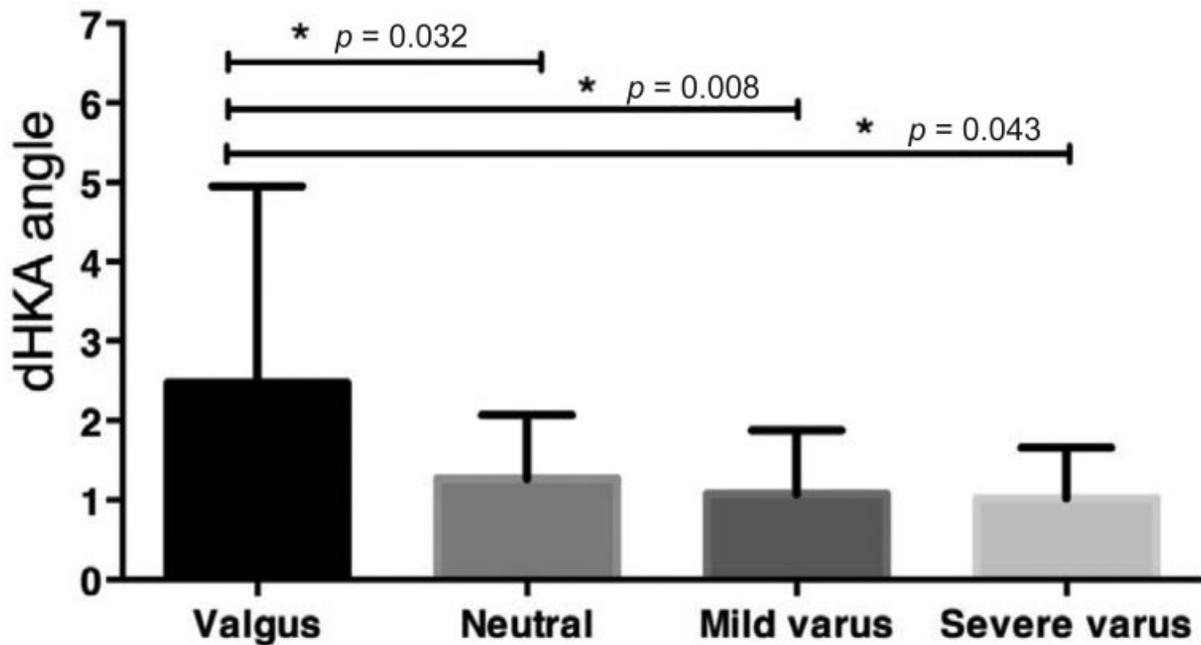
Abbreviations: BMI, body mass index; WOAMC, Western Ontario and McMaster Universities Osteoarthritis Index.

<sup>a</sup>The values are given as the mean and standard deviation.

<sup>b</sup>The p values are for the difference between preoperation and last follow-up in each group.



**Fig. 1** The comparison of postoperative Knee score and WOMAC score in different postoperative limb alignment groups at last follow-up. (\*The p-values are for the difference between the groups.). KSS, Knee Society Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.



**Fig. 2** The comparison of postoperative dHKA in different groups at last follow-up. (\*The *p*-values are for the difference between the groups.)

patient-reported outcome scores following TKA using KA are similar to MA, the risk of severe varus ( $>6^\circ$ ) alignment was much higher with MA than KA.<sup>12,22,23</sup> There is no need for patient-specific instrumentation any longer to perform this.<sup>12,22</sup>

On the other hand, many other clinical studies have indicated the lack of association between postoperative lower extremity alignment and postoperative prosthesis survival.<sup>6-8</sup> In the retrospective analysis of the 15-year survival of 398 knees,<sup>6</sup> it was found that a neutral alignment did not improve prosthesis survival; thus, it was concluded that a neutral alignment does not significantly affect the prognosis of survival for modern prostheses. A follow-up over a mean duration of 6.2 years on 84 patients with femoral bowing deformities who underwent TKA and found that the changes in lower extremity alignment in patients with a neutral alignment over the follow-up period were not statistically significant.<sup>21</sup>

For patients with deviations of  $> 3^\circ$  in the lower extremity alignment, the mean HKA angle decreased from  $4^\circ \pm 1^\circ$  postoperatively to  $7^\circ \pm 1^\circ$ , indicating an increase in varus severity, and the results were statistically significant. But there were no differences in other scores and complications among the two groups of patients. In our study, HKA taken within postoperatively and at the final follow-up, it was observed that the differences (dHKA) in the postoperative and final follow-up lower extremity alignment for the valgus group were not statistically significant, whereas the differences were statistically significantly higher than other groups. In addition, complications, such as loosening and osteolysis, were not observed in this group of patients. This result is consistent with the recent findings.<sup>14,15,24</sup>

However, this study has certain shortcomings, such as our results could be affected by the relatively short follow-up

duration (mean duration of 5.5 years), and relatively small number, which resulted in fewer results with statistical significance, especially in “severe varus” group. Therefore, a longer duration and large numbers of clinical follow-up are required for the verification of deviations in lower extremity alignment in patients included in this study.

In summary, improvements in prostheses have reduced the effect of slight alignment deviations on prosthesis survival and made the exploration of alignment methods with better clinical efficacy possible. Therefore, leaving  $< 6^\circ$  residual varus alignment had the same excellent functional outcome as neutral MA after TKA for varus-type osteoarthritis in the mid-term. But caution is advised when leaving valgus or leaving severe varus after TKA. Our results may serve as reference for future TKA procedures in patients with varus knee osteoarthritis.

#### Conflict of Interest

None declared.

#### References

- 1 Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KD. Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? *Clin Orthop Relat Res* 2010;468(01):57-63
- 2 Choi YJ, Ra HJ. Patient satisfaction after total knee arthroplasty. *Knee Surg Relat Res* 2016;28(01):1-15
- 3 Dunbar MJ, Haddad FS. Patient satisfaction after total knee replacement: new inroads. *Bone Joint J* 2014;96-B(10):1285-1286
- 4 Magnussen RA, Weppe F, Demey G, Servien E, Lustig S. Residual varus alignment does not compromise results of TKAs in patients with preoperative varus. *Clin Orthop Relat Res* 2011;469(12):3443-3450

- 5 Vanlommel L, Vanlommel J, Claes S, Bellemans J. Slight under-correction following total knee arthroplasty results in superior clinical outcomes in varus knees. *Knee Surg Sports Traumatol Arthrosc* 2013;21(10):2325–2330
- 6 Parratte S, Pagnano MW, Trousdale RT, Berry DJ. Effect of post-operative mechanical axis alignment on the fifteen-year survival of modern, cemented total knee replacements. *J Bone Joint Surg Am* 2010;92(12):2143–2149
- 7 Matziolis G, Adam J, Perka C. Varus malalignment has no influence on clinical outcome in midterm follow-up after total knee replacement. *Arch Orthop Trauma Surg* 2010;130(12):1487–1491
- 8 Bonner TJ, Eardley WG, Patterson P, Gregg PJ. The effect of post-operative mechanical axis alignment on the survival of primary total knee replacements after a follow-up of 15 years. *J Bone Joint Surg Br* 2011;93(09):1217–1222
- 9 Nishikawa K, Okazaki K, Matsuda S, et al. Improved design decreases wear in total knee arthroplasty with varus malalignment. *Knee Surg Sports Traumatol Arthrosc* 2014;22(11):2635–2640
- 10 Meding JB, Fish MD, Berend ME, Ritter MA, Keating EM. Predicting patellar failure after total knee arthroplasty. *Clin Orthop Relat Res* 2008;466(11):2769–2774
- 11 Howell SM, Shelton TJ, Hull ML. Implant survival and function ten years after kinematically aligned total knee arthroplasty. *J Arthroplasty* 2018;33(12):3678–3684
- 12 Nunley RM, Ellison BS, Zhu J, Ruh EL, Howell SM, Barrack RL. Do patient-specific guides improve coronal alignment in total knee arthroplasty? *Clin Orthop Relat Res* 2012;470(03):895–902
- 13 Hatayama K, Terauchi M, Saito K, Higuchi H. Does residual varus alignment cause increasing varus laxity at a minimum of five years after total knee arthroplasty? *J Arthroplasty* 2017;32(06):1808–1813
- 14 Meneghini RM, Grant TW, Ishmael MK, Ziemba-Davis M. Leaving residual varus alignment after total knee arthroplasty does not improve patient outcomes. *J Arthroplasty* 2017;32(9S):S171–S176
- 15 Nishida K, Matsumoto T, Takayama K, et al. Remaining mild varus limb alignment leads to better clinical outcome in total knee arthroplasty for varus osteoarthritis. *Knee Surg Sports Traumatol Arthrosc* 2017;25(11):3488–3494
- 16 Jeffery RS, Morris RW, Denham RA. Coronal alignment after total knee replacement. *J Bone Joint Surg Br* 1991;73(05):709–714
- 17 Fang DM, Ritter MA, Davis KE. Coronal alignment in total knee arthroplasty: just how important is it? *J Arthroplasty* 2009;24(6, Suppl):39–43
- 18 Choong PF, Dowsey MM, Stoney JD. Does accurate anatomical alignment result in better function and quality of life? Comparing conventional and computer-assisted total knee arthroplasty. *J Arthroplasty* 2009;24(04):560–569
- 19 D'Lima DD, Chen PC, Colwell CW Jr. Polyethylene contact stresses, articular congruity, and knee alignment. *Clin Orthop Relat Res* 2001;(392):232–238
- 20 Morgan SS, Bonshahi A, Pradhan N, Gregory A, Gambhir A, Porter ML. The influence of postoperative coronal alignment on revision surgery in total knee arthroplasty. *Int Orthop* 2008;32(05):639–642
- 21 Huang TW, Lee CY, Lin SJ, Lee MS, Hsu RW, Shen WJ. The influence of alignment on midterm outcome after total knee arthroplasty in patients with marked coronal femoral bowing. *J Arthroplasty* 2015;30(09):1531–1536
- 22 Nedopil AJ, Singh AK, Howell SM, Hull ML. Does calipered kinematically aligned TKA restore native left to right symmetry of the lower limb and improve function? *J Arthroplasty* 2018;33(02):398–406
- 23 Woon JTK, Zeng ISL, Calliess T, et al. Outcome of kinematic alignment using patient-specific instrumentation versus mechanical alignment in TKA: a meta-analysis and subgroup analysis of randomised trials. *Arch Orthop Trauma Surg* 2018;138(09):1293–1303
- 24 Delpont H, Labey L, Innocenti B, De Corte R, Vander Sloten J, Bellemans J. Restoration of constitutional alignment in TKA leads to more physiological strains in the collateral ligaments. *Knee Surg Sports Traumatol Arthrosc* 2015;23(08):2159–2169