



Original article

How are clinical outcomes related to the deviation severity of the tibiofemoral mechanical axis on coronal plane following knee arthroplasty?



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ABSTRACT

Objective: To analyze the effect of tibiofemoral mechanical axis (TFMA) deviation severity on clinical outcomes after total knee arthroplasty (TKA).

Methods: We retrospectively reviewed the patients who underwent primary TKA between January 2002 and December 2010. After applying inclusion/exclusion criteria, we evaluated 70 knees of 51 patients. The mean \pm SD follow-up period was 7.08 ± 1.34 years. The knees were divided into 3 groups based on TFMAs. The first group, identified as “well aligned,” included the TFMAs that were neutral within 3° ($0^\circ \pm 3^\circ$) of alignment. The second group, identified as “outliers 1,” included the slightly deviated TFMAs (-3° to -6° valgus and $+3^\circ$ to $+6^\circ$ varus). The third group, identified as “outliers 2,” included the severely deviated TFMAs of more than 6° from neutral alignment ($<-6^\circ$ valgus and $>+6^\circ$ varus). The clinical outcomes of each group were compared by evaluating the Oxford Knee Score (OKS), visual analog scale (VAS), and Short Form-36 physical component summary (SF-36 PCS) and mental component summary (SF-36 MCS) scores.

Results: We found that OKS, SF-36 PCS, and SF-36 MCS were nearly the same in the well-aligned and outliers 1 groups but worse in the outliers 2 group. VAS scores were nearly the same in all groups. ($p > 0.05$)

Conclusion: Function scores were impaired when the TFMA deviated more than 6° from neutral. However, the differences in clinical outcomes between well-aligned knees and those of outliers were not found to be statistically significant in the medium term.

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1. Introduction

Total knee arthroplasty (TKA) is considered an effective treatment for knee osteoarthritis when nonsurgical interventions fail.¹ With improved implant designs, patient satisfaction after TKA was reported to be over 90%.^{2,3}

One of the surgical aims of TKA is to achieve neutral limb alignment in the coronal plane. Malalignment was associated with high rates of revision surgery and poor survival of the implant.^{4–8} It had been reported previously that more than 3° of deviation from neutral mechanical alignment led to aseptic loosening and implant

failure.^{5,7} However, this was controversial, because two studies claimed that even with coronal alignment within 3° of neutral alignment, there was no significant impact on implant survival and the rate of revision surgery in a 15-year follow-up.^{9,10}

Although the acceptable tibiofemoral mechanical axis (TFMA) limit when performing TKA is also controversial, 3° alignment is typically the gold standard.^{5,11–13} It was reported that TFMA of $0^\circ \pm 3^\circ$ was associated with improved clinical outcomes.^{12,13} However, in later studies, it was claimed that optimal alignment was not associated with better clinical outcomes.^{14–18}

In the current literature, there is no consensus concerning the influence of better limb alignment on clinical outcomes following TKA. However, neutral within 3° was considered optimal, with the remainder defined as “outliers,” in most of the studies.^{11–15,18} The term “outliers” includes any deviation of more than 3° for varus

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and valgus alignment. Evaluating all outliers in a single group can preclude reaching proper results because clinical outcomes might differ by the slight or severe deviation of TFMA from optimal alignment.

The purpose of this study was to analyze the influence of malalignment on clinical outcomes after TKA and to clarify how these clinical outcomes were related to the severity of TFMA deviation. It was hypothesized that increased deviation degree from neutral alignment was associated with poorer functional scores.

2. Material and methods

The study was approved by the hospital's local Ethics committee. A review of the patients who underwent primary TKA in our department between January 2002 and December 2010 was conducted retrospectively. The inclusion criteria for the study were patients with primary osteoarthritis who underwent primary TKA at least 5 years prior to their most recent follow-up visit. Patients who were over 80 years old at their most recent visit, had prior knee surgery, or had <5-year follow-up period were excluded (Table 1).

The clinicodemographic data investigated were sex, age, body mass index (BMI), operation sides, and follow-up periods. The long-leg weight-bearing radiographs, function scores, and life-quality assessment were obtained at their most recent follow-up visit. Function assessment was performed using the Oxford Knee Score (OKS). To determine the relief of pain and quality of life, the visual analog scale (VAS) and Short Form 36 (SF-36) health survey questionnaire—both physical component summary (PCS) and mental component summary (MCS)—were used.

All TFMA measurements were performed on the digital long-leg weight-bearing radiographs by a single orthopaedic surgeon by using Picture Archive Communication Systems (PACS). The angle between a line connecting the center of the femoral head with the center of the knee and a line connecting the center of the knee to the center of the ankle was measured, as described previously.^{12,13} The center of the femoral head was identified using a Mose circle.¹⁹ The knee center was identified as the midpoint of the tibial spines, in the middle of the femoral intercondylar notch. The center of the ankle was identified as the midpoint between the inner edges of the malleoli.^{12,13}

The knees were divided into 3 groups based on TFMAs. The first group, which was identified as “well aligned,” included the TFMAs that were neutral within 3° (0° ± 3°) of alignment. The second group, identified as “outliers 1,” included the slightly deviated TFMAs, which had 3° of deviation from the first group (−3° to −6° valgus and +3° to +6° varus). The third group, identified as “outliers 2,” included the severely deviated TFMAs that exceeded 6° from neutral coronal alignment (<−6° valgus and >+6° varus alignment).

Each group was investigated and tested according to the median age, operation side, median BMI, and median follow-up period. The function scores and clinical outcomes of each group were compared using the OKS, VAS, SF-36 PCS, and SF-36 MCS. In bilateral cases, each knee was included into the belonged group based on the TFMA degree. OKS and VAS which reflect the related

knee were measured separately for each knee. However, SF-36 scores which reflect the general condition of the patient were the same for both of the knees.

2.1. Surgical technique

All operations were performed using a conventional approach by 3 senior arthroplasty surgeons who had a minimum of 10 years of experience of performing TKA. After the standard medial parapatellar incision and arthrotomy, intramedullary guides were used for femoral cuts, and extramedullary guides for tibial cuts in all cases. Three different cemented cruciate ligament retaining implant designs were used without patellar resurfacing in all procedures. A tourniquet was used in all cases. Antibiotics prophylaxis and deep venous thromboembolism prophylaxis were applied after surgery. All patients underwent standardized rehabilitation programmes.

Statistical analysis was performed using Number Cruncher Statistical System 2007 (Kaysville, Utah). Differences categorical data were compared using the chi-square test and Fisher–Freeman–Halton test. A 1-way analysis of variance test was used to compare the results of the 3 groups when there was a normal distribution, and non-normal distributions were compared using the Kruskal–Wallis test. Statistical significance was set as $p < 0.05$.

3. Results

Our internal medical record system was queried and 237 patients with sufficient data (preoperative clinicodemographic data and phone number etc.) were reviewed. Fifty-three of them were over 80 years old at the last follow-up and 17 of them were died. Eighteen patients were underwent surgery prior to seconder osteoarthritis ethiology and 16 of the patients had prior knee surgery. These 34 patients were excluded from the study. Thirty-five patients had not have proper follow-up time and were excluded from the study. The other 47 patients rejected to participate into the study. Remaining 51 patients were included to the study.

Totally, we evaluated 70 knees (37 right and 33 left) of 51 patients who underwent primary TKA. There were no complications, such as wound problems, infection, deep venous thrombosis, or component loosening.

There were 7 knees of 6 males and 63 knees of 45 females. The mean ± SD age of the patients was 68.44 ± 5.07 (range 60–80); BMI, 33.56 ± 5.63 (range 23.44–44.08); and follow-up period, 7.08 ± 1.34 years (range 5–12). At the most recent follow-up visit, based on TFMAs, 4 knees were aligned neutrally (0°), 12 knees were valgus aligned (<0°), and 54 knees were varus aligned (>0°). The mean ± SD OKS was 35.56 ± 7.85 (range 6–47), the mean ± SD VAS score was 3.20 ± 2.14 (range 1–10), the mean ± SD SF-36 PCS was 38.19 ± 9.70 (range 20.4–56.4), and the mean ± SD SF-36 MCS was 45.38 ± 10.82 (range 23.1–65.3).

After the division of the knees into 3 groups based on TFMAs, the well-aligned group included 20 knees, the outliers 1 group 24 knees, and the outliers 2 group 26 knees. The mean ± SD ages of the groups were 72.65 ± 4.12, 72.54 ± 3.16, and 73.12 ± 3.25, respectively. The mean ± SD BMIs of the groups were 34.46 ± 6.06,

Table 1
Inclusion and exclusion criteria.

| Inclusion criteria | Exclusion criteria |
|------------------------------------|--|
| Primary TKA | Revision TKA and prior knee surgery |
| Primary osteoarthritis etiology | Secondary osteoarthritis etiology (rheumatoid arthritis, post-traumatic arthritis, etc.) |
| ≤80 age | >80 age |
| At least a 5-year follow-up period | <5 year follow-up period |

32.65 ± 5.25, and 33.71 ± 5.73, respectively. The mean ± SD follow-up periods of the groups were 7.13 ± 1.16, 7.05 ± 1.26, and 7.07 ± 1 respectively. The differences were not significant between the 3 groups according to the ages, BMIs, follow-up periods, gender distribution, or operation sides ($p > 0.05$) (Table 2).

The mean ± SD OKS of the well-aligned and outliers 1 groups was nearly the same, but it was lower in the outliers 2 group. The mean ± SD VAS was the same in the 3 groups. The mean SF-36 PCS was the same in the well-aligned and outliers 1 groups, but it was lower in the outliers 2 group. Likewise, the mean SF-36 MCS was the same in the well-aligned and outliers 1 groups but approximately 3 points lower in the outliers 2 group. (Table 3). We found that OKS, SF-36 PCS, and SF-36 MCS were nearly the same in the well-aligned and outliers 1 groups but impaired in the outliers 2 group. In this study, we demonstrated that function scores decrease when TFMA exceeds 6°. However, the differences in function scores between the groups were not statistically significant ($p > 0.05$).

There were 16 varus and 8 valgus knees in outliers 1 group. There was no statistically significant difference between these valgus and varus knees based on the VAS, OKS, SF-36 PCS and SF-36 MCS (p values: 0.65, 0.32, 0.49, 0.38, respectively). However there was only one patient with valgus alignment in outliers 2 group. Thus we could not compare varus and valgus knees in the outliers 2 group.

The functional results of the patient with a maximum post-operatively varus alignment (15.8°) based on the VAS, OKS, SF-36 PCS and SF-36 MCS were 2, 40, 43.2 and 58.1, respectively. And the functional results of the patient with a maximum post-operatively valgus alignment (−8.5°) based on the VAS, OKS, SF-36 PCS and SF-36 MCS were 5, 33, 30.5 and 36, respectively.

4. Discussion

The most important finding of our study was that function scores after TKA were impaired when the TFMA deviated more than 6° from neutral. However, the clinical outcomes were not significantly affected by the degree of TFMA deviation at a mean follow-up of 7 years.

Optimal knee alignment following TKA is still a matter of debate. Numerous authors have suggested achieving neutral within 3° coronal alignment as it was believed to be associated with not only long-term implant survey but also better clinical outcomes after TKA.^{5,7,12,13}

Our results challenge the conclusions of some of these studies. Longstaf et al.²⁰ reported that being an outlier in coronal-plane alignment was associated with poorer function after TKA, at 1-year follow-up. Choong et al.¹² and Huang et al.¹³ reported better

International Knee Score and Short Form 12 health survey scores when the TFMA aligned within 3° of neutral by using Computer Assisted Systems. In these 2 studies, in contrast to our findings, function scores were significantly impaired after 3° deviation of TFMA, whereas the impairment occurred after 6° in our study and this was not significant.

Similar to our study, in following studies Matziolis et al.²¹ and Magnussen et al.²² reported that there was no relationship between coronal alignment and clinical outcomes. Harvie et al.¹⁴ and Hoppe et al.¹⁵ demonstrated no significant differences 5 years postoperatively in function scores between well-aligned knees and outliers that deviated more than 3° of the neutral mechanical axis.

Huijbregts et al.¹⁶ recently reported that deviation from neutral alignment did not correlate with OKS. However, the limitations of that study were a short follow-up period and a heterogeneous study population. Our study included medium-term results and a homogeneous study population, consisting entirely of patients who had primary TKA performed.

The non-correlation between well-aligned knees and outliers in clinical outcome might be explained by some reasons in the current study. It was stated that 32% of men and 17% of women in population had constitutional knee varus as a neutral alignment.²³ Instead of restoration to a neutral mechanical alignment of these knees, restoration of their constitutional alignment was believed to be more optimal.^{23,24} Vanlommel et al.²⁴ demonstrated that if preoperative severe varus knees were left in mild varus (3° to 6°) when performing TKA, those knees showed better clinical outcomes compared with knees restored to within 3° of neutral. Because preoperative data are lacking in our study, the degree of correction of deformities could not be evaluated. However, similar function scores in the well-aligned and outliers 1 groups provide some evidence. The preservation of tibial bone mineral density in residual varus-aligned knees may have also prevented poorer outcomes.²⁵

The other issue is that TFMA is measured solely in a static position and does not predict true dynamic tibial loading.²⁶ In addition, TFMA only represents the 2-dimensional coronal plane alignment and probably does not completely reflect the overall outcomes.¹⁴ The effect of sagittal and axial alignment of the components on outcomes was also thought to be considerable in TKA.^{8,27}

This study has some limitations, particularly because of the retrospective design. Preoperative and early postoperative long-leg weight-bearing radiographs were lacking. Therefore, we did not have any documentation regarding the degree of correction of deformities, so we could not perform subgroup analyses. The small number of patients limits the power of the study. Another

Table 2
Clinicodemographic data of groups.

| | | Well aligned | Outliers 1 | Outliers 2 | <i>P</i> value |
|-------------------------|------------------|---------------------|--------------------|-------------------|--------------------|
| Age | Mean ± Sd | 72.65 ± 4.12 | 72.54 ± 3.16 | 73.12 ± 3.25 | ^a 0.828 |
| | Min-Max (Median) | 67–80 (72) | 67–80 (73) | 66–79 (73) | |
| BMI | Mean ± Sd | 34.46 ± 6.06 | 32.65 ± 5.25 | 33.71 ± 5.73 | ^a 0.569 |
| | Min-Max (Median) | 25.50–43.11 (36.25) | 24.97–44.08(31.07) | 23.44–43.11(33.3) | |
| Follow-up period (year) | Mean ± Sd | 7.13 ± 1.16 | 7.05 ± 1.26 | 7.07 ± 1.56 | ^a 0.980 |
| | Min-Max (Median) | 5–9.08 (7.17) | 5–9.58 (7.17) | 5–12 (6.96) | |
| Gender | | n (%) | n (%) | n (%) | ^b 0.240 |
| | Female | 16 (80.0) | 22 (91.7) | 25 (96.2) | |
| Operation side | Male | 4 (20.0) | 2 (8.3) | 1 (3.8) | ^c 0.162 |
| | Right | 7 (35.0) | 14 (58.3) | 16 (61.5) | |
| | Left | 13 (65.0) | 10 (41.7) | 10 (38.5) | |

^a One way ANOVA Test.

^b Fisher Freeman Halton Test.

^c Pearson Chi-Square Test.

Table 3
Function scores of the groups.

| | | Well aligned | Outliers 1 | Outliers 2 | P value |
|-----------|------------------|---------------------|---------------------|---------------------|--------------------|
| OKS | Mean ± Sd | 37.05 ± 5.52 | 36.88 ± 7.57 | 33.19 ± 9.22 | ^b 0.164 |
| | Min-Max (Median) | 23–44 (38) | 17–47 (39) | 6–44 (35) | |
| VAS | Mean ± Sd | 3.05 ± 2.26 | 3.08 ± 1.77 | 3.42 ± 2.40 | ^b 0.849 |
| | Min-Max (Median) | 1–10 (3) | 1–7 (3) | 1–9 (2.5) | |
| SF-36 PCS | Mean ± Sd | 38.81 ± 10.14 | 38.84 ± 10.63 | 37.13 ± 8.70 | ^a 0.784 |
| | Min-Max (Median) | 20.40–54.10 (42) | 20.40–56.40 (38.05) | 24.00–53.30 (35.70) | |
| SF-36 MCS | Mean ± Sd | 46.64 ± 9.86 | 46.19 ± 10.25 | 43.66 ± 12.15 | ^a 0.596 |
| | Min-Max (Median) | 29.30–59.70 (49.40) | 26.00–62.50 (45.95) | 23.10–65.30 (41.90) | |

^a One way ANOVA Test.

^b Kruskal Wallis Test.

limitation is that all of the measurements were performed by a single orthopaedic surgeon, and interobserver reliability could not be evaluated. Also, the mechanical axis alignment which was measured by an orthopaedic surgeon who is included in the study group could cause a bias.

Despite the retrospective design, the characteristics of the groups were quite similar in terms of mean ages, BMIs at most recent follow-up visit, follow-up periods, sex distribution, and operative sides. Previously, it was stated that aging and concomitant comorbidities had a significant effect on function scores after TKA.²⁸ In the current study, patients over 80 years old and knees with secondary osteoarthritis—rheumatoid and posttraumatic arthritis, which can increase the comorbidity burden—were excluded in order to prevent negative clinical outcomes, and function scores more likely reflected the TKA success.

To our knowledge, only the optimally aligned knees and outliers that deviated from the optimal range were compared according to the clinical outcomes in the literature. This study is important as it presents comparison among outliers according to deviation severity.

In summary, the current study demonstrated that function scores impaired after 6° deviation of neutral mechanical alignment. However, the differences in clinical outcomes between well-aligned knees and outliers were not found to be statistically significant in the medium term. Nevertheless, one should bear in mind that these results can be altered in long term follow-up.

Authors contribution

Conceived and designed the study; Emre Bilgin, Hasan Bombacı,

Data collection: Emre Bilgin, Bekir Eray Kılınc, Levent Adıyeye

Data and statistical analysis; Ali Turgut, Hasan Bombacı

Interpreted the data; Emre Bilgin, Levent Adıyeye

Contributed reagents, materials, analysis tools or data; Emre Bilgin, Ali Turgut, Önder Kalenderer

Wrote the paper; Emre Bilgin, Mücahit Görgeç, Önder Kalenderer

Conflict of interest

None.

Compliance with ethical standards

After approval by the institutional review board with number 31/9 on 18/10/2016

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References

- Callahan CM, Drake BG, Heck DA, Dittus RS. Patient outcomes following tricompartmental total knee replacement. A meta-analysis. *JAMA*. 1994;271(17):1349–1357.
- Robertsson O, Dunbar M, Pehrsson T, Knutson K, Lidgren L. Patient satisfaction after knee arthroplasty: a report on 27,372 knees operated on between 1981 and 1995 in Sweden. *Acta Orthop Scand*. 2000;71(3):262–267.
- Lošťák J, Gallo J, Zapletalová J. Patient satisfaction after total knee arthroplasty: analysis of pre-Operative and peri-Operative parameters influencing results in 826 patients. *Acta Chir Orthop Traumatol Cech*. 2016;83(2):94–101.
- Tew M, Waugh W. Tibiofemoral alignment and results of knee replacement. *J Bone Joint Surg Br*. 1985;67(4):551–556.
- Jeffery RS, Morris RW, Denham RA. Coronal alignment after total knee replacement. *J Bone Joint Surg Br*. 1991;73(5):709–714.
- Lotke PA, Ecker ML. Influence of positioning of prosthesis in total knee replacement. *J Bone Joint Surg Am*. 1977;59(1):77–79.
- Ritter MA, Faris PM, Keating EM, Meding JB. Postoperative alignment of total knee replacement: its effect on survival. *Clin Orthop Relat Res*. 1994;299:153–156.
- Kim YH, Park JW, Kim JS, Park SD. The relationship between the survival of total knee arthroplasty and postoperative coronal: sagittal and rotational alignment of knee prosthesis. *Int Orthopaed*. 2014;38(2):379–385.
- Parratte S, Pagnano MW, Trousdale RT, Berry DJ. Effect of postoperative mechanical axis alignment on the fifteen-year survival of modern cemented total knee replacements. *J Bone Joint Surg Am*. 2010;92(12):2143–2149.
- 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(9):1217–1222.
- Abdel MP, Oussedik S, Parratte S, Lustig S, Haddad FS. Coronal alignment in total knee replacement: historical review, contemporary analysis, and future direction. *Bone Joint J*. 2014;96-B(7):857–862.
- 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(4):560–569.
- Huang NF, Dowsey MM, Ee E, Stoney JD, Babazadeh S, Choong PF. Coronal alignment correlates with outcome after total knee arthroplasty: five-year follow-up of a randomized controlled trial. *J Arthroplasty*. 2012;27(9):1737–1741.
- Harvie P, Sloan K, Beaver RJ. Computer navigation vs conventional total knee arthroplasty five-year functional results of a prospective randomized trial. *J Arthroplasty*. 2012;27(5):667–672.
- Hoppe S, Mainzer JD, Frauchiger L, Ballmer PM, Hess R, Zumstein MA. More accurate component alignment in navigated total knee arthroplasty has no clinical benefit at 5-year follow-up. *Acta Orthop*. 2012;83(6):629–633.
- Huijbregts HJ, Khan RJ, Fick DP, Jarrett OM, Haebich S. Prosthetic alignment after total knee replacement is not associated with dissatisfaction or change in Oxford Knee Score: a multivariable regression analysis. *Knee*. 2016;23(3):535–539.
- Mugnai R, Zambianchi F, Digennaro V, et al. Clinical outcome is not affected by total knee arthroplasty alignment. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(10):3339–3345.
- Burnett RS, Barrack RL. Computer-assisted total knee arthroplasty is currently of no proven clinical benefit: a systematic review. *Clin Orthop Relat Res*. 2013;471(1):264–276.
- Mose K. Methods of measuring in Legg–Calve–Perthes disease with special regard to the prognosis. *Clin Orthop Relat Res*. 1980;150:103–109.
- Longstaff LM, Sloan K, Stamp N, Scaddan M, Beaver R. Good alignment after total knee arthroplasty leads to faster rehabilitation and better function. *J Arthroplasty*. 2009;24(4):570–578.
- Matziolis G, Adam J, Perka C. Varus alignment has no influence on clinical outcome in midterm follow-up after total knee replacement. *Arch Orthop Trauma Surg*. 2010;130(12):1487–1491.
- 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.

23. Bellemans J, Colyn W, Vandenuecker H, Victor J. The Chitranjan Ranawat award: is neutral mechanical alignment normal for all patients? The concept of constitutional varus. *Clin Orthop Relat Res.* 2012;470(1):45–53.
24. Vanlommel L, Vanlommel J, Claes S, Bellemans J. Slight undercorrection following total knee arthroplasty results in superior clinical outcomes in varus knees. *Knee Surg Sports Traumatol Arthrosc.* 2013;21(10):2325–2330.
25. Jaroma A, Soininvaara T, Kröger H. Periprosthetic tibial bone mineral density changes after total knee arthroplasty. *Acta Orthop.* 2016;87(3):268–273.
26. Miller EJ, Pagnano MW, Kaufman KR. Tibiofemoral alignment in posterior stabilized total knee arthroplasty: static alignment does not predict dynamic tibial plateau loading. *J Orthop Res.* 2014;32(8):1068–1074.
27. Sikorski JM. Alignment in total knee replacement. *Bone & Joint J.* 2008;90(9):1121–1127.
28. Benjamin J, Johnson R, Porter S. Knee scores change with length of follow-Up after total knee arthroplasty. *J Arthroplasty.* 2003;18(7):867–871.