

# Effect of Anatomical and Mechanical Axis on Total Knee Replacement

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## Abstract

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**The Egyptian Orthopedic Journal;**  
**2019 supplement (1), June, 54: 25-30**

### Background:

The most important item in TKR is the alignment of the total knee prosthesis. If correct, it results in a good functional outcome. If incorrect, it results in abnormal wear, premature loosening, and functional problems.

### Aim of the Work:

To highlight the effect of a properly mechanically aligned replaced knee with the function.

### Patients and Methods:

This retrospective study was conducted on 38 patients who were subjected to primary total knee arthroplasty more than one year ago and assessed postoperatively by knee society score and radiologically by long lower limb standing x-ray from hip to ankle joint of both lower limbs.

### Results:

Significantly higher mean value of knee society scores in the neutral alignment group than in the varus alignment group.

### Conclusion:

Compared to malalignment total knee replacement, neutrally aligned TKR has a better functional outcome, durability, and a lower rate of revision surgery.

**Keywords:** Anatomical and Mechanical Axis, Total Knee Replacement

## Introduction

Knee arthroplasty has been recognized as a standard treatment for advanced knee arthritis, regardless of whether it is accompanied by deformities. It is designed to relieve pain, provide motion, stability, and correct deformities<sup>(1)</sup>.

The surgical procedure known as total knee arthroplasty (TKA) is exceedingly effective in the treatment of end-stage osteoarthritis (OA) of the knee. The purpose of this procedure is to correct malalignment in the lower extremities to alleviate pain and restore joint function<sup>(2,3)</sup>.

It is also recognized that TKA surgery can enhance the long-term survivability of the prosthesis by precisely implanting the prosthesis, thereby achieving the standard axial alignment of the lower extremity in the coronal, sagittal, and rotational planes<sup>(4)</sup>.

Anteroposterior radiographs are a critical determinant of long-term outcomes following TKA, including postoperative lower extremity alignment<sup>(5,6)</sup>.

Potential causes of malalignment following TKA include soft tissue laxity, tibial bone loss, inappropriate bone resection, inaccurate cementation, preoperative varus deformity of 20°, and femoral curvature of 5°<sup>(7)</sup>.

It is still deemed permissible for limb alignment to deviate within a neutral mechanical axis by  $\pm 3^\circ$ <sup>(8)</sup>. The limb alignment of implants following

TKA is correlated with enhanced function, greater stability, a lower rate of retraction, higher clinical scores, and increased longevity<sup>(9)</sup>.

Malalignment following TKA may lead to the overburden of the implant bearing and the bone itself, which can lead to osteolysis, instability, and early detachment. One of the primary mechanisms that contribute to early clinical failure and may require revision surgery is this<sup>(10)</sup>.

Additionally, A multiplicity of studies have demonstrated that the mechanical alignment of the operated limb is crucial for the survivability of prostheses following TKA<sup>(11)</sup>.

## Aim of the Study:

The objective of this investigation was to emphasize the impact of a properly mechanically aligned replacement knee on its functionality.

## Patients and Methods

Patients were assessed retrospectively of primary total knee patients more than one year ago and assessed postoperatively clinically by knee society score and radio logically by long lower limb standing x-ray from hip to ankle joint of both lower limbs.

**1- Physical examination:**

Patients were examined clinically according to the items of knee society score <sup>(12)</sup>.

- The patient's age, sex, body mass index, and operated side were documented.

**Knee Score (Insall Modification - 1993) <sup>(12)</sup>**

|                                  |                     |
|----------------------------------|---------------------|
| <b>Pain 50 (Maximum) Walking</b> |                     |
| None                             | 35                  |
| Mild or occasional               | 30                  |
| Moderate                         | 15                  |
| Severe                           | 0                   |
| <b>Stairs</b>                    |                     |
| None                             | 15                  |
| Mild or occasional               | 10                  |
| Moderate                         | 5                   |
| Severe                           | 0                   |
| <b>R.O.M.</b>                    | <b>25 (Maximum)</b> |
| 8°= 1 point                      |                     |
| <b>Stability Medial/Lateral</b>  | <b>25 (Maximum)</b> |
| 0-5 mm                           | 15                  |
| 5-10 mm                          | 10                  |
| > 10 mm                          | 5                   |
| <b>Anterior/Posterior</b>        |                     |
| 0-5 mm                           | 10                  |
| 5-10 mm                          | 8                   |
| > 10 mm                          | 5                   |
| <b>Deductions Extension lag</b>  |                     |
| None                             | 0                   |
| <4 degrees                       | -2                  |
| 5-10 degrees                     | -5                  |
| >11 degrees                      | -10                 |
| <b>Flexion Contracture</b>       |                     |
| < 5 degrees                      | 0                   |
| 6-10 degrees                     | -3                  |
| 11-20 degrees                    | -5                  |
| > 20 degrees                     | -10                 |
| <b>Malalignment</b>              |                     |
| 5-10 degrees(5° = -2 points)     | 0                   |
| <b>Pain at rest</b>              |                     |
| Mild                             | -5                  |
| Moderate                         | -10                 |
| Severe                           | -15                 |
| None                             | 0                   |
| <b>Knee Score 100 (Maximum)</b>  |                     |



**Fig. (1):** A female patient 64 years old was operated on the right side 1 year ago with a BMI of 40. The replaced knee was varus aligned with HKA17°, range of motion 135°, and knee society score of 84%



**Fig (2):** A female patient with 53 years old was operated on 1 year ago on the left side with a (BMI) of 35. The replaced knee was neutrally aligned with a Hip-knee-Ankle (HKA) angle of 178 degrees range of motion of 130 degrees and a knee society score of 86%.

**Results**

This retrospective study included 38 patients who underwent total knee replacement at Menoufia University Hospital from 2014 to 2018. There were 8 males, and 30 females were studied with a mean age of 56 years old with a range (36-67). The mean body mass index was 36 with a range (24-40). The mean postoperative duration was 2 years with a range of (1-4) years. 20 right limbs were operated and 18 left limbs were operated. (Table 1)

**Table 1:** Demographic data of TKR patients.

| Demographic data                         | TKR patients (n=38) |
|--|---------------------|
| Age (years): Mean± SD                    | 56.44±9.19          |
| Sex: [No (%)]                            |                     |
| Males                                    | 8 (21.0)            |
| Females                                  | 30 (79.0)           |
| BMI (Kg/m <sup>2</sup> ): Mean± SD       | 36.13±6.75          |
| Postoperative duration (years): Mean± SD | 2.16±1.23           |
| Side of TKR: [No (%)]                    |                     |
| Rt                                       | 20 (52.6)           |
| Lt                                       | 18 (47.4)           |

TKR: Total knee replacement SD: Standard of deviation

The mean age of patients with neutrally aligned knees was 55.83, in varus aligned group were 56.80 with no significant relation between postoperative limb alignment and the mean age of patients. The higher mean value of BMI in varus aligned group was 40.5 in comparison to the low mean value of BMI in neutral aligned knees 33.5, with a significant relation between BMI and postoperative alignment, this indicates that higher BMI is associated with varus postoperative limb alignment. There was no significant correlation

between postoperative alignment and postoperative duration, sex of the patient, or side of the operated limb (**Table 2**)

**Table 2:** Demographic data with type of limb alignment in TKR patients.

| Items                           | Neutral alignment (n=18)<br>Mean± SD | Varus alignment (n=20)<br>Mean± SD | t-test   | P-value |
|---------------------------------|--------------------------------------|------------------------------------|----------|---------|
| Age (years):                    | 55.83±3.54                           | 56.80±11.40                        | 0.28     | 0.778   |
| BMI (Kg/m <sup>2</sup> ):       | 33.50±5.66                           | 40.50±6.29                         | 3.25     | 0.003*  |
| Postoperative duration (years): | 2.00±1.21                            | 2.25±1.26                          | 0.55     | 0.585   |
| Sex:                            | No (%)                               | No (%)                             | $\chi^2$ | 0.154   |
|                                 | Males                                | 6 (30.0)                           |          |         |
| Females                         | 16 (88.9)                            | 14 (70.0)                          | 2.03     |         |
| Side of TKR:                    |                                      |                                    | 2.59     | 0.107   |
|                                 | Rt                                   | 7 (38.9)                           |          |         |
| Lt                              | 11 (61.1)                            | 7 (35.0)                           |          |         |

\*: significant

The mean value of the angle of deviation from neutral alignment (180-degree Hip Knee Ankle angle) in neutral aligned group was 2 degrees, and in varus aligned group the mean angle of deviation was 8 degrees. This indicates that a neutrally aligned knee should have an HKA angle of 180 +/-3 degrees. The mean value of the Medial Proximal Tibial Angle in the neutrally aligned group was 89 degrees, in the varus aligned group the mean value of MPTA was 86 degrees. This indicates that properly aligned tibial components should be 90+/-3 degrees. (**Table 3**)

**Table 3:** Radiological data with type of limb alignment in TKR patients.

| Radiographic data                | Neutral alignment (n=18)<br>Mean± SD | Varus alignment (n=20)<br>Mean± SD | t-test | P-value |
|----------------------------------|--------------------------------------|------------------------------------|--------|---------|
| Angle deviation from neutral (°) | 2.00±0.60                            | 8.10±1.86                          | 10.95  | <0.001* |
| Hip knee ankle angle (°)         | 178.67±1.30                          | 168.30±4.57                        | 7.63   | <0.001* |
| Medial proximal tibial angle (°) | 89.00±1.71                           | 86.70±0.92                         | 4.97   | <0.001* |

Neutrally aligned TKR has a higher Knee Society Score with a mean value of 85% than in varus aligned TKR of KSS 82%. With a significant correlation between postoperative alignment and KSS. There was a significant correlation between range of motion and postoperative alignment with the lower mean value of range of motion in neutrally aligned TKR than in varus aligned TKR. (**Table 4**)

**Table 4:** Relationship between type of limb alignment with the knee society score and range of motion in TKR patients.

| Items               | Neutral alignment (n=18)<br>Mean± SD | Varus alignment (n=20)<br>Mean± SD | t-test | P-value |
|---------------------|--------------------------------------|------------------------------------|--------|---------|
| Knee society score  | 85.50±4.42                           | 82.80±3.04                         | 2.81   | 0.009*  |
| Range of motion (°) | 124.17±4.69                          | 129.50±6.67                        | 2.43   | 0.021*  |

Within the varus-aligned group which was sub-grouped to < and >= 10 degrees deviation from neutral alignment, as the degree of varus alignment increases, With a significant correlation, the knee society score and range of motion decrease (**Table 5**)

**Table 5:** Knee society score and range of motion in varus alignment group as regards angle deviation from neutral.

| Variables              | Angle deviation from neutral in varus alignment group |                         | t-test | P-value |
|------------------------|---|-------------------------|--------|---------|
|                        | < 10° (n=12)<br>Mean± SD                              | ≥ 10° (n=8)<br>Mean± SD |        |         |
| Knee society score (%) | 84.00±3.25  | 81.00±1.51              | 2.43   | 0.026*  |
| Range of motion (°)    | 131.67±5.77   | 126.25±6.94             | 1.90   | 0.046*  |

This table showed that: There was a higher mean percent of knee society score in angle deviation < 10 ° than in angle ≥ 10° in varus alignment patients. (**Table 6**)

**Table 6:** Negative correlation between angle deviation from neutral with knee society score, and range of motion in varus alignment group.

| Radiographic data  | Angle deviation from neutral in varus alignment group. (n=20) |         |
|--------------------|---|---------|
|                    | (r)   | P-value |
| Knee society score | -0.518  | 0.019*  |
| Range of motion    | -0.547  | 0.013*  |

(r): Pearson correlation

## Discussion

Complications such as aseptic laxity, instability, polyethylene degradation, and patellar dislocation are the result of mal alignment. The post-operative alignment of the knee has been regarded as the primary predictor and indicator of success in revision surgery, intended to achieve a superior outcome<sup>(13)</sup>. The definition of excellent and poor alignment is entirely subjective. Sikorski<sup>(14)</sup> made an arbitrary unit that was defined as acceptable alignment if it was within 2° of neutral.

Furthermore, other authors have noted that it is imperative to maintain limb alignment within  $3^\circ$  of the normal mechanical axes following TKA to ensure a positive post-TKA outcome<sup>(15,16)</sup>.

The traditional belief among most surgeons is that the postoperative alignment should be within  $0^\circ \pm 3^\circ$  of the mechanical axis. This is hypothesized to enhance the durability of the TKR, as evidenced by data from clinical, retrieval, and finite element studies<sup>(17)</sup>.

We examined 38 patients retrospectively, 18 of them neutrally aligned postoperatively and 20 of them varus aligned postoperatively.

There was a significant correlation between body mass index and postoperative limb alignment with lower mean values of body mass index in the neutrally aligned group (33.5 with standard deviation 5.66) than in varus aligned group of mean body mass index (40.5 with standard deviation 6.29). This indicates that obesity is a risk factor for varus malalignment of the postoperative limb as documented by **Pieter-Jan et al.**<sup>(18)</sup>. There was no significant correlation between age, postoperative duration, sex, and the side of the operated limb and postoperative limb alignment. The mean value of the hip-knee-ankle angle was higher ( $178.67^\circ$  with SD  $1.3^\circ$ ) in the neutrally aligned group compared to the varus-aligned group with a lower mean value of hip-knee-ankle angle ( $168.3^\circ$  with SD  $4.57^\circ$ ). This means that properly neutrally aligned total knee replacement should have a hip-knee-ankle angle within  $180^\circ \pm 3^\circ$  as documented by **Rand, et al.**<sup>(15)</sup>.

The mean value of the medial proximal tibial angle of the neutrally aligned group was ( $89^\circ$  with SD  $1.71^\circ$ ) which is higher than the mean value of the medial proximal tibial angle in the varus-aligned group ( $86.7^\circ$  with SD  $0.92^\circ$ ), which indicates that varus mal-aligned postoperative limb may lead to varus collapse of the tibial component as documented by **Michael et al.**<sup>(19)</sup>, and indicates also that properly neutrally aligned tibial component should be ( $90^\circ \pm 3^\circ$ ) of the mechanical axis of the tibia as documented by **Perillo Marcone et al.**<sup>(20)</sup>. There was the higher mean value of knee society functional score (85.5 % with SD 4.42) in the neutrally aligned group compared to a lower mean value of knee society score in varus aligned group (82.8% with SD 3.04) as documented by **Longstaff et al.**<sup>(21)</sup>. And the lower mean value of the range of motion in the neutrally aligned group ( $124.17^\circ$  with SD  $4.69^\circ$ ) compared to the higher mean value of the range of motion ( $129.5^\circ$  with SD  $6.67^\circ$ ) in varus aligned group. This indicates that although the knee society score

is higher in the neutrally aligned group than in the varus aligned group, the range of motion is higher in the varus group than in the naturally aligned group. This indicates that the knee society's functional score does not depend only on the range of motion but also it depends on the degree of pain at walking, climbing stairs, and at rest and the functional score also depends on postoperative stability, residual postoperative extension lag, and residual postoperative flexion contracture<sup>(12)</sup>. The postoperative limb alignment, knee society score, and range of motion of the prosthetic knee were significantly correlated. In the varus group, which consisted of twenty cases in the study, there was a significant negative correlation between the degree of varus malalignment postoperatively, as assessed by the angle of deviation from neutral alignment, and the knee society score and range of motion. This implies that the knee society score and range of motion decrease as the degree of varus malalignment increases, as indicated by the increase in the angle of deviation from neutral alignment.

Our study is limited by the brief postoperative follow-up period, with a mean of 2.16 years, and the small number of cases assessed. There are only 38 cases.

**Longstaff et al. (2009)**<sup>(21)</sup> Between May 2003 and July 2004, performed 159 TKA interventions. They conducted a computed tomography (CT) scan to evaluate postoperative alignment and discovered that the neutral mechanical axis resulted in superior functional scores (KSS score) and a shorter hospital stay than the mal-aligned groups at the one-year follow-up ( $P = 0.01$ ). Our study was performed in 32 cases at 1 to 4 years follow-up with the same results ( $P$  value = 0.009). From a sequence of 115 TKAs, **Jeffery et al.**<sup>(13)</sup> contrasted the postoperative results to the findings of Macquet's line using long-leg radiographs. Subsequently, the incidence of laxity was 3% in well-aligned groups and 24% in mal-aligned groups (error of approximately  $\pm 3^\circ$ ). This discrepancy was highly significant ( $P = 0.001$ ). This suggested that the precise alignment of the corona is a confounding factor that impedes relaxation after TKA surgery. Our results confirmed the overall function of TKA is better in the mechanical axis line to be  $180 \pm 3$  degrees.

In the same way, a randomized control study was conducted to compare conventional TKR with computer-assisted TKR. **Choong et al.**<sup>(22)</sup> In patients with a mechanical axis within  $3^\circ$  of neutral and well-aligned knees, postoperative International Knee Scores (IKS) were improved. Our study was conventional TKA with the same results.

The retrospective investigation conducted by **Fang et al.**<sup>(23)</sup> The implant survivorship rate was higher in the neutral group (2.4° to 7.2° valgus) in a 2009 study of 3992 patients who underwent primary TKRs. The revision rate for this group was 0.5%, which was lower than that of the neutral group, which was 1.8% for varus and 1.5% for valgus. The 20-year surveillance period yielded a neutral group survival rate of 99%, a varus group survival rate of 95%, and a valgus group survival rate of 97%. The implant survival rate was statistically significant. We concur with these discoveries.

Similarly, **Kennedy et al.**<sup>(24)</sup> Additionally, When the mechanical axis is in the midline of the knee, superior results were observed. In certain failure TKRs, the mechanical axis was detected to be greater than 5 degrees valgus/varus, and a significant amount of polyethylene wear was observed in the medial compartment of the tibial component<sup>(25)</sup>. We agree with these results.

### Conflicts on alignment

The optimal outcome of the surgery is contingent upon the maintenance of neutral alignment, which includes the optimization of knee joint functionality and the preservation of implant durability. However, only two variables determine the alignment of total knee arthroplasty: whether it is within  $0^\circ \pm 3^\circ$  of a neutral axis or is mal aligned<sup>(26)</sup>. Consequently, this fact has continued to be a topic of debate to improve the outcome of TKA. Several studies have been published in the literature that challenge coronal alignment. **Parratte et al.**<sup>(27)</sup> Between 1985 and 1990, 398 primary TKAs were examined. The patients were divided into two groups: those who were aligned (achieving a mechanical axis of  $0^\circ \pm 3^\circ$ ) and those who were mal aligned. The 15-year Kaplan Meier implant survival rate did not exhibit any significant differences between the two groups. The results suggested that the revision rate in the well-aligned groups is 45 in 292 (15.4%). While in the mal aligned groups, it is 14 in 106 knees (13%). This illustrates that mechanical alignment is not an optimal metric for assessing the implant's durability and patient satisfaction.

In 2010 **Matziolis et al.**<sup>(28)</sup> 218 patients were retrospectively examined. In comparison to the neutrally aligned groups, the 30-malaligned varus groups did not experience any adverse medium-term clinical or radiological outcomes (postoperative mechanical axis deviation of 6.3° to 10.7°). With the alignment that occurs following the operation. Obesity also contributes to poor outcomes by affecting the failure of tibial

components, in addition to the mechanical axis. The alignment in TKA surgery is also influenced by the BMI. A study identified a failure in a patient with a body mass index of 44.6 at the time of the initial surgery, which required revision surgery, despite the successful attainment of neutral coronal alignment<sup>(22)</sup>. Similarly, in the study done by **Pieter-Jan et al.**<sup>(18)</sup>, High BMI was associated with a higher likelihood of varus alignment, as evidenced by a significant result ( $P = 0.02$ ). Additionally, they discovered that the medial component was more severely damaged in the valgus group, while the lateral side was more severely damaged in the varus group. In contrast, they were unable to identify any significant results in neutral HKA groups.

**Bonner et al.**<sup>(29)</sup> In 2011, 501 consecutive TKRs performed between 1987 and 1997 were examined using long-leg AP weight-bearing radiographs. Patients were categorized as "aligned" (neutral mechanical axis  $\pm 3^\circ$ ) or "mal aligned" (mechanical axis deviated from neutral by more than  $3^\circ$ ). They realized that the aligned group had a marginally higher implant survival rate; however, there was no statistically significant difference (as determined by Kaplan-Meier survival analysis). According to their findings, the correlation between the survival of a primary TKR and mechanical axis alignment is less robust than that described in previous reports. Additionally, these findings were recorded by **Morgan et al.**<sup>(30)</sup>, **Ritter et al.**<sup>(31)</sup>, and **Vandome et al.**<sup>(32)</sup>.

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### Conclusion

In contrast to malalignment total knee replacement, neutrally aligned TKR yields superior functional results.

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