

Effect of Anatomical and Mechanical Axis on Total Knee Replacement

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Abstract

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Background:

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

Aim of the Work:

To highlight the effect of proper mechanically aligned replaced knee in relation to the function.

Patients and Methods:

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

Results:

Significant higher mean value of knee society score in neutral alignment group than in varus alignment group.

Conclusion:

Neutrally aligned TKR has better functional outcome, durability and lesser rate of revision surgery in comparison to malalignment total knee replacement.

Key words: Anatomical and Mechanical Axis, Total Knee Replacement

Introduction

Knee arthroplasty has been accepted as a standard procedure in treatment of advanced arthritis of the knee with or without deformities. It is designed to relieve pain, provide motion, stability and correct deformities⁽¹⁾.

Total knee arthroplasty (TKA) is a very successful surgical procedure used to treat end stage osteoarthritis (OA) of the knee so that pain can be relieved and joint function can be restored due to the correction of lower extremity malalignment^(2,3).

It is also known that TKA surgery can achieve normal axial alignment of the lower extremity in the coronal, sagittal and rotational planes by implanting the prosthesis precisely, contributing to improve long-term survival of the prosthesis⁽⁴⁾. Postoperative lower extremity alignment, measured on anteroposterior radiographs, is an important determinant of long-term outcomes following TKA^(5,6).

Several factors such as soft tissue laxity, tibial bone loss, inappropriate bone resection, improper cementation, preoperative varus deformity of 20°, and femoral bowing of 5° could contribute to malalignment after TKA⁽⁷⁾.

Limb alignment that deviates within a neutral mechanical axis $\pm 3^\circ$ is still considered acceptable

⁽⁸⁾. Improved limb alignment of implants after TKA is associated with better function, greater stability, a lower rate of loosening, higher clinical scores and increased longevity⁽⁹⁾.

Malalignment after TKA could cause overloading of the implant bearing and the bone itself, leading to osteolysis, instability and early loosening, which is one of the major mechanisms leading to early clinical failure and may result in revision surgery⁽¹⁰⁾.

Many studies have also thought that prosthesis survival following TKA depends on restoration of the mechanical alignment of the operated leg⁽¹¹⁾.

Aim of the Study:

This aim of this study was to highlight the effect of proper mechanically aligned replaced knee in relation to the function.

Patients and Methods

Patients were assessed retrospectively of primary total knee patients of 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.

Physical examination:

1- Patients examined clinically according to the items of knee society score⁽¹²⁾.

- Patient age and sex and body mass index and operated side were recorded.

A- First item of knee society score⁽¹²⁾ is assessment of pain during walking and climbing stairs. If the patient felt pain during walking, he or she was scored from 0 to 35 points according to degree of pain (severe, moderate, mild, none pain during walking). Pain during climbing stairs from 0 to 15 points (severe, moderate, mild, non-pain during climbing stairs).

B- Assessment of range of motion.

- Active range of motion assessed and every eight degrees range of motion achieved by prosthetic knee equal one point of the score.

C- Assessment of stability of prosthetic knee.

- Medial and lateral stability assessed by valgus and varus stress test at maximally extended knee.

- Medial gapping by valgus stress test assessed degree of medial stability of prosthetic knee. Gapping from 0 to 5mm considered stable and scored by 15 points and by the same way varus stress. If gapping from 5 – 10 mm the knee scored by 10 points. If gapping more than 10 mm, knee scored by 5 points.

- Anterior and posterior stability assessed by anterior and posterior drawer test at 90 degree flexed knee so if shifting of prosthetic knee from 0 – 5 mm, the knee scored by 10 points. If shifting from 5 – 10 mm, the knee scored by 8 points. If shifting was more than 10 mm, the knee scored by 5 points.

D- Extension lag, flexion contracture of knee, malalignment and pain at rest were recorded.

2-Radiological evaluation of patients was by long leg standing x-ray from pelvis to ankle of neutrally rotated limb by patella facing forward to assess.

A- Mechanical axis of lower limb by a line running from center of head of femur to the center of talus bone. In properly aligned prosthetic knee, the mechanical axis must pass through the center of the knee. If mechanical axis was running medial to the knee, the limb will be in a varus position of prosthetic knee. And if mechanical axis line pass lateral to knee, it was in a valgus position. Angle of prosthetic limb is the angle between mechanical axis of the limb and the mechanical axis of the femur.

B- Mechanical axis of femur is a line running from center of femoral head to the center of prosthetic femoral condyle. Mechanical axis

of tibia is a line running from center of tibial plateau to the center of tibial plafond. Both mechanical axis of femur and tibia make Hip-knee-ankle angle which should be $180 \pm 3^\circ$ in properly aligned total knee replacement. The medial proximal tibial angle is the angle between a tangential line of tibial implant and mechanical axis of tibial and this angle should be $90^\circ \pm 3$.

Statistical methods:-

Results were collected, tabulated, statistically analyzed by statistical package SPSS version 22 (Armonk, NY: IBM Corp, 2013). Two types of statistics were done:

Descriptive statistics: e.g. percentage (%), mean (x) and standard deviation (SD).

Analytic statistics: e.g.

-Chi-square test (χ^2) was used to study association between two qualitative variables.

-Students t-test is a test of significance used for comparison between two groups having quantitative variables

-Pearson's correlation coefficient measures how variables or rank orders are related.

-A P-value of < 0.05 was considered statistically significant.



Fig. (1): Clinical and radiological examination.

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 mean age 56 years old with range (36-67). The mean body mass index was 36 with range (24-40). The mean postoperative duration was 2 years with range (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)
	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 of neutral aligned knee was 55.83, in varus aligned group was 56.80 with no significant relation between postoperative limb alignment and mean age of patients. Higher mean value of BMI in varus aligned group 40.5 in comparison to low mean value of BMI in neutral aligned knees 33.5, with significant relation between BMI and postoperative alignment, this indicates that higher BMI is associated by varus postoperative limb alignment. There was no significant relation between postoperative alignment and postoperative duration, sex of the patient and side of operated limb.(**Table 2**)

Table 2: Demographic data in relation to type of limb alignment in TKR patients.

Items	Neutral alignment (n=18) Mean± SD	Varus alignment (n=20) Mean± SD	t-test	P-value
Age (years):	55.83±3.54	56.80±11.40	0.28	0.778
BMI (Kg/m ²):	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 (%)	χ^2	0.154
	2 (11.1)	6 (30.0)		
Males	16 (88.9)	14 (70.0)	2.03	0.154
Side of TKR:			2.59	0.107
	Rt	7 (38.9)		
Lt	11 (61.1)	13 (65.0)		
		7 (35.0)		

*: significant

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

Table 3: Radiological data in relation to type of limb alignment in TKR patients.

Radiographic data	Neutral alignment (n=18) Mean± SD	Varus alignment (n=20) 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 higher Knee Society Score with mean value 85% than in varus aligned TKR of KSS 82%. With significant correlation between postoperative alignment and KSS. There was significant correlation between range of motion and postoperative alignment with 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) Mean± SD	Varus alignment (n=20) 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 were sub-grouped to < and >= 10 degrees deviation from neutral alignment, as the degree of varus alignment increases, the knee society score and range of motion decreases with significant correlation . (**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) Mean± SD	≥ 10° (n=8) 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 higher mean percent of knee society score in angle deviation < 10 ° than in angle ≥ 10° in varus alignment patients.

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

Mal-alignment leads to complications such as aseptic loosening, instability, polyethylene wear and dislocation of the patella. The post-operative alignment of the knee has been considered as the key of success and predictor for the revision surgery for better outcome⁽¹³⁾. The definition of good and bad alignment is entirely arbitrary. **Sikorski**⁽¹⁴⁾ made an arbitrary unit that within 2° of neutral was defined as good alignment.

Some other authors also described that limb alignment after TKA to within 3° of the normal mechanical axis is important for good alignment in order for good post TKA outcome^(15,16).

Most surgeons still agree, and it is traditionally believed, that the postoperative alignment should be to within 0° +/- 3° of the mechanical axis. This is thought to improve the durability of the TKR; the evidence of which has been founded on data from clinical, retrieval and finite element studies⁽¹⁷⁾.

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

There was significant correlation between body mass index and postoperative limb alignment with lower mean values of body mass index in neutrally aligned group (33.5 with standard deviation 5.66) than varus aligned group of mean body mass index (40.5 with standard deviation 6.29). This indicates that obesity is risk factor of varus malalignment of postoperative limb as documented by **Pieter-Jan et al.**⁽¹⁸⁾. There was no significant correlation between postoperative limb alignment and age, postoperative duration, sex and side of operated limb. The mean value of hip-knee-ankle angle was higher (178.67° with SD 1.3°) in neutrally aligned group compared to the varus aligned group of lower mean value of hip-knee-ankle angle (168.3° with SD 4.57°). This mean that properly neutrally aligned total knee replacement should has hip-knee-ankle angle within 180° ± 3° as documented by **Rand, et al.**⁽¹⁵⁾. The mean value of medial proximal tibial angle of neutrally aligned group was (89° with SD

1.71°) which is higher than the mean value of medial proximal tibial angle in varus aligned group (86.7° with SD 0.92°), which indicates that varus malaligned postoperative limb may leads to varus collapse of tibial component as documented by **Michael et al**⁽¹⁹⁾, and indicates also that properly neutrally aligned tibial component should be (90° ± 3°) of mechanical axis of tibia as documented by **Perillo Marccone et al.**⁽²⁰⁾. There was higher mean value of knee society functional score (85.5 % with SD 4.42) in neutrally aligned group compared to lower mean value of knee society score in varus aligned group (82.8% with SD 3.04) as documented by **Longstaff et al.**⁽²¹⁾. And lower mean value of range of motion in neutrally aligned group (124.17° with SD 4.69°) compared to higher mean value of range of motion (129.5° with SD 6.67°) in varus aligned group. This indicate that although knee society score is higher in neutrally aligned group than in varus aligned group, the range of motion is higher in varus group than in naturally aligned group. This indicate that the knee society functional score does not depend only on 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⁽¹²⁾. There was significant correlation between postoperative limb alignment and knee society score and range of motion of prosthetic knee. Inside the varus group which were twenty cases of the study, there was significant negative correlation between the degree of varus malalignment postoperatively which is evaluated by the angle of deviation from neutral alignment and the knee society score and range of motion which means that as the degree of varus malalignment increases which described by increase in the angle of deviation from neutral alignment, the knee society score and range of motion decrease.

There are some limitations of our study which are short postoperative duration of follow up with mean 2.16 years and Small number of cases 38 cases only.

Longstaff et al. (2009)⁽²¹⁾ Performed 159 TKA surgeries between May 2003 and July 2004. They observed computed tomography (CT) scan for assessing post-operative alignment and found better functional scores (KSS score) and a shorter hospital stay with a neutral mechanical axis compared to mal-aligned groups at 1 year follow-up (P = 0.01). Our study performed on 32 cases at 1 to 4 years follow up with the same results (P value = 0.009).

From a series of 115 TKAs, **Jeffery et al.** ⁽¹³⁾ compared the results of Macquet's line with the post-operative results using a long leg radiographs. They observed 3% incidence of subsequent loosening in well aligned groups and 24% of loosening in mal-aligned groups (error of approximately $\pm 3^\circ$), which was highly significant ($P = 0.001$). This suggested that accurate coronal alignment is a confounding factor preventing loosening following TKA surgery. Our results confirmed overall function of TKA is better in mechanical axis line to be 180 ± 3 degrees.

Similarly a randomized control study comparing conventional versus computer assisted TKR done by **Choong et.al.** ⁽²²⁾ found better post-operative International Knee Scores (IKS) in a good aligned knees with a mechanical axis within 3° of neutral. Our study was conventional TKA with the same results.

The retrospective study done by **Fang et al.** ⁽²³⁾ in 3992 patients in 2009 for primary TKRs found that the implant survivorship rate was higher in the neutral group (2.4° to 7.2° valgus). The revision rate for this group was 0.5% compared to 1.8% (varus) and 1.5% (valgus) which was different from the neutral group. The implant survival rate was statistically significant: 99% in the neutral group, 95% in the varus group and 97% in the valgus group in the 20 years follow up period. We agree with these results.

Similarly **Kennedy et al.** ⁽²⁴⁾ also found superior results when the mechanical axis falls in the center of the knee. Some of the failed TKRs also found a high degree of polyethylene thickness loss in the medial compartment of the tibial component where the mechanical axis > 5 degree valgus/varus groups ⁽²⁵⁾. We agree with these results.

Conflicts on alignment

It is quite important maintain neutral alignment for better outcome of the surgery, such as durability of the implant and maximizing the function of the knee joint. But the alignment in total knee arthroplasty is only based on two variables, either aligned within $0^\circ \pm 3^\circ$ of a neutral axis or malaligned ⁽²⁶⁾. So this fact has still been in debate for the better result of TKA. There are some studies published in the literature that challenges the coronal alignment. **Parratte et al.** ⁽²⁷⁾ studied 398 primary TKAs between 1985 and 1990. They stratified the patients into aligned (achieving a mechanical axis of $0^\circ \pm 3^\circ$) and malaligned groups. In the 15 year Kaplan Meier implant survival rate they didn't found any significant results between those two groups. The results showed in the well aligned groups there is revision rate of 45 in 292 (15.4%) and in

malaligned groups there is a revision rate of 14 in 106 knees (13%). This shows that mechanical alignment is not a perfect marker for measuring patient satisfaction and durability of the implant.

In 2010 **Matziolis et al.** ⁽²⁸⁾ retrospectively studied 218 patients. Among them 30 malaligned varus groups (post-operative mechanical axis deviation of (6.3° to 10.7°), they didn't found any worst medium-term clinical or radiological outcome compared to neutrally aligned groups. Regarding the post-operative alignment. Besides the mechanical axis, obesity also leads to poor outcome because it has impact on tibial component failures. Body Mass Index has also been found that influence the alignment in TKA surgery. One study found a failure and requiring revision surgery despite achieving neutral coronal alignment in a patient with body mass index, 44.6 at the time of first surgery ⁽²²⁾. Similarly, the study done by **Pieter-Jan et al.** ⁽¹⁸⁾ found a more chance of varus alignment with high BMI with significant result ($P = 0.02$). They also found more damage to medial component damage in valgus groups and damage towards lateral side in varus groups. Whereas they did not found any significance results in neutral HKA groups

Bonner et al. ⁽²⁹⁾ in 2011 studied 501 consecutive TKRs between 1987 and 1997 using long- leg AP weight bearing radiographs. They stratified the patients into 'aligned' (neutral mechanical axis $\pm 3^\circ$) and 'malaligned' (mechanical axis deviated from neutral by more than 3°). They found that implant survival was slightly higher in the aligned group but the difference was not statistically significant (using Kaplan Meier survival analysis). They concluded "the relationship between survival of a primary TKR and mechanical axis alignment is weaker than that described in previous reports." These results were also documented by **Morgan et al.** ⁽³⁰⁾, **Ritter et al.** ⁽³¹⁾ and **Vanlommel et al.** ⁽³²⁾ ..

Conclusion

Neutrally aligned TKR has better functional outcome in comparison to malalignment total knee replacement.

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