Coronal alignment in total knee arthroplasty and its effect on functional outcome A retrospective study

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ABSTRACT

Background

This retrospective study was conducted to compare the coronal alignment of the lower extremity before and after surgery in patients undergoing total knee replacement by assessing the mechanical axis in the full-length weight-bearing radiograph taken preoperatively and post-operatively, and to assess the clinical outcome after TKA with reference to the mechanical axis.

Method

Fifty eight patients who underwent primary TKA from date October 2013 to March 2017 were included in the study. The patient's demographics such as age, gender primary TKA were noted. All patients underwent clinical and radiological evaluation including standardized radiographs (Antero-posterior long length leg X-Ray) was evaluated. For clinical outcome scoring the Hospital for Special Surgery score (HSS) and Western Ontario and McMaster Universities Arthritis Index (WOMAC) were used. One-way ANOVA was used to compare the outcome of the surgery and the alignment ($p < 0.05$).

Result

Out of the 58 patients included in the study, 16 (27.58%) were male and 42 (72.41%) were female with age ranged between 34 to 88 years (mean 65.44 years). The male patient's age ranged from 53 to 85 (median 63 years) and that of female patients ranged from 52 to 83 (median 65.5 years). The overall mean HSS score improved from 59.86 ± 10.91 preoperatively to 82.52 ± 11.04 in one year postoperatively (<0.0001) and WOMAC score improved from 33.98 ± 11.25 to 10.4 ± 6.06 (P<0.0001) after 1 year from the TKA respectively. Both showed a significant difference in the results. There were 50 patients with pre-operative Varus alignment and 8 with pre-operative valgus alignment. Pre-operative Varus groups have a post-operative HSS score of83.98±9.962153 and that of pre-operative valgus groups has HSS score of 77.625±14.20199. Similarly, pre-operative Varus group had a postoperative WOMAC score of 9.38±5.27949 and that of the valgus group had 12±9.273618. In these two groups, there was no significant difference between their post-operative HSS score (P=0.2571) and WOMAC score (P=0.4590). After the surgery, 25 patients (43.10%) had varus alignment, 22 patients (37.9%) had neutral alignment and 11 patients (18.97%) had valgus alignment. The post-operative mechanical axis group was divided into the post-op varus group, post-op neutral group, and post-op valgus group. After comparing within the groups, the neutral group had the highest HSS score (91.3636±4.1946, lowest WOMAC score (5.2272±1.37945), P<0.005, which showed the best result and the HSS score of post-operative varus group was (82.12±7.5), the WOMAC score was (9.64±4.344) showing the moderate result. The postoperative valgus group has HSS score (68.82 + 9.39), WOMAC score (16.3636 + 8.205), showing worst result.

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Conclusion

Total Knee Arthroplasty is a good treatment modality for primary osteoarthritis. The coronal alignment before surgery has no significant effect on the function after total knee arthroplasty. However, the post-operative coronal alignment of the lower limbs was related to the clinical function of the patients. The outcome of the patient with the mechanical axis was the best with neutral groups followed by the Varus group and was the worst in the valgus group.

Keywords: **Total Knee Arthroplasty (TKA), Coronal alignment, Mechanical Axis, Hospital for Special Surgery Knee (HSS), Western Ontario and McMaster Universities Index (WOMAC), International Knee Score (IKS)**

Introduction

Knee arthritis, mainly osteoarthritis is one of the common causes of pain, limitation of activity that causes a huge economic burden to family and society. Total Knee Arthroplasty (TKA) is an important milestone in the history of orthopedic surgery. TKA is one of the most common and successful procedure[1]to replace the diseased or damaged joint surface of the knee with an artificial prosthesis for the relief of disabling pain and restoring the function of the knee. Mal-alignment of the components and mainly the axial alignment of the limb are well within the control of the operating surgeon. Several studies have concluded that the durability of the total knee replacement is dependent on the postoperative axial alignment of the lower extremity[2,3].

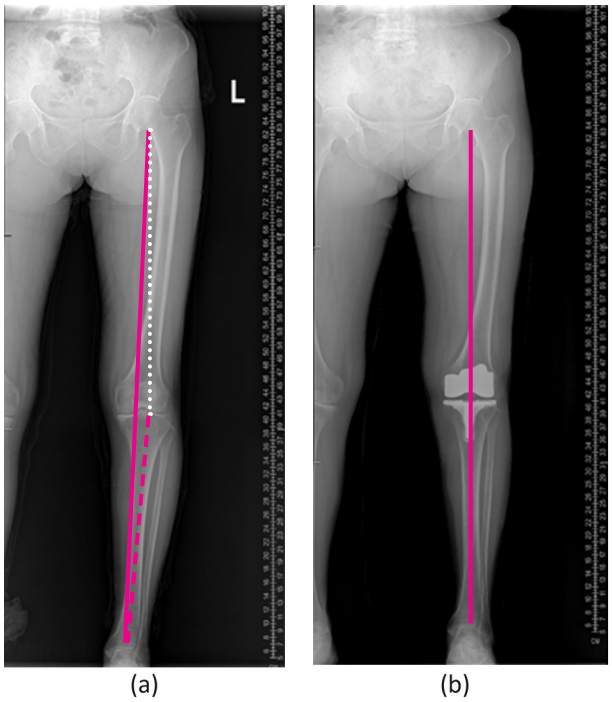
For successful outcome, good alignment of the tibial and femoral components (as well as correct patella tracking) is essential, leading to lower wear of the prosthesis[4]. TKA has become a successful treatment for advanced and symptomatic knee OA, particularly in elderly patients.

Coronal Alignment in Total Knee Arthroplasty

Mechanical Alignment

The use of mechanical alignment in total knee arthroplasty was described by John et al[5]. The mechanical axis is defined as the line drawn on a standing long-leg anteroposterior radiograph from the center of the femoral head to the center of the talar dome. This line is also referred as Macquet's line (figure 2). It is measured on Antero-Posterior view of long leg radiograph. Coronal alignment is usually measured using this line[6]. The mechanical axis usually passes through medial to the tibial spine. This axis typically should project through the center of the knee joint, described as a "neutral" mechanical axis (figure 2). It should be 0° at neutral, following TKA surgery[7]. Insall mentioned that when the mechanical axis lies to the lateral side of the knee center, the knee is in mechanical valgus alignment[8]. In mechanical varus alignment (figure 2), the mechanical axis of the limb lies to the medial side of the knee center as mentioned by Townley in his study[9].

Insall believed that mechanical alignment was the superior method, because if the joint was anatomically aligned this would lead to medial tibial plateau fixation failure, due to the increased forces across the medial joint component if the knee is anatomically aligned[7].Insall et al. also noted that despite the even distribution of joint loading forces between compartments found during the stance phase, but during the gait phase there might be uneven loading of the component due



(a) (b)

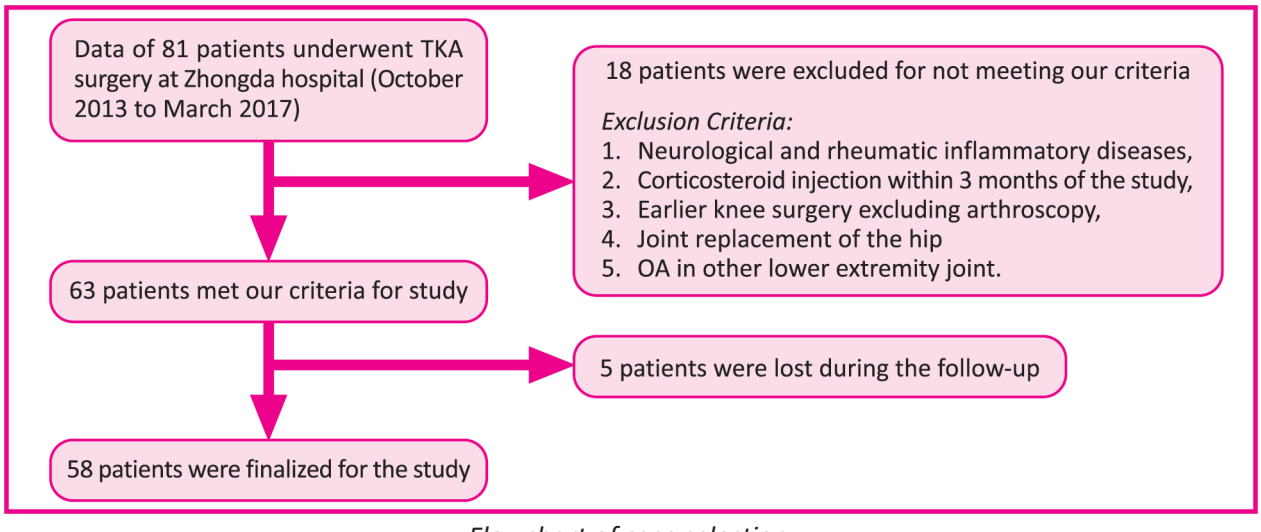
Fig 1: Long-leg radiograph (a) the red line indicating Macquet's line, the dotted line on left figure refers to mechanical axis of femur, and dashed line refers to that for tibia. Leg showing in varus alignment. (b) The figure on right shows mechanical axis well aligned after the TKA surgery of same patient.

to a "laterally" directed ground reaction force[7]Full length radiographs are more useful for assessing mechanical alignment and the position of the implants on load-bearing position.

Methods and Materials

Mechanical Axis in the post-operative groups

We used the long length X-ray of lower limb for the assessment of mechanical axis, whichwas measured on the X-ray films on the computer system of Zhongda Hospital. On the basis ofMacquets line which was observed in the X-ray, the alignments were divided intovarus, valgus and neural groups. Before surgery, none of our patients had neutral alignment.



Flowchart of case selection

Results

Table 1. Demographic data of the total knee arthroplasty performed.

Demographic details		Results
Age		65.44±8.045
Gender	Male	16 (27.58%)
	Female	42 (72.41%)
Operation side	Right	29 (50%)
	Left	29 (50%)

Table 2. Comparison of results between Pre and Post-operative knee score results of TKA

	Pre-op	Post-op	P-value
HSS	59.86 ± 10.91	82.52 ± 11.04	< 0.0001
WOMAC	33.98 ± 11.25	10.4 ± 6.06	< 0.0001

Table 3. Comparison between Pre-operative Alignment groups and their Post-operative results

Pre-op Alignment groups	Post-Op HSS	P-value	Post-op WOMAC	P-value
Varus (n=50)	83.98 ±9.962153	0.2571	9.38 ±5.27949	0.4590
Valgus (n=8)	77.625 ±14.20199		12 ±9.273618	

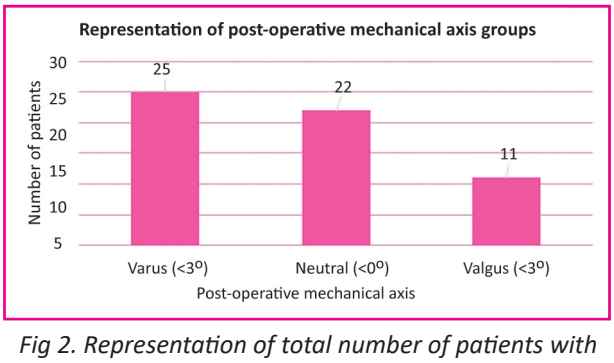


Fig 2. Representation of total number of patients with postoperative mechanical axis

Table 4. Results between post-operative alignment groups after TKA

Post-operative alignment groups	Number	Mean±SD
Varus	25	82.12±7.554
Neutral	22	91.3636±4.1946
Valgus	11	68.82±9.39

Varus: Patient with a postoperative mechanical axis of<3°

Neutral: postoperative mechanical axis = 0°

Patient with a postoperative mechanical axis of >3°

The post-operative HSS scores between different groups are illustrated in table 4 above. This indicates that, varus and valgus alignment cases had low knee scores as compared to neutral groups. Based on the HSS evaluation criteria, (Excellent =>85, Good = 70-84, Fair = 60-69, Poor =<60), Neutral group had excellent, varus group has good, and valgus group had fair functional outcomes respectively.

According to WOMAC score criteria, Neutral group had lower scores indicating better results compared to the Varus group and valgus group.

Comparison was done by one way ANOVA which shows statistically significant results (p value <0.05).

The WOMAC score of three post-operative groups were further compared using Tukey's multiple comparison test, which also showed significant difference (P<0.05) between each group. Similarly, the order of good alignment here is Neutral group followed by varus and valgus alignment.

Table 5. Results of Post-Operative HSS score evaluation in different alignment groups

Tukey's multiple comparisons test	Mean Diff.	95.00% CI of diff.	Significant?	Summary	Adjusted P Value
Varus vs. Neutral	-9.244	-14.1 to -4.383	Yes	****	<0.0001
Varus vs. Valgus	13.3	7.284 to 19.32	Yes	****	<0.0001
Neutral vs. Valgus	22.54	16.4 to 28.68	Yes	****	<0.0001

The comparison was done by one-way ANOVA which shows statistically significant results (p-value<0.0001).

The HSS score of three post-operative groups was further compared using Tukey's multiple comparison test, which also shows a significant difference (P<0.0001) between each group. The order of good alignment here is Neutral group followed by varus and valgus alignment.

Table 6. Post-Operative WOMAC score evaluation

Post-operative alignment groups	Number	Mean ± SD
Varus	25	9.64±4.344
Neutral	22	5.2272± 1.37945
Valgus	11	16.3636±8.205

Varus: Patient with a postoperative mechanical axis of<3°

Neutral: postoperative mechanical axis = 0°

Patient with a postoperative mechanical axis of > 3°

The postoperative WOMAC scores between different groups are stated in Table 6 above. This indicates that varus and valgus alignment cases had higher knee scores as compared to neutral groups.

Discussion

Total knee arthroplasty is an excellent procedure for arthritic patients in whom all the conservative measures are exhausted and if proper attention is made for the patient selection. Proper positioning of the implants is assessed by the central alignment of the mechanical axis[10]. So, good surgical technique and skills is needed to attain satisfactory postoperative alignment.

The most important finding of our study was, with better alignment, the clinical outcome of the surgery was also better. The clinical outcome on the basis of HSS, WOMAC osteoarthritis index all showed significant clinical improvement in well aligned patients. Thus a strong correlation exists between the functional outcome and the axial alignment of the extremity postoperatively. The study analyzed by both the knee score suggested that neutral alignment group remains superior in terms of good functional outcome followed by varus and valgus.

Table 7: Results of Post-Operative WOMAC score evaluation in different alignment groups

Tukey's multiple comparisons test	Mean Diff.	95.00% CI of diff.	Significant?	Summary	Adjusted P Value
Varus vs. Neutral	4.413	1.171 to 7.655	Yes	**	0.0051
Varus vs. Valgus	-6.724	-10.74 to -2.711	Yes	***	0.0005
Neutral vs. Valgus	-11.14	-15.23 to -7.041	Yes	****	<0.0001

TKA has been shown to be a highly effective treatment that results in substantial improvement in patient functioning and health-related quality of life[11]. Until now it has been first-line procedure for end-stage knee OA. The long-term results of TKA have been well documented with survival rates of up to 98% at 15 years[12].

HSS and WOMAC score is regarded as the specific functional outcome measures for the knee arthritis. Some studies revealed that these scores are one of the standard outcome indexes for the evaluation of knee[13,14]. In our study we observed that a neutral alignment group has better knee scores as compared to outlier groups. But our study challenge to other studies. Matzioliset al.[15]didn'tfind any worst medium-term clinical or radiological outcome in outlier groups compared to neutrally aligned groups. Also the study done by Vanlommel and colleagues observed residual varus in 46 knees out of 143 cases. In those post-operative residual varus cases, they found significant better Western Ontario and McMaster University Osteoarthritis Index (WOMAC) and KSS score[16].

The study conducted by Nathaniel Huang et.al in 111 patients, found better IKS score in post-operative mechanical axis within 3° neural at 2 years ($P < .001$) and at 5 years ($P = .028$). They also found better pain score in patients whose alignment was within 3° neural. They also found better SF score as well in those aligned groups. So, better coronal alignment of total knee prosthesis (to within 3° of neutral) results in better function and better quality of life, improved pain scores postoperatively[17].

There is also agreement with other recent studies. There are many studies which showed significant results for the alignment and the outcome after TKA surgery. Longstaffet al.[18] performed 159 TKA surgery 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 ($P = .013$).

Besides the mechanical axis, obesity also leads to poor outcomes because it has an 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 (valgus 1°) in a patient with body mass index, 44.6 at the time of first surgery[19]. Similarly, the study done by Pieter et al.[20] 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.

Other factors also play a role in TKA such as skeletal, neuromuscular factors, dynamic loading around the knee, body posture, genetic factors. But fewer studies have been gone through it regarding these factors and their effects on TKA surgery. Neutral mechanical alignment produces balanced static knee loading. But there is another factor called dynamic loading which affects knee loading more than static loading of knee. The study done by Miller EJ, Pagnano etal.[21] regarding the relationship between tibio femoral angle and static medial plateau loading found that 13 of 15 patients (87%) had static mechanical alignment of 0 ± 3°, only seven of 15 patients (47%) had balanced dynamic loading if the knee joint. This concludes that the cause of bad outcome despite well-aligned knee following TKA, as the mechanical alignment does not predict dynamic loading after modern knee arthroplasty. Our study has some limitations regarding these findings.

Knee radiographs have an important role in the evaluation of patients with knee arthritis. The post-operative long leg radiographs taken after TKA is used for assessing the alignment for the long-term outcome. However, there is a chance of errors of parallax and poor control of patient positioning in the normal standing radiographs[22]. Thus for the accurate assessment of mechanical axis and the axial alignment of the lower extremityfull lengthweight-bearing radiograph of the lower limb including the hip, knee and ankle is essential.

Some studies suggested that the post-operative radiograph alone cannot predict functional outcomes. The rotational alignment may also be a significant factor affecting the accuracy of the assessment which cannot be observed in a plain radiograph. So, measuring the mechanical axis using the plain radiograph has been reported to be inferior to other superior systems like CT scan[23]. One study suggested that alignment assessed by the long leg radiographs is only two dimensional so the kinematics assessment of knee is superior since it provides 3 dimensional alignment component[24].

There are several limitations to this study. Firstly, the follow-up time was poor, we missed many patients due to change of patients contact numbers and addresses. Patient with good results mostly refuse to come back for further follow-up. However we confirmed clinical data, including pre-operative symptoms with individual patients during follow up telephone interviews. Secondly, most of the patients weren't ready to have post-operative radiological investigations. Thirdly, the number of patients was too small to correlate the outcomes of the TKA surgery which is one of the major drawbacks of our study.

Conclusion

The study has shown that a statistically significant improvement between the preoperative and postoperative knee scores, the outlier groups did showed only slight improvement in their knee scores. It also showed that well aligned knees after the TKA surgery correlates with clinical outcome according to the HSS and WOMAC score. Beside the osteoarthritic knee, the general health condition and the mental status should be also considered. Thus a strong correlation exists between the functional outcome and the axial alignment of the extremity postoperatively.

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