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Original Article

Frequency of Restoration of Mechanical Axis in Patients Undergoing Primary Total Knee Arthroplasty by Using Mal-alignment Test in Pre- and Post-Operative Scanogram

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Introduction:
Objective:
To assess the frequency of restoration of mechanical axis deviation (MAD) in patients undergoing primary total knee arthroplasty (TKA) using malalignment test on pre- and postoperative weight-bearing scanograms.
Methods:
A prospective cohort study was conducted from August 2018 to August 2019 at a tertiary care hospital. A total of 30 patients aged 40–100 years with advanced osteoarthritis were included. Pre- and postoperative MAD was measured on full-length weight-bearing scanograms. Patients with revision TKA, rheumatoid arthritis, tumor surgeries, or failed primary TKAs were excluded. Mechanical axis deviation was assessed on the third postoperative day and correlated with functional outcome.
Results:
Among 30 patients, 46.7% were male and 53.3% female, with a mean age of 58.3 ± 9.8 years. The mean preoperative MAD was 26.88 ± 43.26 mm (80% medial, 20% lateral), and postoperative MAD was significantly reduced to 10.56 ± 7.31 mm (100% medial). Restoration of neutral alignment was achieved in 80% of cases. No statistically significant association was found between restoration of MAD and variables such as age, gender, BMI, comorbidities, or side of surgery ($p > 0.05$).
Conclusion:
Primary total knee arthroplasty effectively restored early radiographic mechanical alignment in 80% of patients using a MAD threshold of 15 mm from the knee center. Because immediate postoperative standing radiographs may not reflect physiological loading, these findings should be interpreted as early alignment only. Larger studies with later postoperative imaging, validated functional outcomes, and measurement reliability assessment are recommended.
Keywords: Restoration, Mechanical Axis Deviation, Primary Total Knee Arthroplasty, Mal-Alignment Test, Pre- and Post-Operative Scanogram

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Introduction:

It is well established that advanced osteoarthritis is best managed with Total knee replacement, with a conservative approach having a limited role in management. The main indications are to relieve pain and discomfort at rest and during walking, improve knee stability and function, and restore the neutral alignment of the lower limb [1,2].

The most important factor for the long-term outcome of total knee arthroplasty is to restore the neutral alignment of the lower limb. Malalignment is known to increase mechanical and shear stresses on bearing surfaces and the bone-metal interface, and leads to a poor long-term functional outcome

[1]. It has been shown to cause early wear of the prosthetic implant, periprosthetic fractures, and instability of the knee joint [2]. Various studies have reported on the survivorship of primary cemented total knee arthroplasty, and according to one study, it is approximately 90% at 15 years post-surgery. [3]

Studies reveal that the TKA has a patient dissatisfaction rate of around 20 to 25 % with a large portion being attributed to malalignment. To improve outcomes, the development of newer technologies like computer navigation and patient-specific instrumentation have been shown to better assist in the restoration of the mechanical axis of the knee. However, improved clinical results in many instances have not been achieved even though these innovations have led to improved radiographic alignment and fewer axis outliers on many occasions. [2]

Although the majority of the factors that improve TKA survivability are not within the operating surgeon's control, some factors can be controlled, such as ensuring that the axial alignment of the lower limb and the alignment of the implant are well within the limits. This is where radiology has a role and is considered mandatory for pre- and post-operative assessment, as it can help identify potential complications of the procedure before patients become symptomatic and decrease the chance of the problem being overlooked. [1]

Scanograms are full-length weight-bearing radiographs, in which hip, knee, and ankle joints are assessed to assess the alignment of the lower limb [1, 4]. They are accurate for determining and reporting limb alignment for Total Knee Arthroplasty (TKA) [5].

In order to assess the acceptable restoration of the mechanical axis of the lower limb, parameters such as the mechanical axis deviation (MAD) are measured on a scanogram before and after primary total knee arthroplasty.

International literature has evaluated mechanical axis restoration after TKA using long-leg radiographs/scanograms. However, prospective regional data using weight-bearing scanograms and conventional instrumentation remain limited in our setting. This study provides regional baseline data on early postoperative mechanical axis restoration after primary TKA.

OBJECTIVE:

To assess the frequency of restoration of mechanical axis deviation in patients undergoing primary total knee arthroplasty by using the mal-alignment test in pre- and post-operative scanograms.

MATERIAL & METHODS:

A prospective cohort study was conducted from 3rd August 2018, to August 2019 at our tertiary care hospital. A non-probability consecutive sampling technique was used for the study. Patients undergoing bilateral or unilateral primary total knee arthroplasty secondary to advanced osteoarthritis (Kellgren and Lawrence radiographic grades III–IV), irrespective of race and gender, aged 40 to 100 years, were included in our study. Kellgren and Lawrence classification is a commonly used radiographic grading system for osteoarthritis severity (grades 0–IV), where grades III–IV represent advanced disease with definite joint space narrowing, osteophytes, and deformity. Patients undergoing revision total knee arthroplasty, tumor surgery, failure of primary total knee arthroplasty, and patients already diagnosed with rheumatoid arthritis were excluded.

DATA COLLECTION PROCEDURE:

After ERC approval and informed verbal consent, all patients admitted for primary total knee replacement meeting the inclusion criteria were included in the study.

Patients were enrolled by using a proforma, which includes demographic details (age and gender), pre-op MAD and post op MAD, and duration of osteoarthritis and body mass index (BMI).Pre-operative weight-bearing full-length scanogram was obtained from the Hospital Information Management System (HIMS) of the hospital, and mechanical axis deviation (MAD) was measured by primary researcher.

We used the Mal-alignment test to determine the deformity of the lower limb. It can be tested using different measurables, including the measurement of mechanical axis deviation (MAD) or mechanical lateral distal femoral angle (mLDFA), anatomical distal femoral angle (aLDFA), medial proximal tibial angle (MPTA) and hip-knee-ankle angle on scanogram [4]. For the purpose of this study, MAD was used as the primary indicator of mal-alignment.

Mechanical Axis Deviation (MAD) is defined as the distance between the mechanical axis line and the center of the knee joint in the frontal plane. The

mechanical axis of the lower limb is represented by a straight line from the center of the femoral head to the center of the ankle joint. This line, also known as Maquet's line, ideally passes through the center of the knee joint or just medial to the tibial spine. Any deviation of this line from the center of the knee, as visualized on a weight-bearing full-length scanogram, is recorded in millimeters [4].

For the purpose of this study, "MAD within limits" (acceptable restoration) was defined as a postoperative MAD of 0–15 mm from the knee center on the weight-bearing scanogram (medial or lateral). This threshold was selected to represent near-neutral alignment on the malalignment test, recognizing that the normal mechanical axis typically passes through the knee center or slightly medial toward the medial tibial spine.

On the third postoperative day, once the patient was stable and able to ambulate, another weight-bearing full-length scanogram was obtained. The mechanical axis was measured again by the primary researcher using the same technique.

Patient confidentiality was maintained, and data were stored in a protected computer by the principal investigator.

Patients were followed during admission for routine postoperative care, and a postoperative scanogram was obtained once they were stable and able to ambulate. No validated patient-reported or clinician-reported functional outcome score was collected as part of this study.

DATA ANALYSIS PROCEDURE :

Data were entered and analyzed using SPSS version 27. Descriptive statistics were computed for quantitative variables, including mean and standard deviation for age, height, weight, BMI, and duration of osteoarthritis. Categorical variables such as gender, presence of co-morbidities (diabetes mellitus and hypertension), and restoration of mechanical axis deviation were presented as frequencies and percentages.

Given the small sample size, analyses were primarily descriptive. Quantitative variables were summarized using mean ± standard deviation (or median and range where appropriate), and categorical variables using frequencies and percentages. Exploratory comparisons of patient factors between the "MAD within limits" and "MAD not within limits" groups are presented descriptively; the study was not powered to detect associations and no adjustment for multiple comparisons was planned.

Result:

Out of 30 patients, 46.7% were male and 53.3% were female. The overall mean age was 58.30 ± 9.80 years. Age was further stratified into two groups for analysis. The mean height, weight, and BMI were 153.53 ± 11.77 cm, 70.50 ± 15.66 kg, and 29.67 ± 4.37 kg/m², respectively. The mean duration of osteoarthritis was 9.00 ± 1.31 years, and this variable was also stratified into two groups.

Regarding the side of surgery, right knee replacement was performed in 53.3% of cases, while left knee replacement was done in 46.7%. Among all patients, 36.7% had a BMI ≥30 kg/m². The prevalence of comorbidities was as follows: diabetes mellitus in 30%, hypertension in 40%, hypothyroidism in 10%, and ankylosing spondylitis in 6.7% of patients.

The mean preoperative mechanical axis deviation (MAD) was 26.88 ± 43.26 mm, with 80% showing medial deviation and 20% lateral. Postoperatively, the mean MAD was reduced to 10.56 ± 7.31 mm, and all cases (100%) showed medial deviation. Restoration of MAD within acceptable limits was achieved in 24 patients (80%).

Due to the limited sample size and small subgroup counts for several comorbidities, analyses exploring associations between alignment restoration and patient-related factors (age, sex, BMI, comorbidities, and side) were treated as exploratory and are presented descriptively (Table 3).

Discussion:

Increased mechanical axis deviation of the leg predisposes knee replacements to develop aseptic loosening. Studies have shown superior long-term results when the deviation from the neutral axis is less than 3-4 degrees [6-8]. Measurements of other parameters such as the femorotibial angle, have also shown superior results with acceptable angles of 5-7 degrees[9]. According to one study on 115 patients, prosthetic loosening occurred in 24% of patients when the mechanical axis exceeded ±3˚ of varus/valgus deviation, compared to only 3% when the axis was within ±3˚ [10]. Our results have shown that a correction of the mechanical axis was achieved in 80% of patients, while in 20% of cases, we were not able to correct the mechanical axis.

The conventional method of correcting the mechanical axis of the leg involves using

extramedullary alignment guides or intramedullary rods for placement of the cutting guides. Although convenient, these techniques are prone to potential errors that can lead to malalignment [11–13]. Multiple anatomical factors contribute to the difficulty in accurately measuring limb alignment during orthopedic procedures. These include discrepancies between the mechanical and anatomical axes of the femur and challenges in precisely locating the center of the femoral head to recreate the mechanical axis. Additionally, errors can arise from the placement of surgical instruments, as well as patient factors such as limb rotation, muscle tone, and weight-bearing status. Weight-bearing scanograms are further affected by soft tissue tension and ligament imbalance, leading to disparities in measurements. Moreover, muscle relaxation under anesthesia alters muscle tone, which can influence the assessment of the correct mechanical axis. One study reported that these errors can result in differences of up to 4 degrees in measured limb alignment [14], while other studies have also documented post-operative varus or valgus deviation in a significant proportion of TKA patients [15,16.]

The study by Jenny and Boeri found no significant difference in post-operative outcomes between computer-assisted total knee arthroplasty (TKA) and the conventional technique. They achieved a mechanical axis of ±3˚ varus/valgus in 83% of patients using a navigation system and in 78% using a conventional technique [17]. However, Plaskos et al reported cutting errors in varus/valgus up to 0.4° to 0.8° and 1.3˚ in flexion/extension [18]. Other factors that may affect accuracy include variations in cementing of prosthetic components and inaccuracies in determining the axis on postoperative weight-bearing long-leg radiographs [19].

In our study, restoration of MAD within acceptable limits was achieved in 80% of patients, highlighting that conventional TKA techniques can achieve satisfactory alignment restoration in the majority of cases. The mean preoperative MAD was 26.88 ± 43.26 mm, which reduced significantly to 10.56 ± 7.31 mm postoperatively. This finding aligns with existing literature emphasizing that TKA generally improves limb alignment, though not always to the ideal neutral axis. our results showed that 20% of patients remained malaligned postoperatively, which is clinically significant given the association of malalignment with early prosthesis failure, aseptic loosening, periprosthetic fractures, and poor functional outcomes. Malalignment leads to abnormal mechanical and shear stresses on the polyethylene bearing surfaces and the bone-cement interface, accelerating wear and compromising implant survivorship.

Few studies in the past have shown that navigation TKA are more accurate than long leg radiographs at controlling intraoperative alignment. But, this has not been taken as a gold standard. On the contrary, many studies have postulated that postoperative scanograms are more reliable in measuring coronal plane alignment as compared to navigation system [20, 21].

Robert Karl Zahn et al.[14] showed that immediate postoperative standing long leg radiograph is of limited value because limb loading is altered because of antalgic component and is therefore non physiological. The actual coronal alignment should be assessed at physiological loading.

Limitation of the Study:

The study has several limitations. First, the sample size was small and no power calculation was performed; therefore, the study should be interpreted as an exploratory/pilot assessment and is underpowered to detect associations. Second, postoperative alignment was assessed on postoperative day 3 which may be influenced by pain, quadriceps inhibition, altered weight distribution, swelling, and soft-tissue balance, and may not represent final alignment. Third, MAD measurements were performed by a single observer and no intra- or inter-observer reliability assessment was undertaken, which may affect reproducibility. Fourth, no functional outcome score was collected, and clinical conclusions are therefore limited to radiographic alignment only. Finally, the single-center design may limit generalizability.

Conclusion:

Our findings suggest that primary total knee arthroplasty using conventional instrumentation can achieve near-neutral early radiographic alignment in the majority of patients, although a clinically important minority remain malaligned on early weight-bearing scanogram. Given the known implications of malalignment for implant longevity, continued focus on accurate intraoperative alignment techniques is warranted. Future studies should include larger cohorts, later postoperative imaging under physiological

loading, validated functional outcomes, and measurement reliability assessment.

Table 1.

Patient Demographics (n=30)

Variable	Mean ± SD / Frequency (%)	Median (Range)	Min–Max
Age (years)	58.30 ± 9.80	55.00 (36)	41 – 77
Height (cm)	153.53 ± 11.77	155.50 (40)	135 – 175
Weight (kg)	70.50 ± 15.66	69.50 (54)	46 – 100
BMI (kg/m²)	29.67 ± 4.37	28.15 (18.50)	25.20 – 43.70
OA Duration (years)	9.00 ± 1.31	9.00 (6)	6 – 12
Gender	Male: 14 (46.7%) Female: 16 (53.3%)	-	-
Knee Side	Right: 16 (53.3%) Left: 14 (46.7%)	-	-
BMI ≥30 kg/m²	Yes: 11 (36.7%) No: 19 (63.3%)	-	-
Diabetes Mellitus	Yes: 9 (30%) No: 21 (70%)	-	-
Hypertension	Yes: 12 (40%) No: 18 (60%)	-	-
Hypothyroidism	Yes: 3 (10%) No: 27 (90%)	-	-
Ankylosing Spondylitis	Yes: 2 (6.7%) No: 28 (93.3%)	-	-

Table 2. ***Mechanical Axis Deviation (MAD) and Alignment Outcomes (n=30)***

Pre-operative MAD (mm)	26.88 ± 43.26	35.50 (209)	-91 – 118
Post-operative MAD (mm)	10.56 ± 7.31	10.75 (32)	0 – 32
Pre-op MAD Direction	Medial: 24 (80%) Lateral: 6 (20%)	-	-
Post-op MAD Direction	Medial: 30 (100%) Lateral: 0 (0%)	-	-
MAD Within Limits	Yes: 24 (80%) No: 6 (20%)	-	-

Table 3. ***Association of MAD Within Limits with Patient Factors (n=30)***

Factor	MAD Within Limits Yes n (%)	MAD Within Limits No n (%)
Gender	Male: 12 (85.7%) Female: 12 (75%)	Male: 2 (14.3%) Female: 4 (25%)
Age Group	≤55 years: 13 (76.5%) >55 years: 11 (84.6%)	≤55 years: 4 (23.5%) >55 years: 2 (15.4%)
OA Duration	≤10 years: 22 (78.6%) >10 years: 2 (100%)	≤10 years: 6 (21.4%) >10 years: 0 (0%)
Knee Side	Right: 13 (81.3%) Left: 11 (78.6%)	Right: 3 (18.8%) Left: 3 (21.4%)
BMI ≥30 kg/m²	Yes: 10 (90.9%) No: 14 (73.7%)	Yes: 1 (9.1%) No: 5 (26.3%)
Diabetes Mellitus	Yes: 9 (100%) No: 15 (71.4%)	Yes: 0 (0%) No: 6 (28.6%)
Hypertension	Yes: 10 (83.3%) No: 14 (77.8%)	Yes: 2 (16.7%) No: 4 (22.2%)
Hypothyroidism	Yes: 3 (100%) No: 21 (77.8%)	Yes: 0 (0%) No: 6 (22.2%)
Ankylosing Spondylitis	Yes: 2 (100%) No: 22 (78.6%)	Yes: 0 (0%) No: 6 (21.4%)

Conflict of Interest:

The authors declare that there are no conflicts of interest regarding the publication of this abstract. No financial support, grants, or benefits have been received by any author related directly or indirectly to the subject of this study.

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