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Basic Science

Postoperative Increased Loading Leads to an Alteration in the Radiological Mechanical Axis After Total Knee Arthroplasty

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ABSTRACT

Background: Standing long-leg radiographs allow assessment of the mechanical axis in the frontal plane before and after total knee arthroplasty (TKA). An alteration in loading, and hence in the forces acting on the knee joint, occurs postoperatively. We therefore postulated that the mechanical axis measured in the long-leg standing radiograph would change within the first year after TKA.

Methods: Standing long-leg radiographs of 156 patients were performed 7 days, 3 months, and 12 months after TKA with determination of mechanical axis of the lower limb.

Results: Seven days after surgery, the mechanical axis amounted 0.8° ± 1.7° valgus. Three months after the operation, at 1.3° ± 1.3° varus, it was significantly different ($P < .001$) from the primary measurement. No further alteration in the mechanical axis occurred during the first year after TKA. This difference was even more pronounced ($P < .001$) in patients with a postoperative lack of complete extension. Seven days after surgery, they had a valgus axis deviation of 1.6° ± 1.6°; after 3 months, the measurement amounted 1.2° ± 1.3° varus.

Conclusion: Measured by a standing long-leg radiograph, the frontal mechanical axis after TKA changes over time. The predictive power of a standing long-leg radiograph in the first week after surgery is limited because limb loading is altered because of pain and is therefore nonphysiological. The actual mechanical axis resulting after TKA can only be assessed in a standing long-leg radiograph at physiological loading.

The influence of a neutral mechanical axis on function and survival after total knee arthroplasty (TKA) is controversially discussed [1]. Nevertheless, the restoration of a neutral mechanical axis with an acceptable range of 3° varus or valgus deviation is currently recommended [2-8].

Mechanical axis and leg geometry can be assessed by standing long-leg radiographs and radiographs of the knee joint in 2 planes [9-11]. To evaluate the quality of endoprosthetic surgery in addition to knee joint radiographs in 2 planes, a postoperative long-leg standing radiograph is recommended [12-15].

However, the time when the mechanical axis of the lower limb axis can be correctly determined is not clear. From a biomechanical perspective, an alteration in the forces exerted on the knee joint and mechanical axis can be expected with increasing loading [5,16-18]. In the early postoperative period, therefore, it is not possible to rule out errors in determining the mechanical axis caused by nonphysiological loading of the limb due to pain.

Until now, there are no examinations that have evaluated the changes over time or influence of loading on alteration in the mechanical axis after TKA.

This study therefore aimed to assess the mechanical axis of the lower limb using standardized long-leg radiographs at different times after TKA and to derive a recommendation for an appropriate examination time. A change in alignment over time would modify the interpretation of immediate postoperative standing long-leg radiographs and a shift in the rate of alignment/malalignment with time would be clinically significant.

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Materials and Methods

One hundred fifty-six patients (86 women and 70 men; age: 70.22 ± 6.71, 53-87 years; body mass index [BMI]: 29.54 ± 2.57, 22.1-35.6 kg/m^2) with primary osteoarthritis of the knee were included in a prospective study. The exclusion criteria included previous knee joint surgery, an extension deficit of >20°, and frontal-plane malposition of >15°. The competent ethics committee gave approval for the study, and an informed consent was obtained from all patients.

The defined examination times for all patients were preoperative, 7 days, 3 months, and 12 months after TKA. The range of motion was determined using a goniometer at these moments.

The patients were divided into 2 groups according to the postoperative range of motion of the knee joint. A distinction was made between complete and incomplete active extensions. All the patients included in the study were followed up.

At each defined examination time, standardized standing long-leg radiographs were performed and the mechanical axis of the leg was measured (Centricity Enterprise Web 3.0; GE Healthcare Pty Ltd, Piscataway, NJ) [1,3,19]. The preoperative planning had aimed for a neutral mechanical axis [1,5,20]. The anterior-posterior longitudinal radiographs were taken with patients standing with feet at shoulder width, distributing their weight as evenly as possible between both feet, with the patella pointing straight forward and with maximum possible knee extension at shielded gonads. The X-ray beam was centered to the joint line level. The digitally processed radiographs were obtained in one exposure with a tube-to-plate distance of 2 m on an imaging plate measuring 354 × 1245 mm, at 80-90 kV, and 63-100 mA depending on the BMI. Criteria for correct rotation of the radiograph were central patellar tracking, coverage of the fibular head by the tibia, and position of the ankle [21]. Radiographs were included and accepted for the study only if they were performed correctly from a technical viewpoint and showed a proper neutral rotation of the leg with correct visualization and projection of the trochanter minor, patella, and fibula head [1,21-25]. Ten radiographs were excluded because these criteria were not complied and repeated. The mechanical axis was defined as a connecting line between the center of the femoral head and the center of the talus. This axis can be further subdivided into a femoral mechanical axis, which runs from the femoral head to the intercondylar gap of the distal femur, and a tibial mechanical axis, which extends from the center of the proximal tibia to the center of the talus. The tibiofemoral angle is calculated from the medial angle between the femoral mechanical axis and the tibial mechanical axis [26]. Positive angles indicate a varus axis, negative angles a valgus axis [27]. All radiographs were assessed by 2 authors (HH, RZ). The mean correlation coefficient of interobserver variability of all measurements was 0.913 (range: 0.89-0.935), whereas the mean correlation coefficient of intraobserver variability was 0.933 (range: 0.915-0.954).

All surgeries were performed under general anesthesia. In each case, implantation was via a medial parapatellar approach. The resection levels were chosen depending on the technique and prosthesis used. The following prostheses were implanted on a randomized basis: 96 Journey Bicruciate Substituting Knees (Smith & Nephew, Memphis, TN), 25 PFC Sigma knees (DePuy Synthes, Warsaw, IN), 7 Attune knee prostheses (DePuy Synthes), 17 NexGen prostheses (Zimmer, Warsaw, IN), and 11 Vega prostheses (B. Braun, Tuttlingen, Germany). No retropatellar replacement was performed.

A standardized program of somatic and functional follow-up treatment was implemented in all patients, including immediate mobilization under full weight-bearing and passive, assisted, and active mobilization of the knee joint [21]. All patients received the same multimodal pain therapy, and thromboembolic prophylaxis included the use of low-molecular-weight heparin [21]. Means, standard deviations, and ranges were ascertained for the selected parameters. The statistical analysis was performed for paired samples using the Wilcoxon test; for nonpaired samples, the Mann-Whitney *U* test was used (SPSS version 21; SPSS Inc, Chicago, IL). A clinically acceptable postoperative alignment was assumed, and patients were defined as inliers when the mechanical leg axis was within a varus/valgus deviation of ±3° [28]. The level of significance was $P < .05$. The alpha level was set at 0.05 for statistical significance.

Results

The mean preoperative mechanical axis of all patients was 4.9° ± 3.8° varus (range: −8° to +15°). The mechanical axis measured immediately after surgery of patients with complete extension showed a valgus axis deviation of 0.8° ± 1.7° (Table 1, Figs. 1 and 2A). Twelve weeks after surgery, this axis amounted 1.3° ± 1.3° varus, a significant difference compared with the primary measurement ($P < .001$; Fig. 2A, Table 1). The slightly varus axis was confirmed at the end of the first year after TKA (1.3° ± 1.2°; range: −2° to +4°).

At the time of the first postoperative long-leg radiograph, 50 patients (32%) did not have complete active extension; there was an extension deficit of 5°-15° (Table 1). These patients' mechanical axis showed a significantly greater valgus deviation of 1.6° ± 16° compared with the patient group with complete extension ($P = .006$; Table 1, Fig. 2B). Three months after surgery, 152 of the 156 patients could completely extend their knee joint actively (Table 1). The mechanical axis of the patient group with initially incomplete extension was now 1.2° ± 1.3° varus, significantly different from the first postoperative measurement ($P < .001$). The difference in the mechanical axis between the patient groups with postoperative complete extension and delayed complete extension was no more statistically significant after 3 months ($P = .85$). The final measurement 1 year after TKA found no further alteration of the mechanical axis with 1.2° ± 1.1° (range: −2° to +3°; $P = .9$).

Valgus outliers were only observed in the first measurement, and 14 patients had a valgus deviation >3° (range: −5° to −4°). All of the patients with an initial increased valgus deviation showed an alignment of 1° valgus to 3° varus in the second and last measurements. At the first measurement, no varus deviation >2° was observed. Seven patients displayed a varus >3° in the measurement at the 12th week, which remained high after the first year in all patients (range: +4° to +5°, respectively).

Table 1 contains an overview of the mechanical axes of all patients measured up to the third month after TKA, taking the extension deficit into account. Type of prosthesis, age, gender, and BMI had no influence on the mechanical axis measured over the course of the study.

Table 1
Time Course of Mechanical Axis Alignment in Regard of Knee Extension at Seventh Postoperative Day After TKA.

Time point	All (N = 156)	Knee Extension at 7th Day After TKA	
		Complete (n = 106)	Incomplete (n = 50)
Mechanical axis (°) 7 d after TKA			
Mean ± SD	−1.03 ± 1.72	−0.8 ± 1.7	−1.6 ± 1.6
Minimum (valgus)	−5	−5	−4
Maximum (varus)	2	2	2
Mechanical axis (°) 3 mo after TKA			
Mean ± SD	1.3 ± 1.3	1.3 ± 1.3	1.2 ± 1.3
Minimum (valgus)	−2	−2	−1
Maximum (varus)	5	5	3

SD, standard deviation; TKA, total knee arthroplasty.