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Intraoperative Measurements of Joint Line Changes Using Computer Navigation Do Not Correlate With Postoperative Radiographic Measurements in Total Knee Arthroplasty

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ABSTRACT

Background: The adverse effects of joint line (JL) changes on kinematics and outcomes of total knee arthroplasty (TKA) have been studied. Some authors have quantified JL changes using intraoperative data from computer navigation, despite no studies validating these measurements to date. We designed a prospective study to determine whether intraoperative measurements of JL changes using computer navigation correlate with measurements obtained on weight-bearing radiographs postoperatively.
Methods: A total of 195 consecutive patients (195 knees) underwent computer-navigated cruciate-retaining TKA by the senior author. Twenty-four patients had missing radiographic data and were excluded from the study. The final JL change was calculated intraoperatively from the verified bony cuts and planned JL change as determined by the computer. JL position was also measured on preoperative and postoperative radiographs using an anteroposterior method.
Results: One hundred seventy-one knees were evaluated. Using computer-navigated and radiographic measurements, the mean JL change was 1.95 ± 1.5 mm (0-8.0 mm) and 4.05 ± 2.9 mm (0-17.3 mm), respectively. One hundred fourteen (67%) vs 129 (75%) had JL elevation, 44 (26%) vs 30 (18%) had JL depression, and 13 (7%) vs 12 (7%) had no JL change, respectively. Inter-rater and intrarater reliability of radiographic measurements was excellent. We found a poor correlation between computer-navigated and radiographic measurements ($r = 0.303$).
Conclusion: There is a poor correlation between computer-aided and radiographic measurements of JL changes post-TKA. Elevation/depression of the JL needs to be considered in patients who remain symptomatic despite TKA, although the optimal method of assessment remains uncertain.

The success of total knee arthroplasty (TKA) hinges upon the restoration of the mechanical axis, joint line (JL), balanced flexion/extension gaps, balanced soft tissues, and restoration of patellofemoral alignment [1]. Gap balancing affects the final knee kinematics [2], and suboptimal soft tissue balancing can lead to accelerated polyethylene wear.

JL changes with respect to the attachments of the collateral ligaments can result in instability, decreased range of motion, patella maltracking, and an increased incidence of anterior knee pain [3,4]. JL malposition may also result in instability and an increased incidence of anterior knee pain, accounting for a decrease in joint flexion [4]. Martin and Whiteside [5] demonstrated that a proximal displacement of the JL as little as 5 mm could result in midflexion instability. Restoration of the JL is therefore essential.

Before the evolution of computer-navigated TKA, there have been no reliable methods to evaluate changes in JL intraoperatively. Moreover, the control of the JL is difficult intraoperatively as the only useful reference point is the transepicondylar axis of the femur [6]. As such, JL measurements have traditionally been taken using

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radiographic measurements preoperatively and postoperatively. Numerous studies have evaluated the effect of JL changes in posterior cruciate-retaining mobile-bearing TKA [7] and in revision TKA [8], most of which are based on measurements using preoperative and postoperative anteroposterior (AP) [9-12] or lateral view [4,13] radiographs.

At present, computer-assisted surgery (CAS) has been proven as a useful tool to improve accuracy in alignment and implant positioning in TKA [14] and can provide quantitative data to balance the JL both in flexion and in extension [15]. Few authors have quantified JL changes using the intraoperative data collected during CAS [16-19]. However, there are no studies comparing the JL changes measured during computer navigation with those measured on weight-bearing radiographs to date.

We therefore designed a prospective study of patients undergoing a computer-navigated TKA to determine whether the intraoperative measurements using computer navigation correlate with preoperative and postoperative measurements obtained on weight-bearing radiographs. With the increased precision offered by computer navigation, we hypothesized that JL measurements acquired from computer navigation are as accurate as radiographic measurements and are therefore a reliable tool to assess JL changes intraoperatively.

Materials and Methods

Study Design

Between October 2007 and May 2010, 195 consecutive patients (195 knees) underwent CAS TKA by a single surgeon. Patients were included in this prospective study after approval was sought for our study protocol from our institutional review board. The inclusion criterion was primary osteoarthritis of the knee requiring primary unilateral TKA after a failed trial of conservative treatment. Exclusion criteria included patients with rheumatoid arthritis, previous knee surgery, infection, and those who could not be treated with unconstrained TKA and a short stem tibial implant. Of the 195 patients, 24 had missing radiographic data and were excluded from the study. Hence, 171 knees were available for this study.

Operative Technique

All operations were performed by the senior author using the same surgical technique over the duration of this study. A cobalt-chrome cruciate-retaining femoral component and an all-polyethylene fixed-bearing tibial prosthesis (PFC; Depuy Orthopaedic International, Leeds, UK) were used in each patient. All patellae were resurfaced. The software used for the CAS was Ci Mi TKR version 2.0 by BrainLab/Depuy Orthopaedic Inc (Johnson and Johnson, Leeds, UK). Anatomic landmarks were registered through the use of dual 3-mm unicortical pins drilled into the femur and tibia at a distance from the surgical approach, and a pointer with passive infrared reflectors. The tibial cut was made first. This was followed by bone morphing of the femur and ligament balancing. The Tensor Sensor from Depuy was used to deliver a constant pressure of 23 N/cm^2 to both medial and lateral compartments simultaneously [20]. Soft tissue releases were made to achieve a rectangular gap at 0° extension and the space between the distal femur and proximal tibia was stored. Subsequently, the knee was brought to 90° flexion and the space between the posterior femoral condyles and proximal tibia recorded. The size and the position of the femoral component were adjusted on a virtual computer model to achieve equal flexion and extension gaps and the planned polyethylene thickness was recorded. The planned femoral component was then rotated to achieve a rectangular flexion space at 90° flexion. Following this, the navigated anterior and distal femoral bone cuts were made to within 1 mm as planned. The femoral chamfer cuts and tibial preparation were completed, and this was followed by a trial of the tibial and femoral components with a tibial insert. Further soft tissue releases were made if necessary to obtain rectangular and equal flexion and extension gaps. Subsequently, the appropriately sized tibial and femoral components were implanted with cement, and the final flexion and extension gaps were recorded.

Measurement of Joint Line Changes Using Computer Navigation

After the femoral modeling, the computer automatically generated the amount of bony resection, size of femoral component, and the thickness of the tibial insert, to create rectangular gaps. The amount of JL shift was also demonstrated. The bony resections were performed as planned, and the amount of resection was confirmed by the plane verifier.

For the calculation of the JL level at the tibia, the thickness of the polyethylene insert was considered. This was the distance between the deepest point of the polyethylene insert and its base. After prosthesis component implantation, the tibial JL level was assumed as the highest tibial prosthesis compartment between the medial and lateral tibial plateaus. Tibial JL variation was assumed as the difference between after and before prosthesis component implantation. The femoral JL level was also analyzed similarly. The femoral JL level before prosthesis implantation was assumed to be the maximum between the medial and lateral femoral resections. Femoral JL level variation was the difference in the JL between before and after prosthesis component implantation. The total thickness of the resected segments was assumed to be the maximum value between the 2 sums on the medial (medial tibial and femoral resections) and lateral (lateral tibial and femoral resections) compartments. Similarly, the overall thickness of the implanted prosthesis was assumed to be the maximum value between the 2 sums on the medial (medial tibial and femoral prostheses) and lateral (lateral tibial and femoral prostheses) compartments. The change in the JL position was determined by the difference in the 2 thicknesses [19]. All values were calculated by the navigation system using digitized point clouds.

Measurement of Joint Line Changes Using Radiographs

Standardized coronal hip-to-ankle radiographs were taken with the patient standing and the knee in full extension on a 5-cm riser to visualize the ankle joint. Both lateral malleoli were placed 20 cm apart with the toes pointing forward. The patella was placed in the direction of the X-ray source as a rotation guide, with its anterior surface perpendicular to the X-ray source. We acknowledged the need to reproduce accurate and consistent X-rays for assessment. Radiographs were repeated if malrotation was detected. Malrotation was defined as follows: (1) asymmetry of the distal medial and lateral femoral condyles or (2) unequal medial and lateral joint spaces in the ankle joint. They were done preoperatively and at 6 weeks postoperatively. The JL positions were measured on AP radiographs using a modification of the Kawamura method as described by Lee et al [21]. The JL was defined as the line through the distal aspect of the lateral femoral condyle, whereas the JL position was defined as the distance from the proximal tip of the fibular head to the JL in the weight-bearing AP radiograph (Figs. 1 and 2). The reliability of measurements was assessed by intraobserver and interobserver variability. Measurements were made independently twice with an interval of 1 week by 2 authors on preoperative and postoperative radiographs.