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Original Article

Technical Considerations and Accuracy Improvement of Accelerometer-Based Portable Computer Navigation for Performing Distal Femoral Resection in Total Knee Arthroplasty

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ABSTRACT

Background: Accelerometer-based computer navigation has been shown to be highly accurate for performing distal femoral and proximal tibial component alignment in total knee arthroplasty (TKA), although the procedure for the femoral component is less accurate than for the tibial component.
Methods: First, 30 knees without hip osteoarthritis or proximal femoral surgeries were selected. Sequential hip adduction, abduction, and flexion were performed, and the femoral head was monitored fluoroscopically in the coronal plane before TKA. Significantly more movement was detected during hip adduction than during abduction and flexion. Then, postoperative femoral and tibial component alignment was retrospectively evaluated in 48 TKAs before fluoroscopic monitoring (early group) and in the next 61 TKAs with femoral registration using smaller adduction movements to avoid large femoral head movements (later group). Another 47 TKAs treated with the conventional intramedullary method for the distal femoral component and the extramedullary method for the proximal tibial component were also analyzed (IM and EM group) for historic control.
Results: Significantly large variances in the femoral component implantation of the early group were detected in both the coronal and sagittal planes. The sagittal femoral implantation angle of the early group (4.6 ± 3.0°) was significantly larger than that of the later group (3.2 ± 1.8°) when 3.5° was the target for both groups. No significant difference was detected in the variances of either the coronal or sagittal tibial component implantation, although the coronal tibial implantation angle was significantly smaller (−1.3 ± 1.3°valgus) in the early group than in the other groups.
Conclusion: Accelerometer-based navigation sometimes has technical issues during registration associated with hip adduction. We showed that femoral registration without large adduction movements will enable more accurate femoral implantation. Surgeons should also keep in mind that the coronal tibial component is likely to be in valgus alignment (about 1°) even if a neutral angle (0°) is selected with this particular device.

Although total knee arthroplasty (TKA) has been a tremendously successful procedure in the management of degenerative joint disease, femoral, and tibial component, malalignment remains a significant concern. Several recent studies have questioned the significance of overall postoperative mechanical alignment on survivorship, but most studies still report that alignment is a crucial factor in the clinical success of TKA [1]. Ritter et al [2], in a review of 6070 TKAs, noted that the risk of aseptic failure significantly increases with a femoral component orientation greater than 8° of valgus relative to the femoral axis and a tibial component orientation less than 90° relative to the tibial axis (failure rate of 8.7%). Similarly, Berend et al, in review of 3152 TKAs, demonstrated that a tibial varus alignment of greater than 3° increased the odds of implant failure and medial bone collapse by roughly 17 times [3].

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Recently, accelerometer based, portable surgical navigation systems for TKA have become available that do not require the use of a large computer console for registration and alignment feedback, the KneeAlign 2 system (OrthAlign Inc, Aliso Viejo, Calif), and iASSIST (Zimmer Inc, Warsaw, IN). The use of accelerometer-based navigation has previously demonstrated encouraging results for achieving accurate femoral and tibial resections [4–15]. Both accelerometer-based portable surgical navigation systems use essentially the same procedure for registration. Tibial registration is carried out in a static condition, whereas femoral registration requires dynamic motion (hip adduction, abduction, and flexion) for detection of the center of the hip. Nam reported that tibial coronal component alignment is more accurate (97.5% within 2°) than femoral coronal component alignment (92.5% within 2°) using the KneeAlign 2 system [9]. Huang et al [14] also reported that tibial coronal component alignment accuracy (96.2% within 3°) is superior to femoral coronal component alignment accuracy (87% within 3°) using iASSIST. We also experienced the situation where accelerometer-based navigation did not accurately reproduce the indication for cutting the femoral bone during surgery based on a single femoral registration. This dynamic femoral motion during registration could adversely affect the accuracy. There have been no articles on femoral head motion during registration and the accuracy of femoral component alignment from the point of view of femoral registration. The aim of this study was to determine the movement of the hip center during the registration procedure and subsequent distal femoral and proximal tibial component alignment accuracy. Our hypothesis was that the center of the hip moved to some extent during registration (hip adduction, abduction, and flexion), and that by avoiding this error more accurate femoral alignment can be achieved.

Materials and Methods

In February 2014, the KneeAlign 2 system was introduced to our hospital, and we immediately started TKA operations using the system. To eliminate the learning curve effect, TKAs over some of the initial months were excluded in this study. From August 2014 to August 2015, 109 patients (16 male, 93 female) received a TKA from the senior author (Yoshiaki Sasashige) and were evaluated retrospectively. No patients underwent bilateral TKA, and there were 50 left knees and 59 right knees. Inclusion criteria for this study were patients with a history of osteoarthritis who received a primary cruciate-retaining TKA. Patients undergoing revision TKA were excluded.

In March 2015, we began femoral head center movement assessment using fluoroscopy. From March 2015 to August 2015, the later half of the study period, 61 patients received TKAs (61 TKAs: later group). Thirty of 61 patients without hip osteoarthritis or proximal femoral surgeries received fluoroscopic assessment of femoral head center movement before TKA. Each patient lied on the operating table and a portable fluoroscope was inserted from the lateral side (Fig. 1). A fluoroscopic ruler was inserted between the table and mattress and placed perpendicular to the patient's body. After several cycles of hip adduction, abduction, and flexion, the lower extremity was placed with 45° hip flexion, neutral adduction/abduction, and knee 90° flexion (starting position). First, the fluoroscopic image was digitally recorded at the starting position. Each fluoroscopic image was recorded with the knee moved 10 cm medially (hip adduction), 10 cm laterally (hip abduction), and 10 cm proximally (hip flexion). After the fluoroscopic image was recorded at the starting position again, fluoroscopic images were recorded with the knee moved 15 cm medially (hip adduction), 15 cm laterally (hip abduction), and 15 cm proximally (hip flexion). After the fluoroscopic image was recorded at the starting position once again, fluoroscopic images were recorded with the knee moved 20 cm medially (hip adduction), 20 cm laterally (hip abduction), and 20 cm proximally (hip flexion). The amount of femoral head center movement was measured using these images corrected using a fluoroscopic ruler (Fig. 2). The X line was defined as movement in the medial/lateral direction and a positive value meant medial movement. The Y line was defined as movement in the proximal/distal direction and a positive value meant distal movement.

Fig. 1. The movement of the femoral head center is monitored fluoroscopically in the coronal plane with 10, 15, and 20 cm of knee motion in 3 directions (medial, lateral, and proximal) on the operating table before total knee arthroplasty.

Postoperative femoral and tibial component alignment was also assessed in the first half (48 TKAs: early group) and second half (61 TKAs: later group) of the study period. To compare the results with conventional TKA component alignment, 47 patients who received a TKA from the same senior author (Yoshiaki Sasashige) and were

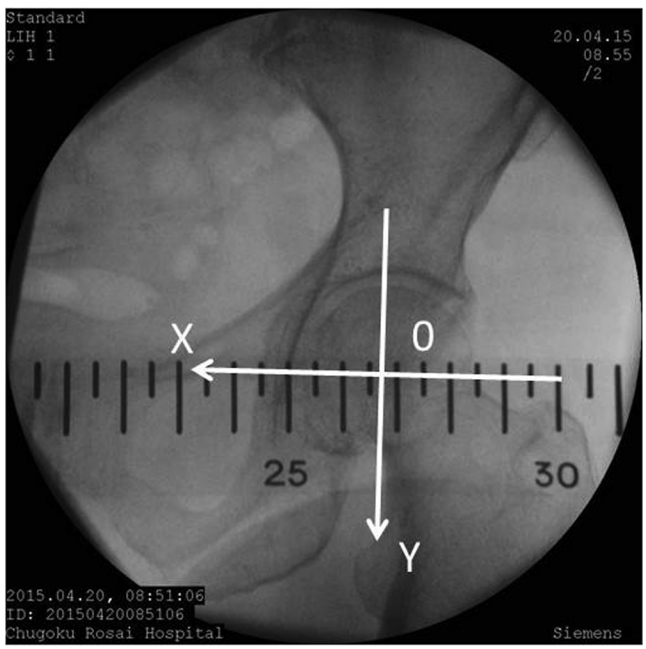

Fig. 2. The center of the femoral head is measured and the movement of the center of the femoral head is evaluated. The X line was defined as movement in the medial/lateral direction and a positive value meant medial movement. The Y line was defined as movement in the proximal/distal direction and a positive value meant distal movement.