Clinical and Radiologic Outcomes of Contemporary 3 Techniques of TKA

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abstract

This report compares the radiologic and early clinical results of total knee arthroplasty (TKA) performed by the same surgeon using 3 techniques. In this prospective study, 75 knees were randomized to conventional technique (25 knees), image-free navigation system (25 knees), or minimally invasive surgery (MIS) (25 knees). Age range of the 43 women (65 knees) and 5 men (10 knees) was 58 to 81 years. Posterior stabilized knee prosthesis was used in all patients. Data was collected according to Knee Society System for radiologic evaluation of x-rays. Knee Society clinical (KS-C) and functional knee scores were measured preoperatively and at 6 weeks, 3 months, 6 months, 1 year, and 2 years. The postoperative KS-C was not statistically better in the MIS group (mean, 88±11.5; range, 70-100) than the conventional (mean, 85.9±7.8; range, 74-94) (P=.68) or navigation group (mean, 85±11; range, 63-100) (P=.59). Mean postoperative delta (mechanical axis) angle was significantly different (P=.014): 2.38° in the conventional group (SD=2.88°; 95% CI, 1.19°-3.57°; range, –1.59° to 6.86°), 0.61° in the navigation group (SD=2.07°; 95% CI, –0.24° to 1.46°; range, –2.07° to 4.25°), and 4.25° in the MIS group (SD=6.52°; 95% CI, 1.56°-6.94°; range, –6.72° to 15.60°). Significant difference could be elicited between navigation-assisted and MIS groups, with navigation-assisted surgery providing more accurate alignment of the mechanical axis (P=.014). Of the three techniques, navigation-assisted surgery gives superior prosthesis alignment and promising longevity of TKA.

The conventional method of total knee arthroplasty (TKA) is the oldest and most time tested procedure, and it is the technique most practiced. The scenario is changing, however, and arthroplasty surgeons may be required to perform different techniques, particularly with media attention focused on emerging technologies and with increased patient awareness. Media exposure is often misleading, though, and sometimes results in high patient expectations that cannot be met. The claims for minimally invasive surgery (MIS) usually include that the technique reduces the rehabilitation requirement, with minimal or no postoperative pain, normal knee function, and only a cosmetic scar. A similar claim for navigation-assisted knee arthroplasty states that the technique eliminates malalignment of limb and prosthesis, which significantly increases the longevity of the prosthesis. These claims might be attainable soon, but some of these objectives cannot be achieved with current techniques and technology.

A compelling factor for surgeons to perform a variety of techniques is the chance to increase their market share of certain procedures that result from use of new cutting-edge techniques. We report here a series comparing the short-term radiologic and clinical results of 3 different techniques of TKA (conventional, navigation-assisted, MIS) performed by a single surgeon.

MATERIALS AND METHODS

Study Design and Patients

In a consecutive prospective randomized study, TKA was performed in a total of 75 knees in 48 patients between May

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2006 and September 2007 using the conventional technique (n = 16, knees = 25), the image-free navigation system (n = 17, knees = 25), and the MIS technique (n = 15, knees = 25). The study included 43 female patients (65 knees) and 5 male patients (10 knees) with the mean age of 68.3 years (SD, 6.92; range, 58-81 years). Patients were assigned to these groups according to a randomization table generated by an ad hoc program based on the pseudorandomized routine of the STATA 5.0 (Stata Corp, College Station, Texas) statistical package. Patient demographic data are listed in Table 1. No statistically significant difference was identified among the 3 groups. Indication for surgery was primary osteoarthritis in all patients. Posterior stabilized knee prosthesis was used in all cases. All patients were operated by a single surgeon (K.J.O.). The follow-up rates for each group were 96% (24/25 knees), 92% (23/25 knees), and 92% (23/25 knees) for conventional group, navigation group, and MIS group, respectively. This study was approved by the institutional review board at KonKuk University Medical Center, and informed consent was obtained from each patient.

**Surgical Procedures**

Conventional. For the conventional group, operation was carried out through a midline incision using a medial parapatellar approach. The medial capsule was incised 5 mm medial to the patella and extended into the vastus medialis obliquus muscle at the middle of the insertion just long enough so that the patella was easily everted when flexing the knee. Intramedullary referencing was used for the femur and extramedullary referencing for the tibia. A distal femoral cut was followed by a proximal tibial cut. The goal of the placement of the femoral component was perpendicular to the mechanical axis of each patient examined preoperatively using a long leg radiograph in the coronal plane and perpendicular to the femoral axis in the sagittal plane. The tibial component was intended to be placed perpendicular to its anatomic axis in the coronal plane and with a 7° posterior tilt in the sagittal plane. The patellar cartilage and bone were removed at the same thickness as the component. Patellar resurfacing was performed in all cases. The posterior cruciate ligament was sacrificed. The soft tissues were released until an adequate balance was obtained. A spacer block was used to ascertain the balancing. All femoral and tibial components were cemented. The patella tracking was examined by the no-thumb test. A lateral retinacular release was performed when needed. A tourniquet was used during the procedure.

Navigation. In all cases of navigation-assisted surgery, the surgical approach was via a standard median parapatellar incision. The patellar was subluxed laterally, the Tibia was subluxed anteriorly, and the posterior cruciate ligaments were sacrificed. The medial meniscus and osteophytes were removed, and soft tissue balancing was conducted before any bone cuts were made. The OrthoPilot navigation system (B. Braun Aesculap, Tutlingen, Germany) is an active PC-based guidance system that assists the surgeon with decision making for accurate alignment and orientation of the implants. This system is imageless and does not require preoperative computed tomography or intraoperative fluoroscopy. The arrays of the navigation system were set up using a femoral trackers mounted to screws. A screw was fixed to the medial aspects of the femur and the tibia. At the registration stage, the positions of selected points, including the lowest point of the lateral tibial plateau, were registered. The center of the proximal tibia was visually identified and its coordinates were input into the computer using a pointer specific to the navigation system. The tibial mechanical axis was then defined as the line joining the center of the proximal tibia and the calculated center of the ankle joint. After marking all reference points, correction of varus deformity with respect to the neutral axis was carried out by medial release in extension. Limb alignment was checked using the navigation system to achieve a neutral axis. Further soft tissue release and posterior osteophyte removal were done at this stage when necessary.

Proximal tibial cutting was done in a perpendicular plane to the mechanical axis of the tibia. We intended to incorporate the resection plane at the sclerotic level of the medial tibial plateau with 2° of posterior slope. A laminar spreader that could separately adjust the medial and lateral compartments was inserted to determine adequate collateral tension in extension and at 90° of flexion. These coordinates were then recorded and the femoral cutting block was oriented to achieve equal extension and flexion gaps. Implantation was performed with bone cement in all cases. Patellar tracking was tested intraoperatively using the towel clip method, and lateral retinacular release was performed if necessary.

Minimally Invasive Surgery. For the MIS group, a quadriceps-sparing approach was used. A straight skin incision was made beginning 1 cm proximal to the patella, crossing the medial one-third of the patella, and extending to the level of the tibial tuberosity. The medial capsule was incised 5 mm medial to the patella and extended 2 to 4 cm into the vastus medialis obliquus muscle at the superomedial corner of the patella. The patella was not everted, but was displaced laterally. Femoral and tibial resections were performed independently using small modified instruments. The rest of the procedures were the same as for the conventional method.

**Postoperative Management**

Postoperative management was the same in all three groups. Patient-controlled analgesia was continued for 2 days with oral analgesics. The day after surgery, patellar setting and active straight-leg-raising were encouraged. Patients were allowed full weight bearing as tolerated. On the second day after surgery, the drainage tube was removed. Range-of-motion (ROM) exercise was started, and gait exercise bearing full weight was
evaluation. Continuous passive motion machines were used for all patients. Outpatient physical therapy was started immediately after discharge.

Assessment

The length of the skin incision and the duration of the surgery were assessed in each group. The total blood loss was calculated by adding blood loss during surgery to the closed suction drainage amounts during the 2 days after surgery. At 3, 6, and 12 months and then yearly after surgery, a trained physiotherapist blinded to the technique of surgery measured the range of motion and the Knee Society clinical (KS-C) and functional (KS-F) scores. Complications in each group were also recorded.

Evaluation of Radiographs

Standard radiographs of the knee included (1) standing anteroposterior (AP) view from hip center to ankle center, (2) standing AP and lateral views of the knee joint, and (3) axial view of the patella. Postoperative radiographs were evaluated for standing tibiofemoral alignment as well as AP and lateral position of the prosthesis components by a second author who was blinded to operative technique. Data were collected according to the Knee Society Total Knee Arthroplasty Roentgenographic Evaluation and Scoring System for radiologic evaluation. Alpha, beta, gamma, and sigma angles for femoral and tibial components were measured. The mechanical axis (delta angle) was measured from a line from the hip joint center to the knee joint center and a line drawn from the knee joint center to the ankle joint center. The patellar inclination angle was measured between a line drawn parallel to the surface of the patellar prosthesis and a line parallel to the femoral condyles in axial view.

Statistical Analysis

Statistical analysis was performed with one-way ANOVA test using SPSS software (SPSS for Windows Release 17.0; SPSS Inc, Chicago, Illinois). The preoperative demographic data and limb alignment angles were compared to detect any significant dissimilarity between groups. The postoperative data including postoperative limb alignment, prosthesis implantation angles, KS-C, and KS-F were compared to find any statistically significant differences between the three groups. If significant differences existed, the pair-wise P value was calculated. Values of P < .05 were considered to be statistically significant.

RESULTS

Clinical Results

The average incision length was 16, 14, and 10 cm in the conventional group, navigation group, and MIS group respectively. The average blood collected in drain was 400 mL (range, 270-600 mL) in the conventional group, 410 mL (range, 400-600 mL) in the navigation group, and 450 mL (range, 300-610 mL) in the MIS group. Preoperatively, the average KS-C and KS-F in the 3 groups were comparable according to the ANOVA test (Table 1). The postoperative KS-C was not statistically better in the MIS group (mean, 88 ± 11.5°; range, 70°-100°) compared with the conventional group (mean, 85.9° ± 7.8°; range, 74°-94°) (P = .68, Student t test) or the navigation group (mean, 85° ± 11°; range, 63°-100°) (P = .59, Student t test). The KS-C included a stability test, which measured <5 mm in AP translation and <5° in mediolateral toggle in all patients. The postoperative KS-F was also not significantly better in the MIS group (mean, 70° ± 10°; range, 60°-80°) compared with the conventional group (mean, 77° ± 12°; range, 60°-100°) (P = .56, Student t test) or the navigation group (mean 68° ± 10.9°; range, 50°-90°) (P = .45, Student t test). The preoperative ROM was marginally better in the MIS group than in the conventional group and the navigation group, but the difference was not statistically significant (P = .18). Postoperative ROM at 3 months was significantly better in the MIS group than in

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*aANOVA test.
bFisher exact test.
Abbreviations: KS-C, Knee Society Clinical Knee Score; KS-F, Knee Society Functional Knee Score.
the conventional group and the navigation group \(P=.016\). This difference became statistically insignificant at 2-year follow-up, but the MIS group was still marginally better than other groups \(P=.21\). In the immediate postoperative period, 1 patient who underwent TKA by conventional method had deep vein thrombosis, which was managed by inactive observation, and 2 patients in the MIS group had superficial skin maceration at the lower end of their incision, which healed with primary skin care.

### Radiologic Results

The preoperative and postoperative radiologic results are summarized in Table 2. Mean postoperative alpha angle was significantly different \(P=.028\). No pair comparison was carried out for alpha angle, because the angle varies with the anatomic lateral bowing of the femur and no ideal/exact angle is documented in the literature that could justify the comment that 1 group was better than others.

Mean postoperative beta angle was significantly different \(P=.008\). On comparison of subgroups in terms of beta angle, navigation and conventional groups had more accurate alignment of prosthesis than the MIS group \(P=.015\) and \(.041\) (Figure 1). No significant difference could be elicited between the conventional and navigation groups \(P=.925\).

Mean postoperative delta angle was significantly different \(P=.014\). On comparison of subgroups, significant difference could be elicited between navigation and MIS groups, with navigation-assisted surgery providing more accurate alignment of the mechanical axis \(P=.014\). No significant difference could be elicited on comparison of the MIS group with the convention group or the navigation with the convention group \(P=.310\) and \(.351\).

The incidence of outliers was highest in the MIS group and least in the navigation group. The outliers in the navigation group were evenly distributed toward varus alignments as compared with the MIS group in which they were widely scattered in all directions (Figure 2).

Mean postoperative sigma angle was significantly different \(P=.002\); however, we did not carry out any pair comparison because this dissimilarity was anticipated because of different posterior slope cut angle with different implants.

The mean postoperative gamma angle and the patellar inclination angle were not significantly different between the 3 groups \(P=.87\) and \(.197\).

### DISCUSSION

The longevity of well-performed TKA is approaching 20 years, and implant position with correct mechanical alignment has been implicated as a significant factor affecting the long-term results of TKA.\(^2\)\(^,\)\(^7\) Mechanical axis within range of \(3^\circ\) valgus-varus has been proven to be associated with better outcome.\(^4\)\(^,\)\(^6\) Incorrect positioning of the implant and improper alignment of the limb can lead to accelerated implant wear and loosening, as well as suboptimal function.\(^2\)\(^,\)\(^9\)
In the mid-1990s, TKA underwent a revolution with the invention of the computer-aided navigation systems to address the limitations of mechanical guides in accuracy of prosthesis implantation, and to assist more precise control over prosthetic angles. Most studies report reduced incidence of outliers, although overall mean data remain the same, some authors have reported statistically significant improvement in mechanical axis with navigation-assisted surgery. The benefit does not come without drawbacks: additional time required for registration of anatomic landmarks, limited area for assistants because the computer needs to “see” the diodes, and overcongestion of the operative field with wire or large diodes.

In our experience, significantly better mechanical alignment was achieved in the navigation group than in the MIS group (P=0.014). The delta angle was distributed as a spectrum from best in the navigation group, through the conventional group, to worst in the MIS group. Mean postoperative delta (mechanical axis) angle was 2.38° in the conventional group (SD 2.88°; 95% CI, 1.19°-3.57°; range, −1.59° to 6.86°), 0.61° in the navigation group (SD 2.07°; 95% CI, −0.24° to 1.46°; range, −2.07° to 4.25°), and 4.25° in the MIS group (SD 6.52°; 95% CI, 1.56° to 6.94°; range, −6.72° to 15.6°). The prosthesis alignment was also better in the navigation group according to the beta angle (Figure 1), and the difference was significant when compared with the MIS group. Although no statistically significant difference could be elicited in comparison with the conventional group, distribution of the conventional group was more widespread with a greater number of outliers. Better alignment in the navigation group highlights the fact that the surgeon has more precise control over the bone cutting angles with computer assistance. Better alignment with the navigation system compared with the conventional system has been reported by other series also, although the difference did not reach statistical significance.

The navigation system is not free of errors: poor alignment can result from several factors, including the accuracy of the reference system placement and the software algorithm. The slightest movement of the rigid body can cause error of all resection planes.

The advantage with the navigation system is that all these small errors can be detected intraoperatively in real time and corrected to some extent. The incidence of outliers (outside 3° valgus-varus range) was lowest in the navigation group and outliers were evenly distributed toward varus alignment, which believe to be due to the surgeon’s tendency to prefer varus alignment to valgus alignment. The outliers in the MIS and conventional groups were widely scattered in valgus and varus alignment. This we believe is due to the lack of accuracy with mechanical jigs. Except for limitation of mechanical guides and surgeon factor, deviation of the saw blade in dense or weakened bone stock can be an important reason for variation in leg axis. Plaskos et al reported a cutting error of 0.6° to 1.1° in varus-valgus and 1.8° in flexion-extension. Other important factors for small variations is cementing the prosthesis with an uneven cement layer. The greater number of outliers in the MIS group highlights the fact that poor visibility of landmarks can lead to gross malpositioning of the prosthesis. Rapid recovery of function and a short rehabilitation period are important, but these should not be achieved at the price of limb alignment and soft tissue balance because the longevity of the procedure is directly related to the latter mentioned factors.

The conventional technique requires large instruments with long incisions and result in extensive injury to soft tissues along with scars. The concerns have shifted to better cosmetic and functional results, leading to a new era of MIS for TKA. MIS for unicondylar knee arthroplasty (UKA) was introduced in the late 1990s by Repicci and Eberle, and soon Tria and Coon demonstrated that MIS for TKA could be performed with the concepts of MIS for UKA.
while maintaining conventional principles of TKA as described by Insall. With MIS, the premise is to minimize the injury of the quadriceps mechanism, with resultant early recovery and better functional outcome, along with reduced blood loss and reduced postoperative pain. The major disadvantage of the MIS technique seems to be increased operation time and risk of component malpositioning, especially early in the learning curve. But patient demand, possibility of decreased cost from reduced hospital stay, and development of new instruments and techniques all have contributed to increased focus on MIS. As expected, the postoperative ROM was better in the MIS group than in the conventional and navigation groups at 3 months ($P=0.016$). This is accounted for by the lesser degree of trauma to the extensor mechanism in MIS procedures. It might also partially be because the preoperative ROM was better in the MIS group than in the other groups, although the difference was not statistically significant ($P=0.18$), but we believe this difference should not be considered as a selection bias. The ROM in the MIS group is demonstrated to be better at early follow-up, although long-term results are similar to those of the conventional method. In our study, the difference of ROM between the 3 groups diminished to statistically insignificant level at 2-year follow-up. Overall, it should be noted that the MIS group had the most outliers, which were evenly distributed throughout the whole series. This may be due to limited visualization of anatomic landmarks, which might result in poor accuracy of bone cutting angles.

Limitations of this work should be noted. The mean follow-up of our series is short. However, because the parameters measured in this study are related to the immediate postoperative period, we believe that collecting data for 2 years postoperatively was appropriate.

**CONCLUSION**

Regarding the 3 contemporary surgical techniques for TKA, navigation-assisted surgery gives superior prosthesis alignment and promising longevity of TKA. Alignment is less predictable with the MIS technique, so extra caution should be exercised while attempting MIS. The future of TKA includes improved instruments and techniques that will strengthen the role of MIS in TKA with significantly reduced number of outliers even in the early stage of the learning curve. Navigation-assisted MIS has great potential because it adds the benefits of both systems and more importantly overcomes the shortcomings of both systems by providing better alignment of the prosthesis but retaining all the other advantages of MIS.

**REFERENCES**