Outcomes of Robotic Arm–Assisted Unicompartmental Knee Arthroplasty

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Abstract

Early outcomes of unicompartmental knee arthroplasty performed with a robotically assisted navigation system have been favorable. The surgical technique enhances accuracy of bone preparation and component positioning. Technical errors of the system have been minimal. The surgeon's learning curve is not adversely affected. Early patient outcomes are excellent and complications minimal. Further follow-up and study will help to determine whether these early outcomes are sustained over time.

The enthusiasm for unicompartmental knee arthroplasty (UKA) continues. The underlying current seems to be patients' clear-cut preference for UKA over total knee arthroplasty (TKA).[1,2] Studies have demonstrated that, compared with patients who had TKA performed, patients who underwent UKA enjoyed a higher level of daily function and were able to participate in sports to a greater degree.[3,4] Despite these advantages, reliably successful outcomes may be more difficult for most surgeons and their patients to obtain with UKA, for several reasons. First, it is imperative that patients be screened thoroughly to determine whether they are appropriate candidates.[5] In most practices, when strict screening criteria are applied, only about 4% to 6% of patients with knee arthritis are deemed appropriate candidates.[6] It then follows that knee arthroplasty surgeons perform relatively few UKAs. It has been suggested that surgeons must perform about 50 procedures a year in order to gain and maintain adequate competence in arthroplasty.[7] Compounding this barrier to good outcomes is that UKA can be more technically challenging than TKA. The success of UKA is easily affected by component malposition and malalignment,[8-10] with as little as 2° to 3° of malposition significantly compromising results.

Nevertheless, patients want high levels of function from their surgery, so attempts to improve the quality of UKA reconstruction have continued. In one UKA procedure, the MAKO surgical robot (MAKO Surgical Corp., Fort Lauderdale, FL), with its tactile guidance system (TGS) and 3-dimensional preoperative planning, closes the loop in surgical decision making. Not only can surgeons precisely plan final component position, but they can accurately reproduce the plan with the help of the TGS. Many questions are being asked about this new technique and its outcomes, and the data continue to accumulate.

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Materials and Methods

To help determine the utility and applicability of the TGS, I evaluated 4 outcome parameters: accuracy of bone preparation and implant placement; TGS failures; MAKOplasty complications, including those both attributable and not attributable to the TGS; and patient-specific measures of outcome. The data were summarized from 6 early-term peer-reviewed scientific presentations given at a recent meeting (International Society for Technology in Arthroplasty; October 1-4, 2008; Seoul, Korea). Randomized, controlled trials have not been reported yet, and there have been no peer-reviewed publications. As a result, the articles in this supplement are the first to describe the technique and the early results of robotically assisted UKA.

> **"...initial results of TGS-UKA are no worse than those of conventional UKA with respect to complications, patient function, and surgeon learning curve."**

Results

Accuracy of Bone Preparation and Implant Placement

Desirable radiographic parameters, based on predictability of UKA failure, are summarized in the Table. In an evaluation of their first 43 MAKOplasty patients, Roche and colleagues[11] obtained 344 radiographic measurements. An independent reviewer considered 3 femoral components to be outliers (slight anterior medial overhang, placement of 1 component too distally). Therefore, fewer than 1% of the measurements were thought to be outliers.

Sinha and colleagues[12] evaluated their first 20 cases performed with an inlay tibial component. In this series, attempts were made to place the components as close as possible to native anatomy to recreate the patients' normal

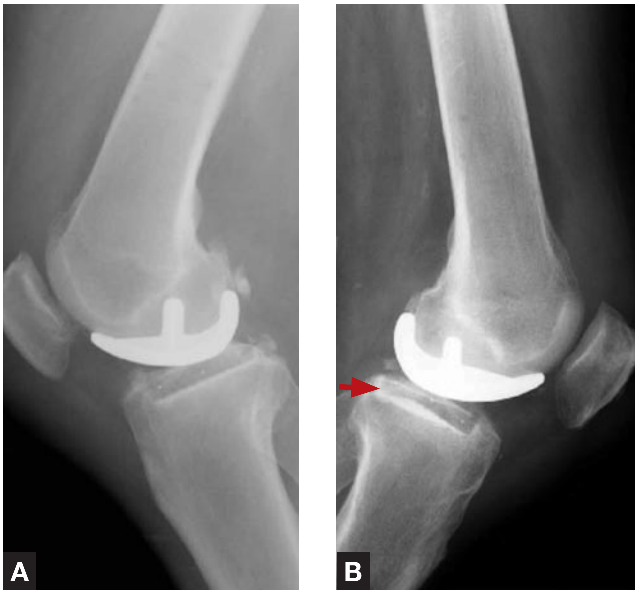

Figure. (A) Good alignment of tibial component with prosthesis in excellent alignment parallel to bone preparation level. (B) Migration of tibial component. Arrow indicates where posterior aspect of implant has risen from bone preparation level.

alignment. Before surgery, 62.5% of the medial femoral condyles were in mechanical varus, and 37.5% were in valgus; after surgery, all femoral components matched their preoperative varus or valgus alignment. In addition, no components were outliers in terms of flexion. Furthermore, all tibiae had a varus deformity, and tibial components were placed in a mean of 4.60° (SD, 1.76°) of varus, with all components placed in varus as preoperatively planned. Before surgery, mean tibial slope was 5.00° (SD, 2.37°), with 25% outliers (Table); after surgery, mean slope was 4.29° (SD, 3.24°), with 19% outliers, one third of which were outliers before surgery as well. However, in a comparison of bone preparation and final tibial component position, there was a slightly higher error, which suggests that care must be taken while the polymethylmethacrylate polymerizes (Figure).

Coon and colleagues[13] compared 44 standard UKAs implanted with manual instruments and 33 UKAs implanted with TGS. The variance in tibial slope in attempts to match native slope was 2.8 times larger when manual instruments were used. In the coronal plane, mean error was 3.3° (SD, 1.8°) additional varus with manual instruments versus 0.1° (SD, 2.4°) with TGS (*P*<.0001).

TGS Failures

Sinha and colleagues[12] reported no failures of the TGS among their first 20 patients. However, among their next 17 patients, there was 1 failure of tibial registration, which necessitated an intraoperative switch to manual techniques. No other published reports have addressed the issue of system reliability.

MAKOplasty Complications

Three centers contributed 223 cases to a registry approved by their institutional review boards.[14] Within 1 year, there were 6 reoperations—2 for infection, 1 for femoral shaft fracture through a navigation pin track, 1 for arthrofibrotic band release, 1 for arthrotomy dehiscence, and 1 for unexplained pain. No implant loosening has been reported. Sinha and colleagues[12] reported no clinical complications in their initial series.

Patient Outcomes

Coon and colleagues[15] compared 45 minimally invasive UKAs, performed with manual instruments, with their initial 36 UKAs performed with TGS. Patients were evaluated 3, 6, and 12 weeks after surgery. There was no significant difference in mean Knee Society Score (KSS),[16] change in KSS, or Marmor rating[17] between the 2 groups at any postoperative time. In addition, there were no significant differences in the individual measures that are comprised by these scores. TGS results were comparable with results with established techniques, which suggests that the learning curve effect was minimal.

Of the 223 patients who were reported to the registry in the 3-center study,[14] 84 satisfied the minimal (1-year) follow-up. These patients showed significant preoperative-to-postoperative improvement in range of motion (*P*<.02), KSS (*P*<.0001), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores[18] (*P*<.01), particularly Pain (*P*<.01) and Stiffness (*P*<.01).

Roche and colleagues[11] reported on their first 43 patients. Range of motion increased (*P*<.001) from 121° (SD, 8°) to 126° (SD, 6°); KSS improved (*P*<.001) from 95 (SD, 16)

Table. Acceptable Positions for Each Component

Component	Minimum	Ideal	Maximum
Femoral			
Flexion/extension	4° flexion	10° flexion	15° flexion
Proximodistal position	1 mm distal of bone	2 mm distal of bone	3 mm distal of bone
Varus/valgus	0° valgus	5° valgus	10° valgus
Mediolateral position	No medial overhang	Ideal coverage	No lateral overhang
Tibial			
Posterior slope	0° posterior	4° posterior	7° posterior
Proximodistal position	3 mm proximal of bone	2 mm proximal of bone	4 mm distal of bone
Varus/valgus	10° varus	3° varus	Neutral
Mediolateral position	2 mm minimum from cortex	2 mm minimum from cortex	2 mm from eminence

to 150 (SD, 27); and Medical Outcomes 12-Item Short Form Survey (SF-12) Physical Summary scores[19] improved (*P*<.001) from 30 (SD, 9) to 39 (SD, 12). Regarding WOMAC scores, Total improved (*P*<.001) from 41 (SD, 15) to 21 (SD, 17); Pain improved (*P*<.001) from 8 (SD, 4) to 4 (SD, 3); Stiffness improved (*P*<.001) from 4 (SD, 1) to 2 (SD, 1); and Physical Function improved (*P*<.001) from 29 (SD, 11) to 15 (SD, 13).

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Discussion

Three conclusions can be drawn from the early-term results. First, initial results of TGS-UKA are no worse than those of conventional UKA with respect to complications, patient function, and surgeon learning curve. Second, bone preparation is extremely accurate relative to the preoperative plan. Third, the computer-guided robotic system is very reliable.

Limitations of using the TGS include initially longer operative times, the learning curve issues that are usually associated with new techniques, and the cost of the robotic arm base unit. Obviously, longer term data are needed to determine whether implant survival mirrors the experience with traditional UKA. In addition, research should focus on how accuracy of bone preparation correlates with patient function, satisfaction, and sports activity, and to what degree. The cost–benefit ratio of implementing a new technology such as TGS will also become elucidated with further research. Last, this technology represents a possible platform technology for applications in other joints—including implant placement, bone contouring for cartilage transplantation, ligament reconstruction, and pedicle screw placement. The future of UKA promises to be exciting.

Author's Disclosure Statement

Dr. Sinha wishes to note that he is a consultant for MAKO Surgical Corp.

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