Robotic Arm Guided UKA is More Accurate than Manually Instrumented UKA

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Introduction

Successful clinical outcomes following unicompartmental knee arthroplasty (UKA) depend on accurate component alignment, which can be difficult to achieve using manual instrumentation. A new technology has been developed using a tactile robotic arm system that replaces traditional UKA instrumentation. In addition to potentially improving accuracy, this technology utilizes a bone preserving inlay tibial design (as opposed to traditional onlay designs), which may result in reduced post-operative pain and quicker recovery due to preservation of the medial tibial plateau periphery and its densely innervated periosteum. This study compares the accuracy of UKA component placement and early clinical outcomes with traditional jig-based instrumentation versus robotic arm guided surgery.

Materials and Methods

- 77 UKA patients from a single surgeon were included in this study
  - 44 standard onlay UKAs were performed using standard manual instrumentation
  - 33 inlay UKAs performed with a robotic arm guided implantation system employing a tactile-guided burr for all bone resection
- Each was performed using a minimally invasive surgical approach
- The two groups were identical in terms of age (p=0.74), gender (p=0.65) and BMI (p=0.72)

Figure 1. Robotic arm guided implantation system (top) and associated inlay UKA components with all polyethylene tibia (left).

Figure 2. Extramedullary alignment guide representative of standard manual instrumentation (left) and associated onlay UKA components with metal backed tibia (right).

- The coronal and sagittal alignment of the tibial components were measured on pre- and post-operative AP and lateral radiographs
- A radiographic technique was developed to measure the depth of resection of tibial bone stock relative to the initial medial joint line

Results

- For both techniques, the surgical objective was to match the natural tibial posterior slope. The RMS error of the tibial slope was 3.5° manually compared to 1.4° using the robotic arm.
- In addition, the variance using manual instruments was 2.8 times greater than the robotic arm guided implantations (p<0.0001).
- In the coronal plane, the goal of the manual technique was to implant the tibial component perpendicular to the anatomic tibial axis, while the robotic arm guided implantations attempted to match the natural varus of the medial compartment. The average error was 3.3 ± 1.8° more varus using manual instruments compared to 0.1 ± 2.4° when implanted using the robotic arm (p<0.0001).

Conclusion

- Tibial component alignment in UKA is significantly more accurate and less variable using robotic arm guided surgery compared to manual, jig-based instrumentation.
- By enhancing component alignment, this novel technique provides a potential method for improving outcomes in UKA patients.

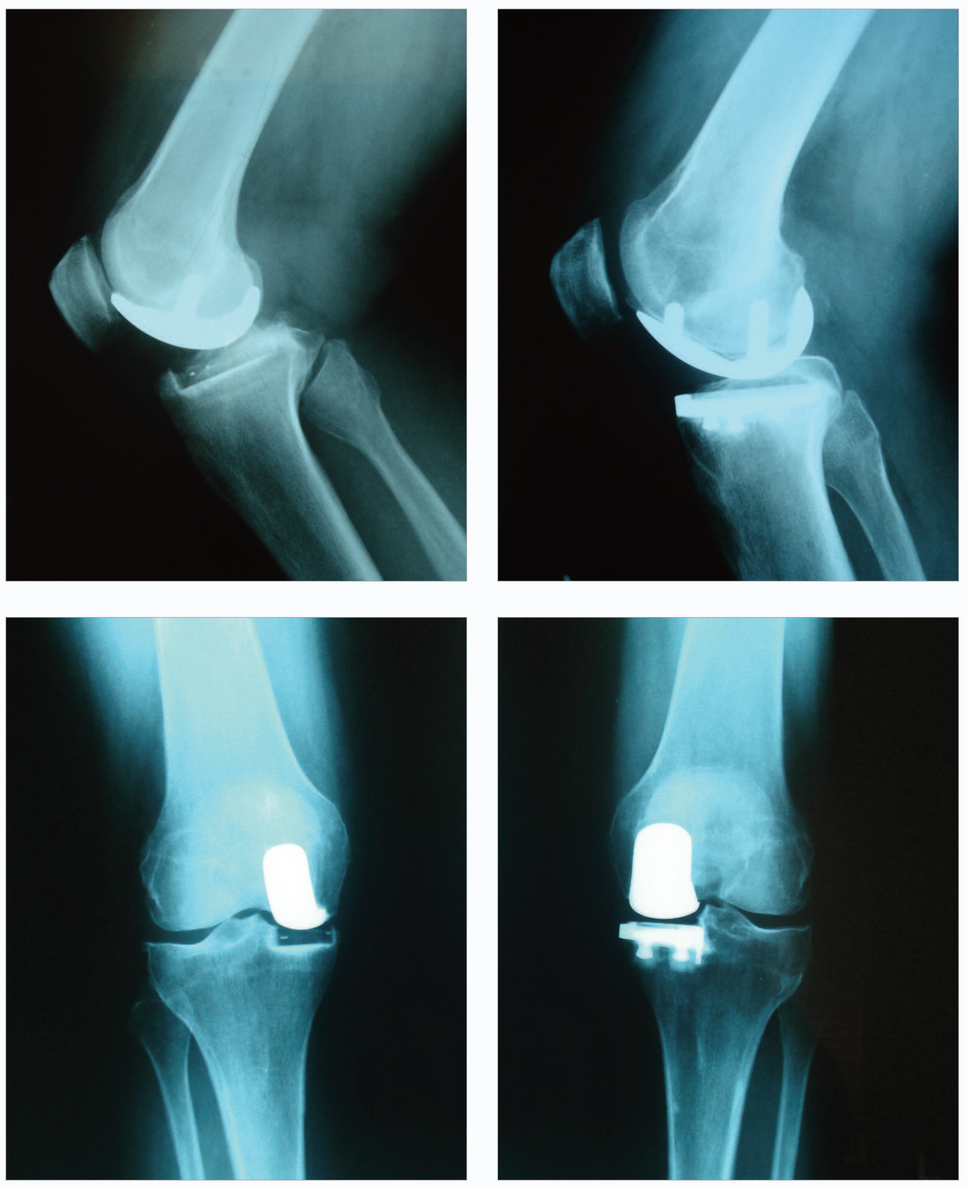

Figure 3. Accurate posterior slope reconstruction accomplished with robotic arm guidance (left) compared with excessive posterior slope resection with manual instrumentation (right).

Figure 4. Accurate reconstruction of medial plateau varus resulting from robotic arm guidance (left) compared with valgus alignment of tibial component resulting from manual instrumentation (right).

Presented at the 21st Annual Congress of the International Society for Technology in Arthroplasty (ISTA 2008), Seoul, Korea - 201837 r00

One Year Outcomes of Robotic Arm Guided UKA

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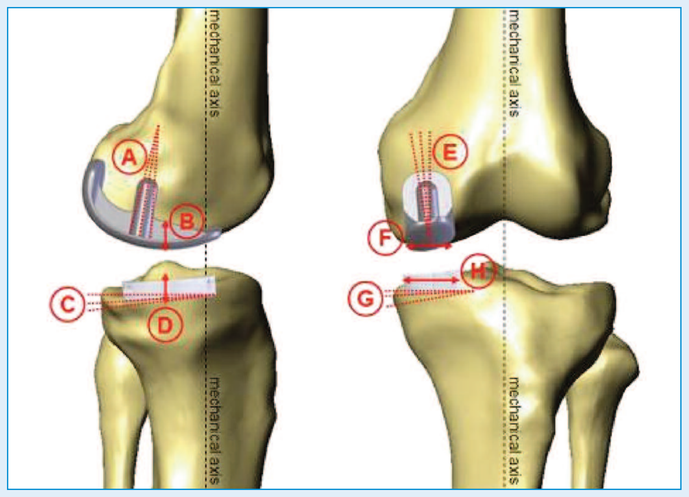
Introduction

Unicompartmental knee arthroplasty is an underused procedure in orthopedics due to its level of difficulty and the number of published reports on the sensitivity of successful outcomes to component malalignment. New robotic arm technology has been developed to assist the surgeon in accurately and reproducibly preparing the femur and the tibia for a minimally invasive, bone sparing unicompartmental knee arthroplasty. The purpose of this study was to assess the functional and radiographic outcomes of the initial series of this new procedure.

Materials and Methods

- Forty-three UKA procedures performed in 42 patients (1 bilateral) for treatment of isolated medial compartment osteoarthritis
- Surgical technique used a novel robotic arm system (MAKO Surgical Corp., Fort Lauderdale, Florida)
- UKA design used in this study was an inlay design with an all polyethylene tibial insert

- The patient group consisted of:
  - 23 women and 19 men.
  - Average age of 73±10yrs (range: 49 to 97yrs)
  - Average height of 67±3in
  - Average weight of 182±35lbs
  - Average BMI of 29±5
  - 38% classified as obese
- Standard lateral and AP radiographs were taken for all patients 2 weeks post-operatively
- Evaluated by a single independent orthopedic surgeon
- Eight different aspects of component to host bone alignment were assessed

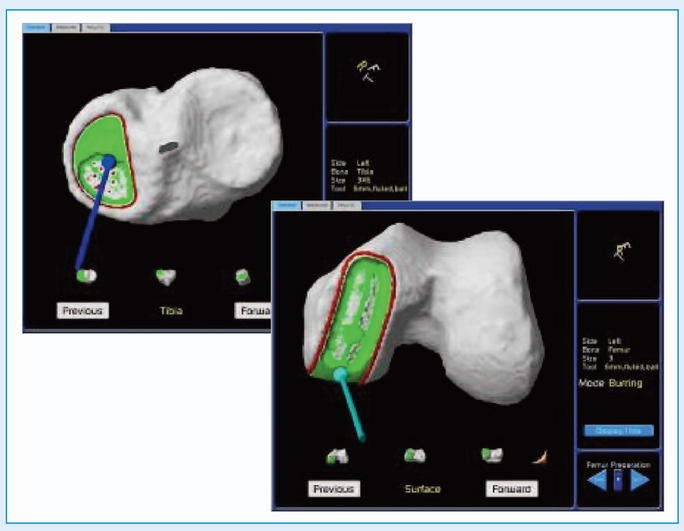


- Pre- and post-operative (3 month) data were collected including the Knee Society Score, WOMAC Osteoarthritis Index, SF-12 health survey and range of motion

Results

Surgical Technique

- A pre-operative CT scan was taken of each patient and the three dimensional reconstructions of the femur and the tibia along with models of the implanted components were used by the surgeon to create an optimized pre-operative plan determining the size, the orientation and the placement of the components relative to the bones.
- This plan was then realized intra-operatively by a robotic arm system providing computer guided control of the cutting and burring instruments.
- The surgeon using this robotic arm system, which takes the place of traditional intra-operatively aligned instruments, created the cut bony surfaces as planned pre-operatively to which the implants were cemented.
- Unicompartmental arthroplasty components were then cemented into the femur and the tibia.



Clinical Results

- The average flexion significantly increased at three months post-operatively to 126±6° compared with 121±8° pre-operatively (p<0.001).
- Post-operative KSS and WOMAC total scores significantly improved from 95±16 to 150±27 (p<0.001) and 41±15 to 21±17 (p<0.001), respectively.
- Quality of life, as measured by the SF-12 Physical Summary also significantly improved from 30±9 to 39±12 (p<0.001).
- Robotic arm guided UKA significantly improved every measured clinical outcome.

Functional Metrics	Pre=op	Post-op	p-value
ROM	121 ± 8°	126 ± 6°	p<0.001
Knee Society Score	95 ± 16	150 ± 27	p<0.001
Sf-12 Physical Summary	30 ± 9	39 ± 12	p<0.001
WOMAC total	41 ± 15	21 ± 17	p<0.001
WOMAC pain	8 ± 4	4 ± 3	p<0.001
WOMAC stiffness	4 ± 1	2 ± 1	p<0.001
WOMAC physical function	29 ± 11	15 ± 13	p<0.001

Radiographic Results

- The radiographic below show a typical series of pre- and post-operative radiographs from one patient.

- Radiographically, outliers were identified as any specific measurement outside a particular range set by a clinical advisory board of orthopedic surgeons.
- Of the 344 radiographic measurements, only 4 (1%) were identified as outliers.
  - Three of those were a slight medial overhang of the femoral component.
  - Upon review of the Merchant view radiographs from these cases, this overhang was actually only overhang of the most anterior (extension) portion of the implant due to slight internal rotation of the femoral component.
  - The fourth outlier was an overstuffing of the joint space with a femoral component that appears to be one size too large.

Conclusion

- This new procedure provides comprehensive, three-dimensional planning of UKA components, including soft tissue balancing, followed by accurate resection of the femur and the tibia.
- This preparation allows for precise placement and alignment of the components.
- All patients showed significant improvement in the post-operative function in every functional measurement.
- The introduction of new procedures and technologies in medicine is routinely fraught with issues associated with learning curves and unanticipated pitfalls. Because the explicit objectives of this novel robotic arm technology are to optimize surgical procedures to provide more safe and more reliable outcomes, these favorable results provide the potential for significant improvements in orthopedic surgery.

Presented at the 21st Annual Congress of the International Society for Technology in Arthroplasty (ISTA 2008), Seoul, Korea - 201836 r00

Does Less Medial Tibial Plateau Resection Make a Difference in UKA

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Introduction

Potential benefits of an inlay design of UKA compared to onlay components include less post-operative pain and quicker recovery due to a lower volume of bone removed, in particular preservation of the densely innervated periosteum and medial tibial plateau periphery. A new technology has been developed using tactile robotic arm technology that replaces traditional UKA instrumentation. In addition to potentially improving accuracy, this technology utilizes a bone preserving inlay tibial design (as opposed to traditional onlay designs). This study assesses the clinical consequences of removing less tibial bone in UKA.

Figure 1. Robotic arm guided implantation.

Materials and Methods

- 79 UKA patients from a single surgeon were included in this study
  - 45 patients receiving a standard onlay UKA
  - 34 receiving an inlay UKA implanted using a robotic arm guided system
- Each surgery was performed using a minimally invasive surgical approach
- The two groups were identical in terms of age (p=0.74), gender (p=0.65) and BMI (p=0.72)
- A radiographic technique was developed to measure the depth of resection of tibial bone stock relative to the initial medial joint line
- All patients received the same pain management and rehabilitation protocol and the length of hospital stay was measured

Figure 2. Inlay UKA components with all polyethylene tibia (left) and onlay UKA components with metal backed tibia.

Results

- The average depth of medial tibial plateau resection was significantly less with inlay tibial components (3.7 ± 0.8mm) relative to onlay tibial components (6.5 ± 0.8mm, p<0.0001).
- While the average length of hospital stay was the same for both onlay (LOS = 1.0 ± 0.2days) and inlay (LOS = 0.9 ± 0.5days) UKA procedures, a significantly higher percentage of inlay patients went home the day of surgery (18% vs. 2%, p<0.0001).

Conclusion

- The depth of medial tibial plateau resection with a typical fixed bearing onlay UKA design is twice as much as an inlay tibial UKA.
- This has significant consequences for potentially using only primary components at future conversion to TKA.
- Likely due to the less invasive (from a host bone perspective) nature of robotic arm guided inlay UKA, a significantly higher percentage of these patients are able to be treated as outpatients.

Figure 3. Examples of bone preparation with inlay UKA components (left) and onlay UKA components (right).

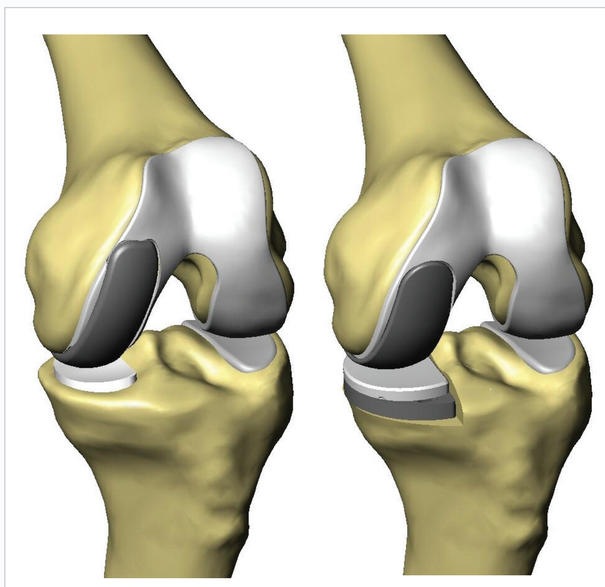
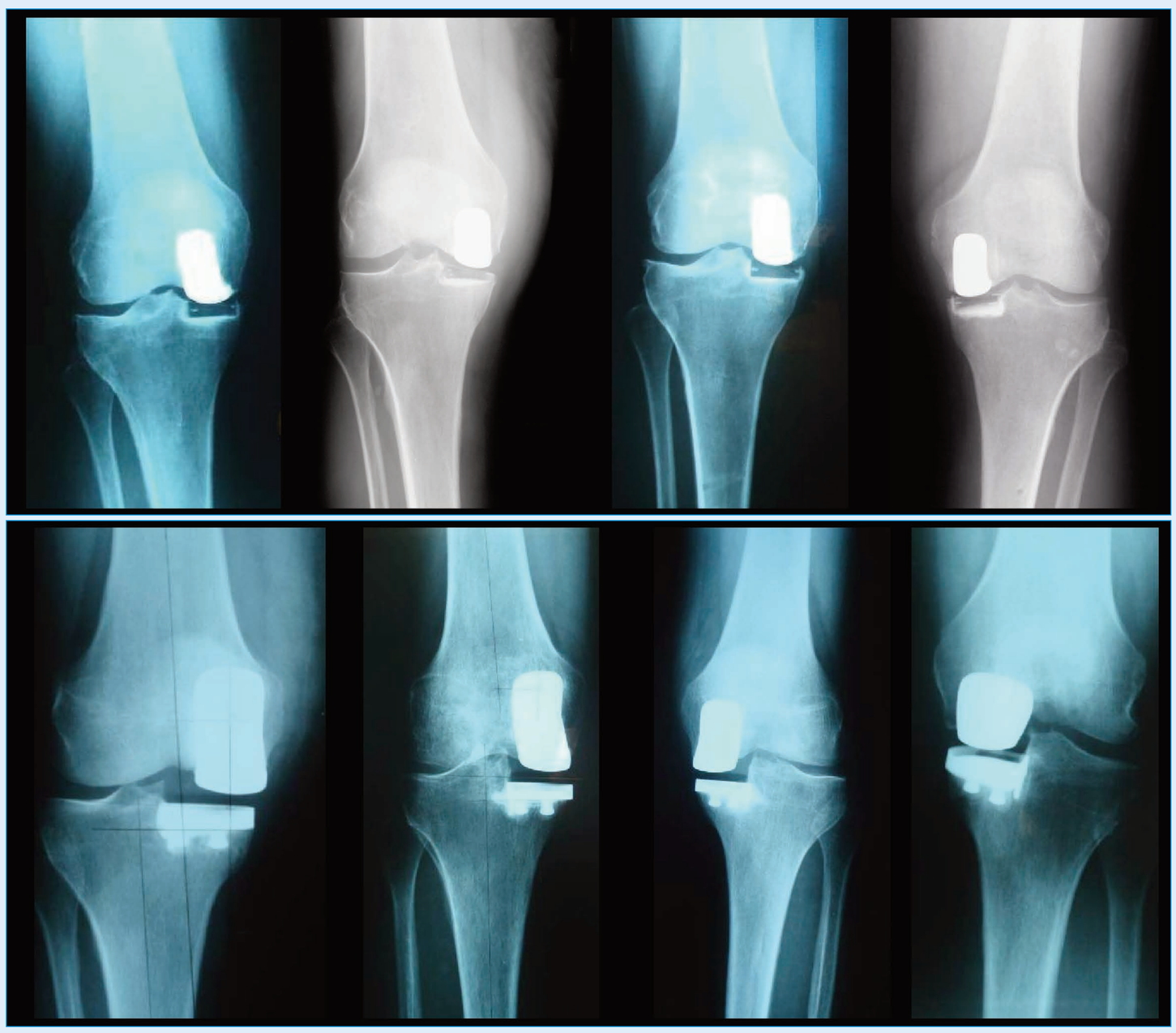


Figure 4. (Below) Post-operative anteroposterior radiographs following robotic arm guided implantation of inlay UKA components with an all polyethylene tibial component. Note that the tibial component matched the joint line in the coronal plane. (Bottom) Post-operative anteroposterior radiographs following implantation of onlay UKA components with a metal backed tibial component. Note the depth of resection.



Presented at the 21st Annual Congress of the International Society for Technology in Arthroplasty (ISTA 2008), Seoul, Korea - 201838 r00