The Computer-Aided-Surgery Improved the Accuracy of Femoral Component Rotation in Total Knee Arthroplasty for the Advanced Osteoarthritis with Valgus Deformity

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Abstract

Purpose: Arthritic knees with genu valgus deformity present with soft tissue and osseous anomalies that make Total Knee Arthroplasty (TKA) difficult. We retrospectively investigate whether advanced valgus deformity would benefit from Computer-Aided Surgery-TKA (CAS-TKA).

Materials and methods: From January 2003 to September 2011, twenty-six patients having osteoarthritis with valgus deformity in the mechanical axis more than 10 degrees who underwent CAS-TKA were entered into this retrospective study. The usefulness of CAS-TKA was analyzed by the accuracy of placement of the components and postoperative alignment determined using radiographic parameters and Computed Tomography (CT). The Hospital for Special Surgery (HSS) and International Knee Society (IKS) functional scores were obtained for all patients preoperatively and postoperatively.

Results: The mean postoperative mechanical axis was 181° (range, 176°-181°). The CT revealed proper femoral and tibial rotational alignment. The joint line was not substantially elevated. No patient required conversion to a constrained TKA to achieve stability. At a mean follow-up of 43 months, the Hospital for Special Surgery (HSS) knee score improved from a mean preoperative score of 54 to 92 postoperatively. The International Knee Society (IKS) functional scores were obtained for all patients preoperatively and postoperatively.

Conclusions: Computer-aided surgery-TKA is a useful alternative technique for advanced valgus knee arthritis where accurate restoration of the joint line, proper alignment of the limb and prosthetic components in coronal, sagittal and axial plane may be challenging because of bony deformities and soft tissue contractures.

Keywords: Knee Arthroplasty; Computed Tomography; Femoral Hypoplasia

Introduction

Total Knee Arthroplasty (TKA) is a reliable, effective and reproducible procedure for treatment of the advanced arthritic knee. Approximately 10% of patients requiring TKA have a valgus deformity [1]. Because of associated bony abnormalities such as distal femoral hypoplasia, posterior femoral condylar erosion, increased femoral neck-shaft angle, external rotation deformity of the distal part of the femur, patellar maltracking and metaphysical remodeling of both the femur and the tibia, surgery on knees with valgus deformity is technically challenging [1-3]. Many surgeons find it difficult to correct a valgus deformity using mechanical alignment guiding systems based on intramedullary or extra medullary rods without relying on the use of a constrained implant [4].

The advanced arthritic knees with genu valgus were classified into three types by Ranawat et al. [3] in 2005. The type-I deformity has minimal valgus deformity (<10°) and medial soft-tissue stretching. Performing TKA on this type is not more challenging than usual, due to less deformity and presence of an intact Medial Collateral Ligament (MCL). A type-III deformity was defined as a severe osseous deformity after a prior osteotomy with an incompetent medial soft-tissue sleeve. A varus-valgus constrained type of prosthesis is often required to compensate for the lax MCL [3-5].

The long-term outcome of TKA depends on good anatomical alignment, component position, and a reconstructed mechanical axis that is within 3 degrees of neutral in the coronal plane. The choice of cutting block used to achieve a distal femoral bone cut perpendicular to the mechanical axis of the femur is dependent on the valgus correction angle of the distal femur. Computer-Aided Surgery (CAS) has been reported to provide more accurate bone cuts, more precise component placement in coronal, sagittal and axial planes (within 3 degrees of target component and limb alignments), better restoration of coronal limb alignment and joint line position, and less gap asymmetry [6-12]. CAS may be advantageous in TKA for valgus arthritis because precise cuts of the femur and tibia in conjunction with meticulous soft tissue release should produce more favorable results. Little has been published regarding the usefulness of CAS-TKA in arthritic knees.

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with advanced valgus deformity. The purpose of this study was to retrospectively investigate the effectiveness of CAS-TKA in implanted patients with advanced pre-operative valgus deformity.

Materials and Methods

This study was approved by the Ethics Committee and institutional review board of the Chang Gung Memorial Hospital (99-2386B).

The computer databases from our hospital were searched for the records of patients who had arthritic knees with a preoperative valgus deformity and who underwent CAS-TKA between January 2003 to September 2011. A total of 26 patients (26 knees) who had a preoperative valgus angulation of the mechanical axis greater than 10° (based on long-leg weight-bearing split scanograms) were enrolled in this study. The clinical data, radiographic data and functional outcomes were reviewed. Clinical data collected include age, sex, diagnosis, intraoperative procedures, tourniquet time (the tourniquet was inflated before skin incision and was deflated after setting of cement), total amount of blood loss (including intraoperative blood loss and blood accumulated in the drain used for forty-eight hours postoperatively), and antibiotic prophylaxis.

The mean age was 71 years (range, 52 to 80 years) at the time of surgery. The diagnosis was degenerative osteoarthritis in 24 knees and rheumatoid arthritis in the other 2 knees. The mean body height was 156 cm (range, 145 to 172 cm), the mean body weight was 66 kg (range, 40 to 81 kg), and the mean body mass index was 27.2 kg/m² (range, 20.8 to 32.1 kg/m²). The mean follow-up time was 43 months (range, 24-70 months) (Table 1). The mean tourniquet time was 72 minutes (range, 50-120 min), and the mean total blood loss was 648 ml (range, 230-765 ml). Seven patients received local autograft for the lateral tibial plateau (Table 1).

All patients received the same Cruciate-Retaining (CR) type of cemented total knee prosthesis (Deputy PFC Sigma Knee System, Deputy Orthopaedics, Warsaw, Indiana). The tourniquet was used in all cases. The knees were exposed using an anterior midline longitudinal skin incision and a medial Parapatellar arthroscopy. After removal of osteophytes from the femur, the soft tissues of the lateral compartment were then released from the proximal tibia. The CAS-TKA was implanted with the use of a Computed Tomography (CT)-free navigation system (Brain LAB, Munich, Germany). The synovium was adequately removed to make registration precise. The femoral reference arrays were fixed to the distal femur using 2 bi-cortical half-pins and the tibial reference arrays were fixed to the proximal tibia. An infrared camera was equipped to track the femoral and tibial reference arrays. After exact identification of the anatomic landmarks, the implant size and orientation were identified by dragging the pointer along the bony surface to reconstruct the three-dimensional bone model. The femoral preparation was performed first, followed by the tibial preparation under the guidance of the navigation system. The femoral component was referenced parallel to the anterior cortex of the distal femur and the transepicondylar line which were previously registered in the navigation system. The rotation of the tibial component was adjusted to match the femoral component and made parallel to the axis between the medial-third of the tibial tuberosity and the center of the tibial plateau. After the osseous cuts of femur and tibia were completed, a spacer block was then used to check the rectangular gap in flexion and extension. The contracted soft tissue was sequential release under the method of Whiteside [13] taking advantage of the quantitative feedback of navigation. The femoral and tibial reference arrays were retained until the cement had fully set and were removed after the alignment was verified under navigation. The tourniquet was then deflated and hemostasis and assessment of patellar tracking were performed. All procedures were performed by the senior surgeon (R.W.-W.H.) who has extensive experience in the use of both conventional mechanical guides and computer-assisted navigation.

Prophylactic antibiotics with 1 gram of a first-generation cephalosporin (cefazolin) were administered intravenously 1 hour before the operation and every 4 hours for 48 hours postoperatively. All patients were allowed full weight-bearing immediately after the surgery. A continuous-passive-motion machine was used from the day of surgery until discharged from the hospital.

All patients were evaluated by radiographic analyses before and after surgery using short-film standing anteroposterior and lateral radiographs of the knees and full-length weight-bearing hip-knee-ankle radiographs [14]. The lateral patellar tilt was measured according to the method of Laurin et al. [15,16]. Radiographic parameters including the mechanical axis, valgus correction angle of the distal femur [17], and four component alignment angles (the Femoral Valgus, TV angle, Tibial Valgus (TV) angle, Femoral Flexion (FF) angle, and Tibial Flexion (TF) angle [18]) were assessed. The position of the prosthetic joint line was measured on radiographs at the last follow-up. We considered as ideal a tibial component positioned at a valgus angle of 90° in the coronal plane and at a flexion angle of 87° in the sagittal plane (3° of posterior slope). We considered as ideal a femoral component positioned at a flexion angle of 0° in the sagittal plane. The desired valgus angle in the coronal plane was determined according to the valgus correction angle of the distal femur which was measured by full-length weight-bearing hip-knee-ankle radiographs. The goal of achieved alignment was to reconstruct the postoperative mechanical axis to be within 3° of neutral and all component angles to within 3 degrees of ideal. Adequate restoration of joint line was defined as being within 10 ± 3 mm proximal to the fibular head and within 25 ± 3 mm distal to the medial epicondyle of the femur [19]. All measurements were done by a blinded observer using digital radiographs.

All limbs underwent CT scanning to evaluate the rotational alignment of the femoral component using the ‘Perth CT Protocol’ [20,21] at the time of the last follow-up. CT scans were performed over the hip, knee and ankle joint of the same leg. The leg axis was reconstructed from the CT data set and this allowed assessment of the coronal and sagittal mechanical axis of the leg along with component alignment in the coronal, sagittal and axial plane. The Femoral Rotational (FR) angle was defined as the angle between the surgical

| Parameters                      | N= 26          |
|---------------------------------|----------------|
| Age (yr)                        | 71 ± 8 (52-80) |
| Gender                          |               |
| Male                            | 11 (42.3%)     |
| Female                          | 15 (57.7%)     |
| Body height (cm)                | 156 ± 8 (145-172) |
| Body weight (kg)                | 66 ± 11 (40-81) |
| Body mass index (kg/m²)         | 27.2 ± 3.2 (20.8-32.1) |
| Type of arthritis               |               |
| Primary osteoarthritis          | 24 (92.3%)     |
| Rheumatoid arthritis            | 2 (7.7%)       |
| Hospital stay (days)            | 7 ± 1 (4-10)   |
| The mean follow-up time (mo)    | 43 ± 24 (24-70) |

The values are presented as the mean ± SD with the range in parentheses or n (%), where appropriate. **Table 1**: Patients’ demographic data.

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epicondylar axis and the tangent to the posterior femoral condyles of the femoral component. The Tibial Rotational (TR) angle was defined as the angle between a line connecting the center of the tibial component and the medial third of the tibial tubercle and a line perpendicular to the tangent to posterior condyles of the tibial component. The ideal femoral and tibial component rotational angles are defined to be within 3° of the target angle (0°) [20,21].

Pre- and postoperative functional scores were assessed using the Hospital for Special Surgery (HSS) [22] and International Knee Society (IKS) scoring system [23]. Active maximum Range of Motion (ROM) of the knee was measured using a goniometer. Patients who had extra-articular deformity of the femur or tibia related to trauma or previous surgery and those with incomplete medical records, radiographic analyses and functional evaluation were excluded.

All data were entered into an Excel spreadsheet (Microsoft Corp, Redmond, WA), checked for missing and illogical data, and subsequently copied into SPSS version 13.0 (SPSS Inc., Chicago, IL). Statistical analysis was performed by an independent statistician blinded to the surgical procedures. The independent t-test and the chi-square test were used for comparison of preoperative and postoperative (the last follow-up visit) radiographic parameters and functional results. The level of statistical significance was set at p<0.05.

Results

The mean tourniquet time was 72 minutes (range, 50-120 min), and the mean total blood loss was 648 ml (range, 230-765 ml). Seven patients received local autograft for the lateral tibial plateau. Twelve patients did not receive additional soft tissue release after removing osteophytes and releasing the soft tissues of the lateral compartment from the proximal tibia. The IT band was released by the pie-crusting technique in 14 patients. No patient had need for further surgical intervention to restore Medial Collateral Ligament (MCL) tension. A total of 3 patients required release of the lateral retinaculum to obtain adequate patellar tracking. No joint line elevation occurred in this study. The thickness of the polyethylene spacer was 8 mm in 3 patients, 10 mm in 18 patients, and 12.5 mm in 5 patients. No patient was converted to a posterior-stabilized type or constrained knee prosthesis during the surgery (Table 2). No complications (e.g., peroneal nerve neuropaxia, pulmonary emboli, deep vein thrombosis, perioperative or postoperative fracture related to pin placement for the femoral and tibial reference arrays, perioperative periarticular fracture, postoperative wound infection, wound healing problems, joint instability, or patellar problems) were encountered. No patients showed loosening or osteolysis on radiographs at the time of the last follow-up. No patients received revision surgery for any reason by the last follow-up.

In the radiographic evaluation, the mean preoperative mechanical axis was 193° (range, 192-196°), and the mean valgus correction angle of the distal femur was 4° (range, 2-6°). The mean postoperative mechanical axis was 181° (range, 176-181°). The mean FV angle was 96° (range, 92-96°); the mean FF was 2° (range, 0-3°); the mean FR angle was 1° (range, 0-3°); the mean TV was 90° (range, 89-91°); the TF angle was 87° (range, 84-90°); and the mean TR angle was 2° (range, 0-3°). All TKAs in this study were achieved the target component and limb alignments (Table 2).

Clinically, the active Range of Motion (ROM) improved from 96° to 115° (p<0.001). The HHS score improved from a mean preoperative score of 54 to 92 postoperatively (p<0.001). According to the IKS rating

| Parameters | N=26 |
|------------|------|
| Preoperative data | |
| Total blood loss (ml) | 648 ± 243 (230-765) |
| Tourniquet time (min) | 72 ± 16 (50-120) |
| Bone grafting | |
| 7 (26.9%) |
| Soft tissue release | |
| No release | 12 (46.2%) |
| Lateral retinaculum for patellar tracking | 3 (11.5%) |
| Joint line elevation | 0 |
| Thickness of polyethylene spacer | |
| 8 mm | 3 (11.5%) |
| 10 mm | 18 (69.2%) |
| 12.5 mm | 5 (19.2%) |
| Radiographic data for leg axis | |
| Valgus correction angle of the distal femur (°) | 4° ± 1 (2-6°) |
| Preoperative MA (°) | 193° ± 1 (192-196°) |
| Postoperative MA (°) | 181° ± 1 (176-181°) |
| Component alignment | |
| Femoral valgus angle (°) | 96° ± 2 (92-96°) |
| Femoral flexion angle (°) | 2° ± 1 (0-3°) |
| Femoral rotation angle (°) | 1° ± 1 (0-3°) |
| Tibial valgus angle (°) | 90° ± 0 (89-91°) |
| Tibial flexion angle (°) | 87° ± 2 (84-90°) |
| Tibial rotational angle (°) | 2° ± 1 (0-3°) |

MA=mechanical axis, AA=anatomic axis

The values are presented as the means SD with the range in parentheses or n (%). The values are presented as the means SD with the range in parentheses or n (%). The values are presented as the means SD with the range in parentheses or n (%).

Table 2: Perioperative and radiographic data.

| Parameters | Preoperatively | Follow-up | (p-value) |
|------------|---------------|-----------|-----------|
| HSS score (points) | 54 ± 6.2 (41-65) | 92 ± 3.0 (88-99) | <0.001* |
| IKS score for clinical knee score (points) | 38 ± 10.1 (16-60) | 97 ± 4.6 (90-100) | <0.001* |
| IKS score for pain (points) | 15 ± 5.2 (10-20) | 48 ± 3.5 (40-50) | <0.001* |
| IKS score for functional knee score (points) | 32 ± 9.5 (20-50) | 96 ± 5.0 (90-100) | <0.001* |
| Active range of motion (°) | 96 ± 13.5 (80°-120°) | 115 ± 11.3 (100°-125°) | <0.001* |

 IKSS Score=International Knee Society Score
 HSS Score=Hospital for Special Surgery Score

The values are presented as the means SD with the range in parentheses.

*p<0.05

Table 3: Knee Scores, Hospital for Special Surgery Score and active range of motion proper actively and at the last follow-up visit.

Discussion

The focus of this series is on the type-II valgus deformity, which has a more substantial deformity (>10°) with medial soft tissue stretching. Surgery is technically demanding because it may be associated with hypoplasia of the distal femur, rotational deformity of the tibia and femur, and femur and tibial medullary channels, and other osseous abnormalities along with the soft-tissue contracture [3]. There is a greater risk of component malposition, elevation of the joint line (by an over thickness of polyethylene to compensate for excessive laxity) and unplanned conversion to a varus-valgus constrainedtype prostheses (to compensate for excessive MCL laxity or improper management
of the contracted soft tissues) [3,25,26]. Moreover, obtaining accurate size may be difficult using conventional sizing guides in the hands of less experienced surgeons. The deficiencies in the lateral femoral condyle often render sizing guide unsuitable and choice of a smaller size chamfer block which may lead to over-resecting of the medial femoral condyle.

Amar et al. [3] suggested that for valgus knees, a 3° valgus distal femoral cutting block instead of the usual 5°-7° valgus distal femoral cutting block should be used. In this study, we found that the valgus correction angle of the distal femur ranged from 2° to 6°. Routinely using a 3° valgus distal femoral cut may not be advisable. With CAS-TKA, the surgeon can focus on the centers of the hip, knee, and ankle joint and ignore any extra-articular deformities of the femur and tibia, allowing cuts that can provide the desired reconstructed alignment of the limb and the components.

Malrotation of the femoral component affects patellofemoral tracking and may increase the contact pressure and lead to accelerated wear of the patellar button [5,27]. When using conventional intramedullary femoral guidance jigs, the deficiencies of the lateral femoral condyle often render the posterior condylar axis inaccurate as a reference for determining femoral component rotation. Guidance systems fixed 3° external rotation may not be suitable for valgus knees. During CAS-TKA, the same anatomic landmarks used are determined by the surgeon. The accurate rotational alignment depends on the exact identification of anatomic landmarks and accurate chamfer cuts. By using the commercial conventional instrumentation (Deputy PFC Sigma Knee System). After performing the distal femoral resection and the exact identification of the anatomical landmarks, we drew the surgical transepicondylar line for judgment of femoral rotation. We placed the reference sizing guide against the resected distal surface of the femur and then selected the proper femoral rotation according to the transepicondylar axis. Because of the osseous deficiency, exact placement of the chamfer block is difficult by using the commercial instrumentation (with the posterior condyles resting on the posterior plate of the guide). The mistake in the judgment of femoral rotation may be difficult to be prevented visually. In CAS-TKA, taking care of identification of anatomic landmarks and then sequential registration into the navigation system was performed. Instead of intraoperative judgment of chamfer block in axial plane visually, the surgeon can judge the accuracy of chamfer block under the real-time quantitative feedback of the navigation system.

Using post-operative CT scans, several authors have demonstrated significant improvement in the rotational alignment of the femoral component with CAS-TKA [7,8,11,13], however, other researchers have reported no differences between CAS-TKA and conventional TKA [17,28-29]. The different types of preoperative knee deformity (varus or valgus deformity) seen in their respective study population may be another possible confounding factor.

Joint line elevation secondary to placement of a thick polyethylene spacer increases the risk of the peroneal nerve neuropraxia and the patellofemoral contact forces and may be a contributing factor to postoperative complications such as pain, polyethylene wear, and inferior clinical result [27,30,31]. Figgie et al. advised limiting joint line elevation to less than 8 mm in primary TKAs [32]. Ensini et al. [33] and Lee et al. [34] reported that the joint line is well restored and the risk of overstuffing is limited with CAS-TKA. In our study we found no joint line elevation, our results were compatible with literatures [33,34].

Several limitations of this study should be acknowledged. First, this is a retrospectively designed study with all its inherent limitations and bias. All patients were managed by a single experienced surgeon using the same protocol, which might decrease some confounding factors. Second, this study includes the small number of patients with short-term follow-up. There were only 26 knees in this study, which reflects the relative rarity of advanced genu valgus deformities (valgus deformity in the mechanical axis more than 10°) in patients undergoing TKA. In the current study, the CAS-TKA provided good results without additional osteotomy in all patients. The mechanical axis was corrected from 193° (range, 192°-196°) preoperatively to within 3° of the neutral axis. Similar results were presented for component alignment; all components were within 3° of the planned alignment. Excellent functional improvement was also achieved after a mean follow-up of 43 months. Finally, there were no instances of Ranawat type-III deformities (a severe osseous deformity after a prior osteotomy with an incompetent medial soft-tissue sleeve.) so we are unable to comment whether CAS would have any advantage.

In conclusion, CAS-TKA appears to be an effective alternative for accurate restoration of mechanical axes as well as femoral component placement in coronal, sagittal and axial planes. However, with regard to clinical function, we were unable to show whether the radiographic benefits translates into future better clinical outcomes during further long-term follow-up.

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