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ADVANCES IN TOTAL KNEE ARTHROPLASTY

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Abstract*:The purpose this article is to improve the knowledge in Total Knee Replacement (TKA) related with design, materials and wear. Advances in this area have been done to increase the satisfaction for patients and doctors. The TKA is one the most successful procedures in orthopedics, but complications can be devastating. Accuracy, good alignment, stability and new materials decrease the comorbities and can be important to achieve good functional results.*

Keywords*: knee; replacement; ceramic; wear*

1. Introduction

Total knee arthroplasty (TKA) has been a reliable procedure providing durable pain relief for elderly patients with modest physical demands. Numerous studies have reported a prosthetic survivorship more than 90% at 10 years or more after implantation. Nevertheless, with longer followup, prosthetic failure becomes increasingly common. Approximately 1/4 of all TKAs can be expected to fail by 20 years after implantation, even when surgery has been done at a highly specialized, large volume center.22 In young, heavy, male patients, failure rates of as much as 65% have been reported at 10-year follow-up. Polyethylene (PE) wear and osteolysis are cited as common reasons for prosthetic failure.

The aim of this update on total knee arthroplasty surgery is to discuss, in summary fashion, topics presented at selected orthopaedic meetings and in articles published in orthopaedic journals mentioned some topics related advances in this specific area.

2. New designs and materials

While a uniform definition of less or minimally invasive surgery remains evasive, many reports were presented or published on this topic and on the role of computer assistance in the operating room. Koyonos et al., using an image-free navigation system with manual instruments, found that alignment errors most commonly occur during manual pinning of the tibial and femoral cutting blocks.The minimally invasive surgery group had less pain, more rapid achievement of 90° of flexion, and a shorter time to performing a straight leg raise.While the knees in the minimally invasive surgery group had more rapid progression of range of motion and required the use of less pain medication, they were associated with a longer surgical time, increased minor wound-healing complications, and more frequent tibial component malalignment (observed in four of thirty knees).Scuderi et al. reported on 100 consecutive primary total knee arthroplasties (excluding those in knees with deformity, <90° of flexion, or previous incisions) that were performed through incisions of <5.5 in (<14.0 cm) and found a lower drop in the hemoglobin level (3.1 compared with 4.2 g/dL) and slightly shorter length of stay (3.9 compared with 4.4 days) in the mini-incision group and reported no differences between the two groups with regard to postoperative alignment, motion, walking ability, or pain scores. Bonutti et al. reviewed the minimum two-year results of 219 minimally invasive total knee arthroplasties and reported a 98% rate of good and excellent Knee Society scores, six manipulations, and five reoperations (including two revisions for the treatment of infection, two tibial revisions for the treatment of pain, and one revision for the treatment of posterior cruciate ligament rupture). Laskin et al. evaluated the use of a mini-midvastus approach without patellar eversion in a study of fifty-one patients and found that these patients had a shorter time to straight leg raising, used less epidural analgesia, had a more rapid progression of flexion, and were discharged 18% faster compared with patients who had been managed with a standard incision. Hungerford, in a symposium at the open meeting of the Knee Society, discussed the opposing view that there is no proven meaningful benefit of minimally invasive surgery techniques and that the reduced exposure will only make appropriate alignment more difficult to obtain, especially for the occasional knee surgeon, with a resultant increase in technical errors.

Several investigators reviewed the value of computer assistance in total knee arthroplasty. Victor performed a prospective, randomized, controlled trial to evaluate the use of image-based computer-assisted surgery in total knee arthroplasty and reported significant differences in operative time ($p < 0.005$) but found no differences in blood loss, patellar alignment, tibial slope, or postoperative scores. However, he found significant improvement in coronal alignment, with neutral mechanical alignment being achieved in all knees that were treated with the computer-assisted procedure ($p < 0.0001$). Bolognesi and Hofmann described a study in which fifty total knee arthroplasties that were performed with an imageless computer-assisted-surgery system were compared with fifty total knee arthroplasties that were performed with standard instruments. The authors found that 98% of the femoral components and 100% of the

tibial components were aligned within 3° of the goal position in the computer-assisted-surgery group, compared with 90% of the femoral components and 92% of the tibial components in the standard group. Kim and Wixson performed a similar comparison and found that 58% of the components were within 2° of neutral alignment in the manual group, compared with 78% of those in the computer-assisted-surgery group ($p = 0.008$).

Stulberg et al. used computer assistance with preoperative and postoperative computed tomography scans and found that the mean relationship between the posterior condylar axis and the epicondylar axis was 4.69° of internal rotation. Similarly, the mean relationship of Whiteside's line to the epicondylar line was 0.07°. The authors found that the intraoperative determination of the posterior condylar axis and the epicondylar axis using surface registration techniques was unreliable, suggesting that the use of Whiteside's line was more reliable. Blaha used a cadaveric model to calculate the average flexion-extension axis for five specimens and found that this "functional plane" passed just lateral to the anterior-inferior iliac spine to the center of the distal part of the femur, through the tibial tubercle and the neck of the talus. On the basis of this information, he concluded that, in clinical practice, a "functional alignment" that is achieved by cutting the distal part of the femur in 3° of valgus (in contrast to the usual 6°) would aid in reestablishing the normal plane of flexion and extension. Sodha et al., evaluated the need for lateral retinacular release as a function of femoral component rotation and found that the need for release significantly decreased ($p < 0.0001$) when the method of using the epicondylar axis as a guide to rotational alignment was compared with the method of performing equal posterior condylar resections. Hanada et al., in a study of twelve cadaveric knees, compared the alignment and stability characteristics of six knees that were aligned and resected with use of a tensioned gap technique with those of six knees that were treated with a measured resection technique. In the group treated with the tensioned gap technique, all six knees shifted toward varus in flexion and the patellar groove shifted laterally relative to the neutral position. In the group treated with the measured resection technique, all six knees had near normal varus-valgus and rotational stability tests, alignment, patellar groove positioning, and load-transfer characteristics. Incavo et al. compared these two resection techniques in a study of fifty total knee arthroplasties and found that the flexion space-balancing technique led to a smaller size selection in 56% of knees ($p < 0.05$) when compared with the measured resection technique, especially in varus knees. The authors indicated that a tight flexion space could lead to inferior clinical outcomes.

Stiffness following total knee replacement remains a difficult problem to treat. Haidukewych et al., in a study of sixteen knees that had undergone formal revision of well-fixed components because of stiffness after primary total knee arthroplasty, reported that the rate of satisfaction was 73% and that the Knee Society pain score improved from 28 to 65. Maloney et al. reviewed twenty-three knees that had undergone a reoperation for the treatment of stiffness (including twelve knees that had undergone polyethylene exchange and soft-tissue releases, three that had undergone tibial component revision, and eight that had undergone revision of both components) and reported improvement in the mean arc of motion from 60.5° to 82.5°. Kim et al. reported a 1.3% prevalence of stiffness (defined as a >15° flexion contracture and/or <75° of flexion) after total knee arthroplasty and found that revision surgery was a satisfactory treatment option in this subgroup of patients, with 93% having a modestly improved arc of motion.

Wear and osteolysis remain a major concern following total knee arthroplasty. Conditt et al. studied 124 retrieved polyethylene tibial inserts of twelve different designs after implantation periods ranging from zero to 180 months and frequently found moderate to severe wear of the nonarticulating surface (backside) in association with all designs, independent of the capture mechanism, suggesting that design modifications are needed. Tomek et al. evaluated ninety-seven retrieved constrained tibial inserts and noted that burnishing, scratching, pitting, and deformation were uniformly present, although infection, loosening, and instability were the most common forms of failure.With regard to osteolysis, Miura et al. reported that the oblique posterior femoral condylar radiographic view was significantly better than a true lateral view for the detection of radiolucencies of the posterior femoral condyles ($p < 0.0005$). Reish et al. found that, when multiple-detector computed tomography was used as the standard, plain radiographs detected only 20% of osteolytic lesions around twenty-six total knee arthroplasties.

3. High flex design

Cinical experience has shown the need for high flexion (>120[degrees]) in certain patients after TKA, particularly in some ethnic populations that require high flexion for social, religious, or occupational activities. Previous studies using fluoroscopy have shown the importance of certain femorotibial motion patterns (increased internal tibial rotation, increased posterior femoral rollback) to achieve a high degree of knee flexion in traditional designs of total knee replacements. These fluoroscopic studies after TKA have also found an average weightbearing flexion angle smaller than 120[degrees] and have pointed out the possible deleterious effect on the polyethylene (PE) insert of notable liftoff at flexion angles larger than 90[degrees]. Finally kinematic studies of nonimplanted patellas have shown the importance of patellofemoral motion patterns (patellofemoral contact position, patellotibial angles, patellofemoral separation) in deep knee flexion.The high flex total knee system is a posterior stabilized design to accomodate flexion to 155 degrees.By posterior femoral condyles is extended to provide great arc of flexion by attempting to prevent "digging in"of the posterior femur into the articular surface.The femoral component with a short antero posterior width and a deep patellar groove improve the patellofemoral tracking.The cam-spine mechanism has a modified posterior stabilized to increase subluxation resistance and enhance posterior femoral translation at deep flexion.This tibial insert has

incorpored design modifications to reduce femoral rise, improve collateral ligament function in deep flexion, and reduce torsiona constraint during internal and external rotation.The anterior margin of the tibial articular component should be recessed.This provide clearance for the patella and patella tendon.

4. Polyethylene Wear and Osteolysis

Total knee replacement is a long-lasting pain-relieving procedure with a high success rate over both the short and long term. When one talks about long-term failure of a knee replacement, the underlying cause is usually polyethylene wear. The sequelae of that wear can include osteolysis, instability, and loosening of the implants from the underlying bone.Over the past 20 years, there have been numerous attempts made to decrease the wear of polyethylene in knee replacement prostheses. One area of investigation has been in changing the physical properties of the polyethylene itself. Some of these changes, including the addition of carbon fibers or heat pressing, were ineffective and actually caused an increase in wear. Presently there is ongoing investigation of the use of beam irradiation of polyethylene to increase cross linking and thereby decrease wear.Although such cross linking increases the hardness of the material, the polyethylene becomes more susceptible to abrasive wear from a rough countersurface.There are many mechanisms by which polyethylene in a bearing surface can wear.These mechanisms include fatigue and delamination (which are predominately related to the polyethylene itself) and adhesion and abrasion (which are predominately related to the countersurface articulating with the polyethylene).

Collier et al. investigated the factors of backside interface and polyethylene sterilization method in a study of 365 cruciate-retaining total knee replacements (Anatomic Modular Knee; DePuy) with at least five years of follow-up. The authors found that staggered shifts toward a polished baseplate and away from gamma-irradiated-in-air polyethylene dramatically reduced the prevalence of osteolysis associated with this design, from 24% to 2%. Lachiewicz and Soileau reviewed the results of 193 total knee arthroplasties that had been performed in 131 patients with use of the modular Insall-Burstein II posterior stabilized prosthesis (Zimmer, Warsaw, Indiana) and reported no instances of tibial loosening, eight tibial osteolytic lesions, a 16% prevalence of nonprogressive radiolucent lines, and three reoperations after a mean duration of follow-up of seven years. Fehring et al. reported on 1287 primary total knee arthroplasties after a minimum duration of follow-up of five years. Radiographic analysis was performed by an independent radiologist. The prevalence of wear-related failure was 8.4%, and the thirteen-year survival rate was 82.6%. Five variables were found to be significantly correlated with wear-related failure: patient age, gender, polyethylene sheet vender, polyethylene finishing method, and polyethylene shelf age.

5. Oxinium

Oxidized Zr was selected as a possible bearing material in knee replacements based on laboratory testing of the properties of the material itself. These tests attempted to elucidate whether the material could lessen the coefficient of friction when it articulated against polyethylene and/or cartilage and whether it would be resistant to scratching. If both of these situations could be demonstrated, then it would aid in decreasing both adhesive and abrasive wear of the polyethylene surface.Tests were performed to determine the nanohardness of the material and the bonding strength between the surface oxide and the substrate. The nanohardness of the surface was twice that of cobalt chrome and titanium alloy. The bonding strength of the 5-[mu]m oxide surface was excellent with no evidence of debonding even when the surface was artificially chipped with a diamond tip.Mechanical testing and finite element analysis of oxidized Zr and cast CoCrMo femoral components showed equivalent device fatigue strength between the materials, both being in the range of 450 MPa. The fatigue strength of the ceramic-surfaced oxidized Zr alloy was significantly greater than that of an all-ceramic component and did not fail even when eccentrically loaded in a cantilever bending mode.Based on this extensive mechanical testing, it was felt that the decrease in the potential for adhesive and abrasive wear of polyethylene articulating against oxidized zirconium would suggest using this material for younger patients in whom longevity of the polyethylene is crucial.

In conclusion, computer-assisted surgery is a very promising technique because correct alignment is a critical factor in the longevity of total knee replacements, and may be associated with minimally invasive procedure.The concept that these high-flexion designs may simply accommodate more flexion if the patient can obtain it.Design factors that influence the durability and, therefore, the generation of wear debris include articular geometry, component thickness, and material and surface characteristics of the components. At the level of polyethylene debris generation is reduced, improvements in fatigue and fracture resistance may help to limit mechanical failures an subsequent loosening.The developments in ceramics are directed toward the continued improvements of properties.

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