

Contemporary Total Joint Arthroplasty

Victor M. Goldberg, MD

Total joint arthroplasty has become a successful and reproducible surgical treatment for significant arthritis. Both pain relief and functional outcomes have been excellent. In 2004 over 475 000 total knee replacements and more than 230 000 total hip replacements were performed in the United States, and this number is increasing at a rate of 11% for knee replacement and 2.5% for hip replacements each year. Although joint replacements have an excellent outcome, there still has been a small although disturbing incidence of mechanical and biological failures. The causes of these failures include implant surface wear, loosening, and instability. Infection remains a long-term concern.^{1,2}

Early in the history of joint arthroplasty, younger, more active patients and very elderly patients were discouraged from having replacements because of the increased incidence of failures in these populations. Recent advances in implant design, materials, and surgical techniques have widened the indication for total joint arthroplasty in all patients with end stage arthritis. For example, alternative bearing surfaces such as metal-on-metal articulations have significantly reduced wear and its associated bone loss and implant loosening.³⁻⁶ Minimally invasive surgical procedures have accelerated patient rehabilitation, and enhanced instrumentation has provided excellent restoration of joint anatomy.⁷⁻⁹ An understanding of the present state of the art of joint arthroplasty is critical in order to provide physicians and patients with the basis of contemporary indications and expected realistic outcomes of the procedure.

Total Knee Arthroplasty

Enhanced designs and techniques have improved the long-term survival rates of total knee replacements so that 90% to 95% of active patients can expect a satisfactory result for 15 to 20 years. Implant fixation can be accomplished by either cementless or cemented methods. The success of cementless fixation depends upon a stable implant with a porous surface composed of either titanium or cobalt chromium alloys configured to support

bone regrowth. Stability of the components can be achieved by using screw fixation and press-fit stems and/or pegs.¹⁰⁻¹² Precise surgical instruments provide close implant-bone interface. Studies indicate that component movement of less than 75 to 100 micrometers will support bone ingrowth, whereas motion of greater than 150 micrometers encourages fibrous tissue ingrowth.⁴

“Recent advances in implant design, materials, and surgical techniques have widened the indication for total joint arthroplasty in all patients with end stage arthritis.”

Contemporary knee component designs have closely reproduced knee anatomy. Recently gender-specific implants have been introduced to better match the size and geometric dimensions of the female distal femur. (See Figure 1.) This should improve patellar tracking and ligament balancing. Knee flexion is important for functional activities. Newer designs are now available that allow as much as 140° to 150° of knee flexion.¹² This is especially important in patient populations that require kneeling activities.

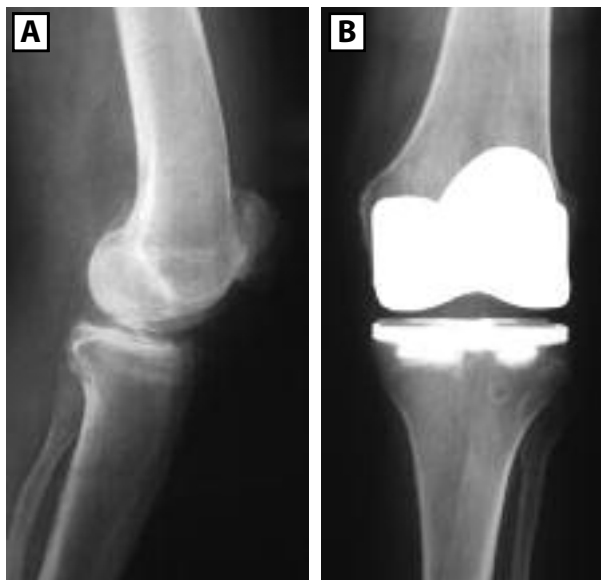
Wear of contact surfaces is a significant cause of failure of total knee replacement. Improvement in the manufacturing technique of polyethylene has reduced wear debris from the articulating surface. These advances include processes to reduce oxygenation of polyethylene to improve fatigue wear of the material.⁴ The use of thicker polyethylene tibial inserts and optimization of component designs has also reduced wear failures in total knee arthroplasty.¹² Another approach to reducing stress on polyethylene has been to increase conformity between

Victor M. Goldberg, MD, is a professor in the Department of Orthopedic Surgery at Case Western Reserve University. He can be reached at vmgoldbg@aol.com or 11100 Euclid Avenue, Cleveland, OH 44106.

Figure 1.

(A) Lateral Radiograph of a Female Patient With Significant Osteoarthritis

(B) Arthroplasty Radiograph Demonstrating the Anatomical Relationship of the Component With the Femur Using an Implant Specifically Designed for Females



surfaces. Mobile bearing prostheses have been developed that provide conformity without sacrificing rotational movements of the knee.¹³ Although the results are satisfactory with a follow-up of 9 to 12 years, there is still an incidence of periprosthetic bone loss as a result of wear-induced osteolysis.

Traditional total knee arthroplasty has been highly successful in pain relief and functional long-term survivorship. Patients, however, have expressed dissatisfaction with the postoperative pain and prolonged rehabilitation. These issues have encouraged surgeons to adopt minimally invasive surgical techniques which use smaller skin incisions and muscle-sparing approaches.⁸ The early results of minimally invasive surgical techniques are encouraging, but usually by 6 months to 1 year after surgery there is no difference in results when compared to traditional approaches. Longer term data will be necessary to substantiate the early results of minimally invasive techniques which are inherently more difficult and have the potential for increased complications.

Optimizing surgical techniques in total knee arthroplasty has been reported to improve long-term survivorship of the procedure.⁷ Adapting computer assisted navigation to the total knee arthroplasty surgical technique may improve knee alignment and component position. The early results indicate that these outcomes can be accomplished using this technique, but extensive exposure is necessary and the instrumentation is complex and difficult to master.⁷ Ultimately this approach combined with a minimally invasive technique will assure anatomically aligned knees with the least intrusion on bone and soft tissues.

Total Hip Arthroplasty

Since total hip arthroplasty was introduced into the United States in 1969, there have been extensive changes in implant designs, materials, and surgical techniques. Using contemporary designs, hip implant survival rates have approached 90% to 95% at 15 to 20 years after surgery.¹⁴ Early concerns focusing on perioperative infection have largely disappeared due to the use of perioperative antibiotics, ultraclean operating rooms using laminar flow methods, and exhaust exclusion hoods that isolate the surgeon from the patient. Implant breakage has virtually been eliminated by the use of high strength materials such as titanium and forged cobalt chromium stems. Newer hip stem designs use more flexible materials that match the stem's material characteristics with the surrounding bone to enhance implant integration with the patient's femur and also preserve native bone.¹⁵ (See Figure 2.) Fixation methods have evolved so that either cemented or cementless modes of fixing the component to bone have been highly successful.^{14,16,17} Major advances in this area have included methods of assuring excellent cementing techniques to provide optimum fixation of the implant to the host bone.¹⁸ Porous surfaces have been redesigned to closely mimic the structure of the surrounding bone.¹⁵ These newer surfaces provide the best geometric configuration to enhance bony ingrowth and long-term component fixation.

The major focus of research and development over the past decade has been directed towards reduction of bearing surface wear and the biologic reaction to this periprosthetic debris.³

Figure 2.

Arthroplasty Radiographs of a Hip Six Years After Replacement With a Component Stem Made of Flexible Materials Demonstrating Excellent Bone Preservation



The resulting bone loss or osteolysis may compromise implant fixation and ultimately result in component loosening. Alternative bearing surfaces have been developed which may reduce wear of the articulating surfaces and prolong the longevity of the total hip replacement.^{4,6} Hard surfaces include metal-on-metal or ceramic-on-ceramic. Although wear is reduced significantly with these surfaces, there still are potential problems that could compromise the replacement. For example, metal-on-metal surface wear results in the release of metal ions which circulate systemically and could have long-term consequences.⁵ Ceramic surfaces have the potential to fracture if any impingement results because of even minor implant malposition.⁶ The recent introduction of highly cross-linked polyethylene as a counter surface to the femoral head also has significantly reduced the generation of wear particles.⁴ However, the ultimate role of each of these bearing surfaces requires longer term follow-up, so that the choice of the best articulating surface can be adapted cost-effectively to the appropriate patient.

Computer assisted navigation and minimally invasive surgical techniques have also been used at selected centers to improve implant positioning and early rehabilitation. Initial experience with both of these approaches has been encouraging, but long-term follow-up is necessary to assess the real value of these approaches compared to established methods.⁹

The use of total hip replacement in young, active patients has always been controversial considering the reported increased failure rate in these patients.¹⁶ Revision total hip replacement is significantly more complicated than the primary procedure because of the bone and soft tissue loss seen with the failed total hip replacement. Recently metal-on-metal surface replacement arthroplasty has been introduced to replace the hips of this younger, active patient population.¹⁹ (See Figure 3.) This replacement preserves bone and resurfaces the acetabulum and femoral head. The larger ball size may enhance range of motion and hip function without the risks of hip dislocation. The early results have been good, however, an additional complication not seen in classical total hip replacement has been observed.²⁰ Femoral neck fractures have been reported which require an early revision, perhaps because the surgical procedure itself compromises the blood supply to the femoral head. The reported incidence of this complication varies from 1.5% to 3%. Prevention of this early failure requires surgeon education and improved sophisticated instrumentation. Longer follow-up is necessary to define the role of this replacement compared to a standard total hip replacement with large heads, now available with the new alternative bearing surfaces.

Total Ankle Arthroplasty

The reported results of the first generation total ankle arthroplasty were significantly poorer than total hip and total knee replacement. Loosening and mechanical failure were the primary reasons for failure of the total ankle replacement.^{21,22} As a result, ankle arthrodesis, inducing ossification between bones, was the preferred treatment for end-stage ankle arthritis.

Recently contemporary implants have been introduced with improved designs, surgical techniques, and materials, and early results have been encouraging.²¹ Both mobile bearing designs and fixed bearing implants have reported satisfactory intermediate clinical results. One recent systematic review of the literature comparing ankle arthrodesis with total ankle replacement indicated that each procedure had about 25% poor results, and the revision rate was 9% for arthrodesis compared to 7% for total ankle replacement.²² However, these results are predominantly retrospective and uncontrolled without direct comparison between the 2 procedures. The major difficulties in designing implants for total ankle replacement are a lack of complete

Figure 3.
Arthroplasty and Lateral Radiographs
Demonstrating Surface Replacement



understanding of the complex kinematics of this joint, material properties of the tibia compared to talus, and the very thin and poorly vascularized soft tissues. By contrast to total knee arthroplasty, the surgical techniques required to obtain anatomical alignment of the ankle and soft tissue balance are not well established. Indications for this procedure are still being refined. It appears that with the second generation total ankle replacement the optimal patient is older with lower demands. Patients who exhibit significant arthritis in the subtalar or midtarsal joints may be better functionally after an ankle replacement compared to arthrodesis. Absolute contraindications for the procedure include active infection and inadequate soft tissues or vascularity. Marked ankle instability, poor bone, or osteonecrosis of the talus are relative contraindications. Presently there are a number of ongoing clinical trials in the United States evaluating the different design philosophies.²¹ Each of the 4 new total ankle replacements being studied do have some clinical concerns such as subsidence and/or dislocation of the components. Wear of the surfaces still remains a long-term worry. Current recommendations are for the procedure to be performed for low-demand patients by surgeons who have completed special training for the technique.

Summary

Total joint arthroplasty is a highly successful procedure for end-stage lower extremity arthritis. Excellent pain relief and significantly improved function is usual after surgery when

used for appropriate indications by highly skilled surgeons using contemporary designed components. Future improvement in

design and materials to reduce wear will further enhance clinical outcomes and long-term implant survival. **NCMJ**

REFERENCES

- 1 Gioe TJ, Killeen KK, Grimm K, et al. Why are total knee replacements revised? Analysis of early revision in a community knee implant registry. *Clin Orthop Relat Res.* 2004;428:100-106.
- 2 Kurtz S, Ong KL, Schmier J, et al. Future clinical and economic impact of revision total hip and knee arthroplasty. *J Bone Joint Surg Am.* 2007;89(Suppl3):144-151.
- 3 Dumbleton JH, Manley MT, Edidin AA. A literature review of the association between wear rate and osteolysis in total hip arthroplasty. *J Arthroplasty.* 2002;17(5):649-661.
- 4 Harris WH. Cross-linked polyethylene: why the enthusiasm? *Instr Course Lect.* 2001;50:181-184.
- 5 MacDonald SJ, McCalden RW, Chess DG, et al. Metal-on-metal versus polyethylene in hip arthroplasty: A randomized clinical trial. *Clin Orthop.* 2003;406:282-296.
- 6 D'Antonio J, Capello J, Manley M. Alumina ceramic bearings for total hip arthroplasty. *Orthopedics* 2003;26(1):39-46.
- 7 Delp SL, Stulberg SD, Davies B, et al. Computer assisted knee replacement. *Clin Orthop Relat Res.* 1998;354:49-56.
- 8 Bonutti PM, McMahon M, Mont MA, et al. Minimally invasive total knee arthroplasty. *J Bone Joint Surg Am.* 2004;86(Suppl 2):26-32.
- 9 Berry DJ, Berger RA, Callaghan JJ, et al. Minimally invasive total hip arthroplasty: development, early results, and a critical analysis. *J Bone Joint Surg Am.* 2003;85-A(11):2235-2246.
- 10 Berger RA, Lyon JH, Jacobs JJ, et al. Problems with cementless total knee arthroplasty at 11 years follow-up. *Clin Orthop Relat Res.* 2001;392:196-207.
- 11 Hoffman AA, Evanich JD, Ferguson R, et al. Ten- to 14-year clinical followup of the cementless Natural Knee system. *Clin Orthop Relat Res.* 2001;388:85-94.
- 12 Bozic KJ, Kinder J, Meneghini RM et al. Implant survivorship and complication rates after total knee arthroplasty with a third-general cemented system: 5 to 8 years followup. *Clin Orthop Relat Res.* 2005;430:117-124.
- 13 Buechel FF. Long-term follow-up after mobile-bearing total knee replacement. *Clin Orthop Relat Res.* 2002;404:40-50.
- 14 Callaghan JJ, Templeton JE, Liu SS, et al. Results of Charnley total hip arthroplasty at a minimum of thirty years. *J Bone Joint Surg Am.* 2004;86A:690-695.
- 15 Akhavan S, Mattheisen MM, Schulte L, et al. Clinical and histologic results related to low-modulus composite total hip replacement stem. *J Bone Joint Surg Am.* 2006;88A:1308-1314.
- 16 Capello WN, D'Antonio JA, Feinberg JR, et al. Ten-year results with hydroxyapatite-coated total hip femoral components in patients less than fifty years old: A concise follow-up of a previous report. *J Bone Joint Surg Am.* 2003;85A:885-889.
- 17 Engh CA, Hopper RH Jr, Engh CA Jr. Long-term porous-coated cup survivorship using spikes, screws, and press-fitting for initial fixation. *J Arthroplasty.* 2004;19(7):54-60.
- 18 Goldberg VM. Surface Replacement Solutions for the Arthritic Hip. *Orthopedics.* 2005;28(9):943-944
- 19 Amstutz HC, Beaulé PE, Dorey FJ et al. Metal-on-metal hybrid surface arthroplasty: Two to six-year follow-up study. *J Bone Joint Surg Am.* 2004;86A:28-39
- 20 Goldberg VM, Ninomiya J, Kelly G, et al. Hybrid total hip arthroplasty. *Clin Orthop Relat Res.* 1996;333:147-154.
- 21 Easley ME, Vertullo CJ, Urban WC, et al. Total ankle arthroplasty. *J Am Acad Orthop Surg.* 2002;10(3):157-167.
- 22 Haddad SL, Coetzee JC, Estok R, et al. Intermediate and long-term outcomes of total ankle arthroplasty and ankle arthrodesis. *J Bone Joint Surg Am.* 2007;89A:1899-1905.

Instructions for Authors

Unsolicited manuscripts containing original material are accepted for consideration if neither the article nor any part of its essential substance, tables, or figures has been or will be published or submitted elsewhere before appearing in the *Journal*.

All unsolicited manuscripts submitted for peer-review must contain a brief structured abstract including the following (when relevant): Objective; Study Design; Data Source(s)/Study Setting; Data Collection Methods; Intervention; Principal Findings; Limitations; Conclusions; Relevance. Papers submitted without a structured abstract may be considered incomplete and returned to the author.

Submit a cover letter and the article (via e-mail attachment) containing the double-spaced text, preferably in Microsoft Word. The letter should indicate that the article is not under consideration for publication elsewhere and has not previously been published in any form.

For more information visit our web site: <http://www.ncmedicaljournal.com/guideline.shtml>

North Carolina Medical Journal
5501 Fortunes Ridge Drive, Suite E
Durham, NC 27713
919/401-6599 ext. 25
919/401-6899 fax
ncmedj@nciom.org

North Carolina
MEDICAL JOURNAL