Specialty Update

What's New in Hip Arthroplasty

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It has been four decades since Sir John Charnley introduced the low-friction arthroplasty. Total hip arthroplasty has become one of the most commonly performed procedures in the United States, with the number performed annually estimated to be more than 200,000. Its clinical efficacy and cost-effectiveness have both been well documented in the literature.

Enormous amounts of data on topics related to total hip arthroplasty are published and presented each year. In this article, we present some of the latest information. We reviewed all of the papers published in major orthopaedic journals as well as abstracts presented at the fall meeting of the Hip Society in September 2000; at the annual meeting of the American Association of Hip and Knee Surgeons in November 2000; at the annual meeting of the American Academy of Orthopaedic Surgeons in February 2001; and at the spring meeting of the Hip Society in February 2001. A total of 132 papers were published and 268 abstracts were presented from April 2000 to May 2001. We have organized the topics into seven general categories: (1) clinical results of primary total hip arthroplasty, (2) clinical results of revision total hip arthroplasty, (3) special clinical settings, (4) wear and biological mechanisms, (5) bearing surfaces, (6) complications, and (7) practice management and outcome measurement.

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WHAT'S NEW IN HIP ARTHROPLASTY

Clinical Results of Primary Total Hip Arthroplasty

Total hip arthroplasty has been offered to younger and more active patients with increasing frequency over the last decade as the clinical success of this operation continues to be validated. Some of the most useful data presented over the last year were related to the durability of the results of total hip arthroplasty in this challenging patient population.

Femoral Stem

Fixation without Cement

Cementless fixation of the femoral stem has gone through a period of evolution over the last two decades. More data are being presented with regard to their medium and long-term clinical performance and durability at ten to fifteen years. Surface texture is an integral factor influencing the success of cementless fixation of the stem. Two main types of surfaces have been in use over the last two decades: porous and hydroxyapatite. Evaluation of the clinical efficacy of the many stem designs over this time-period has been complicated by the variables of stem geometry (straight, curved, tapered, or modular), the extent of surface treatment (proximal or extensive), and biomaterials (titanium alloy or cobalt-chromium alloy). Zenos et al. presented recent data on the Porous Coated Anatomic stem (Howmedica, East Rutherford, New Jersey), which was one of the earliest designs that was widely used clinically in the 1980s. Of 100 total hip prostheses followed prospectively, sixty-five had remained *in situ* at fourteen to fifteen years. Two stems (2%) were revised because of loosening, and sixteen cups (16%) were revised because of osteolysis and loosening.

Tapered stem geometry has received increasing attention over the last ten years. Hozack et al. reported the results at a minimum of fifteen years after forty-nine total hip arthroplasties with use of the Tri-Lock design (DePuy, Warsaw, Indiana). The mean age of the patients was fifty-four years. The mean Harris hip score was 92 points at the time of final follow-up. One stem (2%) was revised because of loosening. Radiographs demonstrated osseous stable fixation in 90% of the hips and fibrous stable fixation in 8%. There was a high rate of cup revisions (32%), all of which were due to wear and osteolysis. McLaughlin and Lee[1] reported on a consecutive series of 108 total hip arthroplasties with use of another tapered design (Taperloc; Biomet, Warsaw, Indiana) in patients less than fifty years old. The mean age of the patients was thirty-seven years, and the mean duration of follow-up was 10.2 years. No stem was revised because of loosening, osteolysis was noted in association with 7%, and osseointegration was judged to have been achieved in 98%.

Hydroxyapatite coating of the stem was introduced in the hope of improving the fixation stability and durability. At the 2000 meeting of the Hip Society, D'Antonio presented his results of 230 total hip arthroplasties after a minimum follow-up of five years (mean, 7.7 years). The mean age of the patients was fifty-six years. One stem had been revised because of loosening, and four stems had been revised for other reasons. No other stem showed radiographic signs of loosening. The rate of mechanical failure was therefore 0.4%. Hozack et al. performed a prospective comparative analysis of hydroxyapatite-coated and porous-coated stems, both of which had a tapered design with a proximal coating. The study included fifty-two pairs of matched patients who were followed for a minimum of five years (mean, 9.3 years). No stem was revised because of loosening in either group, and the clinical outcomes were similar in the two groups.

Thigh pain, especially in association with activity, was a major clinical limitation early in the evolution of cementless fixation of the stem. This particular problem has been reported in all series of total hip arthroplasties with cementless fixation of the stem. Rodriguez and Ranawat demonstrated a difference in the prevalence of thigh pain as a function of the roughness of the nonporous (diaphyseal) portion of the stem. Two cohorts of approximately 100 hips each were analyzed. One group received a stem with a distal roughness of Ra-50, and the other group received an identical stem with a distal roughness of Ra-24. Osseointegration was present at the proximal, porous portion of all stems. The prevalence of thigh pain was significantly lower in the group with a rougher distal part of the stem. Similarly, adverse bone-remodeling demarcation lines were substantially less frequent in the group with the rougher stem. The rougher distal surface may have led to increased osseointegration along the entire length of the stem, perhaps changing the stress-distribution pattern along the femur. Min et al.[2] reported similar findings with regard to the effect of the surface texture of the distal portion of the stem. Those authors performed a matched-pair analysis in which one group of forty-two hips received a stem with a grit-blasted distal surface and another group of forty-two hips received a stem with a smooth distal surface. There were significantly fewer distal radiolucencies around the grit-blasted stems ($p < 0.05$). There also was significantly less pain, both overall and in the thigh, in the grit-blasted group ($p < 0.05$).

Barrack et al.[3] reported on patients' perceptions of pain following total hip arthroplasty. In a study of 320 hips, these investigators used standardized clinical outcome measurement instruments as well as a visual analog pain scale. In addition, they administered pain diagrams to the patients before and after surgery. All stems were judged to be stable according to radiographic criteria. Thigh pain was recorded in association with 23% of the hips. The only parameter that was associated with the thigh pain was the type of stem design and fixation; 42% of the proximally coated stems, 19% of the fully coated stems, and 16% of the cemented stems were associated with thigh pain. The difference between the proximally and fully coated groups was significant ($p < 0.01$), but that between the fully coated and cemented groups was not. Interestingly, nearly one-third of the patients who had had an uncomplicated primary total

WHAT'S NEW IN HIP ARTHROPLASTY

hip arthroplasty still had pain after surgery. Patients with preoperative pain that was principally in the groin according to the pain diagram had the most predictable relief of symptoms after total hip arthroplasty. Pain-diagram analysis may be useful in patient selection and in the preoperative counseling of patients with regard to their expectations after surgery.

Biological enhancement of the bonding between bone and prostheses has been investigated. Lind et al.[4], in an animal model, reported the effects of osteogenic protein-1 in a collagen carrier on the mechanical fixation of titanium implants inserted into bone with a 3-mm gap that would preclude osseous ongrowth. The amount of ongrowth increased to 21.3% in the group that received osteogenic protein-1, and it increased to 16.5% in the group that had application of the collagen carrier alone. A hydroxyapatite coating had a positive impact on ongrowth; the amount of ongrowth was 14.8% in the group treated with the prosthesis alone, 37.2% in the group treated with the collagen carrier, and 40.7% in the group treated with osteogenic protein-1. Such biological adjuncts to improve fixation stability can be particularly useful when bone quality is poor.

Fixation with Cement

With regard to cement fixation on the femoral side, two major topics of interest have been long-term durability, particularly with improved cementing techniques, and early failure of cemented stems with a roughened surface.

Sochart and Porter reported the results at a mean of twenty years after 280 Charnley total hip arthroplasties done with first-generation cementing techniques in patients less than forty years old. The rates of survival of the stems were 82% and 81% at twenty and thirty years. However, the rates for the cups were 71% and 52%, respectively. Patients with osteoarthritis and greater polyethylene wear were at the highest risk for failure. The clinical results remained satisfactory in the majority of patients. These data should serve as one of the standards for evaluating the clinical efficacy and durability of other systems with or without cement fixation.

Smith et al.[5] reported their experience with forty-seven total hip prostheses inserted with use of second-generation cementing techniques in forty patients who were fifty years of age or less. The rate of survival without loosening at eighteen years was 95% for the stems and only 63% for the cups. The cement grades influenced both loosening and femoral osteolysis, with higher rates of both in hips with a poorer grade. Sanchez-Sotelo et al. reported the long-term results of a stem with a matte finish inserted with second-generation cementing techniques. At fifteen years, the rate of revision-free survival of the stem was 92%. The principal predictor of failure was age; the survival rate was 72% in patients less than fifty years of age compared with 95% in patients older than fifty years.

Sylvain et al.[6] reported early failure with use of stems that were grit-blasted, proximally matte-finished, and precoated with methacrylate. All stems were inserted with use of third-generation cementing techniques. The mean duration of follow-up was only three years. Mechanical failure of the stem occurred in 12% of hips. There was no association between the cement grade and failure. Disparate data were reported by Cannestra et al.[7], who followed 102 hips after hybrid total hip arthroplasty with a precoated stem that had a surface texture of Ra-60. This stem had a different design from the one used by Sylvain et al. and offered greater femoral offset. The rate of revision-free survival was 97% at seven years. The cement grade was associated with failure, with all of the implants that failed having a grade of C2.

At the annual meeting of the American Academy of Orthopaedic Surgeons in 2001, two separate groups of investigators reported their long-term results of total hip arthroplasty done with hybrid fixation and a similar femoral stem design with a roughened (Ra-60 to Ra-80), precoated finish. In a study of 150 total hip arthroplasties performed with second-generation cementing techniques, Berger et al. reported a rate of survival without mechanical failure of 96% at fifteen years. Lachiewicz et al. reported that, at a mean of nine years after seventy-four total hip arthroplasties, no stem had been revised because of loosening or was judged to be loose according to radiographic criteria. The cement-mantle grade was not associated with failure.

It has been thought that cracks within the cement mantle coupled with debonding, particularly between the prosthesis and the cement, are the principal initiating mechanisms leading to failure of stem fixation. Duffy et al., in a laboratory study, analyzed the micromotion of smooth (Ra-2) and roughened (Ra-95) stems within the cement mantle when they were loaded in a previously validated simulated stair-climbing mode. Third-generation cementing techniques had been used. There was micromotion of all stems after only one million cycles. There was no difference between the two types of stems at six million cycles, with each having a mean motion of >450 mm. Cracks within the cement developed in all specimens after three million cycles. However, no debonding was observed in any specimen. An important finding was that macrotexturing in the proximal portion of the stem actually resulted in a reduction of the strength of the bone-cement interface and in hollow voids in the stem-cement interface that could lead to crack initiation and propagation.

Acetabular Cup

Fixation without Cement

The clinical success of porous-coated hemispherical cups inserted with or without screws has been widely documented in the literature. More data became available over the last year, particularly with regard to medium to early-long-term performance of these cups. Dunkley et al.[8] reported the results of the use of cementless cups in patients less than fifty

WHAT'S NEW IN HIP ARTHROPLASTY

years of age. The Harris Galante-I design (Zimmer, Warsaw, Indiana) was inserted with supplemental screws. The mean duration of follow-up was seven years. No cup was revised because of loosening. Six cups required exchange of the liner because of wear; however, no measurement data on polyethylene wear were presented. Radiolucency was observed in at least one zone adjacent to 29% of the cups, and 5.5% of the cups had radiolucencies in all three acetabular zones. No cup migrated. One of the major limitations of this study was that 40% of the patients were in the Charnley class-C functional category and were thus presumed to have relatively lower activity demands. Crowther and Lachiewicz evaluated seventy-one hips that had received the same type of cup. All patients were less than fifty years old. At a mean of eleven years, there was an 18% rate of radiolucencies in one acetabular zone and an 11% rate in two zones. No cup had radiolucencies in all three zones. No cup migrated or was revised because of loosening. The liner was exchanged in two hips. The rate of revision-free survival of the cups was 98% at ten years. The linear wear rate of the polyethylene was 0.15 mm/yr. An important finding was that greater polyethylene wear was correlated with a younger patient age and a higher Harris hip score, underscoring the dilemma of a higher rate of wear complications in patients who have the best functional outcome.

Urban et al. performed a histological analysis of twenty-six porous-coated cups that were retrieved post mortem. The mean duration of *in situ* usage was sixty-nine months. The mean extent of bone ingrowth was 35%. These authors concluded that (1) backsided polyethylene wear increased with a longer duration *in situ,* (2) the extent and penetration of the granuloma correlated with a longer duration *in situ,* and (3) granuloma infiltration occurred principally in the passage along the superior rim of the cup and along screw-holes.

Clinical Results of Revision Total Hip Arthroplasty

Femoral Revision

Fixation without Cement

The frequency of revision total hip arthroplasty has continued to increase. The clinical results are inferior to those of primary surgery, and the rate of complications is greater. Engh et al. reported the results of twenty-six femoral revisions in which an extensively coated stem was inserted. At a mean of 13.3 years, the stem had loosened in 15% of hips. The rate of revision-free survival was 89% at ten years. An important finding was that a satisfactory clinical outcome was maintained in 86% of the surviving hips. The efficacy of an extensively coated long-stem design was also reported by Paprosky et al., in a series of 192 femoral revisions done with use of an extended trochanteric osteotomy (mean length, 14 cm). At a mean of four years, two stems had required revision because of mechanical failure and nonunion of the osteotomy had occurred in 1.2% of the hips. The clinical results were satisfactory in the majority of the patients.

In the most extreme situations, a segmental allograft may be required for reconstruction. Blackley et al.[9] reported their experience with sixty-three such complex reconstructions. The mean length of the allograft segment was 15 cm. In general, the stem was fixed to the allograft segment with cement and was inserted into the distal host bone without cement. There was a high rate of reoperation; five stems were revised because of sepsis; three, because of loosening; three, because of failure at the allograft-host bone junction; and two, because of recurrent dislocation. Overall, the rate of success (an improved Harris hip score and a stable implant) was 78% at ten years. These data can be a good reference when assessing the clinical efficacy and durability of alternative techniques of femoral reconstruction.

Fixation with Cement

The frequency of femoral revision with cement fixation has decreased over the last decade. Eisler et al.[10] reported the results of seventy-eight revisions performed with a Charnley stem and third-generation cementing techniques. One stem was revised because of loosening, and two were revised because of sepsis. Two additional stems were scheduled for revision because of loosening. Radiographs demonstrated definite loosening of 33% of the stems. The overall rate of mechanical failure was therefore 38%. A poor cement grade was the most significant predictor of loosening (adjusted odds ratio = 1.8 [95% confidence interval = 1.1 to 3.0]). Hultmark et al.[11] evaluated the results of 109 stem revisions that were performed with use of second or third-generation cementing techniques. A long stem was used in 81% of the hips. The rate of survival without mechanical failure was 85% at ten years. These authors concluded that survival was superior in the hips with a long stem, that a younger patient age and more severe bone-stock deficiency were risks for rerevision, and that radiolucencies in distal-medial zones (zones 4 and 6) were associated with a higher risk of failure. Schmale et al.[12] reported the clinical results of fifty-seven revisions in which a precoated stem was inserted with third-generation cementing techniques as well as those of thirty revisions in which a proximally coated stem was fixed without cement. The fixation failed in 23% of the hips that had fixation with cement and in 7% of those that had fixation without cement. Radiographic failure was apparent in 29% of the hips that had fixation with cement and in 10% of those that had fixation without cement. These data reaffirm the overall poor results associated with cement fixation in femoral revision. Disappointingly, these results remained suboptimal even with improved cementing techniques.

Bone-Grafting for the Treatment of Osteolysis

Osteolysis has become one of the major complications following total hip arthroplasty. Surgeons often have to address these lesions around a stable femoral stem. Benson et al.[13] re-

WHAT'S NEW IN HIP ARTHROPLASTY

cently reported the results of curettage and bone-grafting with use of particulate allograft in seventeen hips. The cups either were revised or underwent exchange of the liner, and no stem required revision. At a mean of three years, the osteolytic lesions had regressed in fifteen of the seventeen hips. This appears to be a viable method for preventing further osseous erosion while restoring bone stock for future reconstructions.

Acetabular Revision

Fixation without Cement

Acetabular revision with use of a cementless hemispherical cup can offer predictable clinical success, especially if there is sufficient support from the osseous columns of the acetabulum. Dearborn and Harris[14] reported the results of sixty-one such revisions in fifty-four patients with hip dysplasia. All cups had supplemental screw fixation, and bone-grafting was done in all but three hips. Pain relief was achieved in 96% of the hips. Two cups migrated, and three had radiolucencies in all three zones without migration. Clinical efficacy and durability were both excellent in this series.

Use of a Reconstruction Ring

The technical challenges of acetabular reconstruction in hips with severe bone deficiency are formidable. Hemispherical or even custom-designed cups are not effective, especially when there is a lack of posterior column support or when there is pelvic discontinuity. Pelvic reconstruction rings are used to achieve the fundamental requirements: adequate bone coverage of the cup; restoration of bone stock of the pelvis; equalization of limb lengths; and stable, durable cup fixation.

Saleh et al.[15] reported on the use of massive structural allograft and a pelvic reconstructive ring in twenty hips in which host-bone support of the cup was <50%. Three cups required revision, but incorporation of the allograft was evident in all other hips. Functionally, 77% of the patients were satisfied as assessed with the Short-Form 36 (SF-36) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Longjohn et al. reported the results of sixty-four revisions done with use of a reconstruction ring. The rate of survival without mechanical failure was only 64% at 6.7 years. The authors concluded that bulk allograft (not cement or particulate graft) was necessary if there was a segmental defect of >60% in the superior weight-bearing dome of the acetabulum. There is also a high rate of dislocation after these complex reconstructions. Lombardi et al. described a technique to specifically address this complication. A pelvic reinforcement ring was used in twelve revisions, and a porous-coated metallic cup was cemented into the ring. The cup was then coupled to a constrained polyethylene liner to address instability. There were no dislocations or loose implants at the time of short-term follow-up.

Special Clinical Settings

Congenital Dysplasia

Callaghan and Johnston, at the 2001 meeting of the American Academy of Orthopaedic Surgeons, reported the results sixteen to twenty-two years after seventy-one total hip arthroplasties performed with cement. All patients had Crowe type-II, III, or IV dysplasia. Aseptic loosening occurred in 11% of the hips: 8% had loosening of the cup, and only 3% had loosening of the stem. These results are similar to those in the extensive experience of the senior author (Johnston), who had performed nearly 5000 total hip arthroplasties, in patients with other causes of hip disease.

Osteonecrosis

Hartley et al.[16] reported the long-term results (mean duration of follow-up, 9.8 years) of forty-eight total hip arthroplasties without cement in young adults who had osteonecrosis. An extensively coated stem was inserted in all hips. No stem was revised because of loosening. There were ten revisions (21%): six because of polyethylene wear, three because of recurrent dislocation, and one because of sepsis. Of the surviving stems, 97% were judged to be osseous stable. In terms of the functional outcome, 93% of the patients had no limitations, 86% had no pain, 79% were able to walk unlimited distances, and 79% were employed full-time. This study demonstrated the efficacy of cementless fixation, and the limitations caused by complications related to the prosthetic bearing surface in this young, high-demand population. Morrey reported his experience with a short-stem design inserted without cement in 162 total hip arthroplasties. Osteonecrosis was a common diagnosis in his series. This "conservative" femoral arthroplasty was shown to be durable after a mean duration of follow-up of 6.2 years; however, these data were not superior to those reported for regular stem designs such as those in the series of Hartley et al.[16].

One-Stage Bilateral Total Hip Arthroplasty

Hozack et al. compared the results of one-stage bilateral total hip arthroplasty with those of unilateral total hip arthroplasty, specifically with regard to perioperative morbidity. The demographic data were similar except for a younger mean age in the group with the bilateral procedure (fifty-four compared with seventy years). The group with the bilateral procedure required more homologous blood transfusion and had lower hemoglobin levels at discharge. There was, however, no difference in the rate of complications, particularly cardiopulmonary complications, and there was no difference in the length of hospital stay or the overall hospital charges. The success was attributed to a program of thorough preoperative medical evaluation and to the strict criteria used to select patients for one-stage bilateral total hip arthroplasty.

Total Hip Arthroplasty Following Acetabular Fracture

Total hip arthroplasty has been used with increasing fre-

WHAT'S NEW IN HIP ARTHROPLASTY

quency as a salvage procedure and on occasion as a primary mode of treatment of acetabular fractures. Two recent reports focused on the medium-term clinical outcomes of total hip arthroplasties following previous acetabular fracture. Tile et al. reported the results of 101 total hip arthroplasties in which a variety of implant designs had been used with or without cement fixation. The mean interval between the initial fracture and the total hip arthroplasty was 8.2 years. The mean age of the patients was fifty-three years. At a mean of 7.5 years postoperatively, there had been five periprosthetic infections and twenty-one dislocations. Twenty-one cups and seventeen stems loosened, resulting in twenty-four revisions. The authors specifically assessed functional outcome with use of the WOMAC scale and found substantially poorer scores for pain, motion, overall function, family relationships, sleep disturbance, and activities of daily living compared with the scores of patients who had undergone total hip arthroplasty because of osteoarthritis. Bellabarba et al. reported the results of thirty acetabular reconstructions in which a hemispherical cup was inserted without cement in patients with a previous acetabular fracture. These results were compared with those of patients who had undergone total hip arthroplasty because of osteoarthritis. Patients with a previous acetabular fracture had a longer operating time as well as greater blood loss, transfusion needs, use of bone-grafting, and use of cup liners with an elevated rim for stability. At a mean of five years, the clinical outcomes were no different from those in the patients with osteoarthritis, with 90% satisfied with the results. Radiographs showed more radiolucencies around the cups in the patients who had had an acetabular fracture, although only one cup had migrated. A higher rate of infection was not reported.

Total Hip Arthroplasty in Older Patients

As the elderly population increases in the United States, data on the clinical efficacy and safety of total hip arthroplasty in patients in the eighth and ninth decades of life are becoming increasingly important. Pagnano et al. reported the results of sixty-six total hip arthroplasties in sixty-five patients who had a mean age of ninety-two years at the time of the operation. Medical comorbidities were common: 52% had cardiac disease, 41% had hypertension, and 33% had anemia. Most of the components were inserted with cement. At a mean of 4.2 years after the operation, there was a substantial improvement in the Harris hip scores. Two reoperations were necessary, complications occurred in seven additional patients, and 25% of the patients required a stay in the intensive-care unit after surgery.

Keisu et al.[17] reported the results of ninety-two total hip replacements with use of cementless fixation in eighty-six patients with a mean age of eighty-three years. All patients received a tapered stem with a proximal porous coating. At the two to eleven-year follow-up evaluation, 65% of the patients were able to walk freely in the community without limitations and 20% required a walker. The mean Harris hip score was 82 points. No revisions had been done because of loosening. Medical complications occurred in 24% of the patients, although none of these complications affected the outcome of the total hip arthroplasty. There were no fatal thromboembolic or cardiopulmonary complications. These data support the clinical efficacy and safety of total hip arthroplasty in older patients, provided that comprehensive preoperative and perioperative medical support is given.

Another challenge is revision surgery in elderly patients. Strehle et al.[18] reported the results of revision total hip arthroplasty in fifty-three consecutive patients older than eighty years (mean age, eighty-four years). More than 50% had cardiac disease, and three patients died during the hospitalization. An additional fifteen patients (28%) died at a mean of twenty-five months after surgery. Nearly 90% of the patients who died were in ASA (American Society of Anesthesiologists) class 3. Moreover, more complications occurred in these patients. However, the functional outcome was excellent; 80% of the patients were able to return to their prerevision living environment, and 80% were relatively pain-free. These data underscore the importance of patient selection and the medical management of elderly patients.

Miller et al. reviewed the mortality rate following 4967 total hip arthroplasties (4164 primary and 803 revision operations) performed by one surgeon over a twenty-seven-year period. The ninety-day mortality rate was 1% for the primary operations and 0.87% for the revisions. The rate of in-hospital deaths was 0.45%, with a slightly higher rate following revision than following primary surgery. The most common cause of death was myocardial infarction, and the most important risk factor for death was increased age. These data should provide a benchmark for other studies focused on death rates following total hip arthroplasty.

Wear and Biological Mechanisms

The effects of wear debris on macrophage and monocyte cell lines have been studied extensively. Recent studies have also shown that osteoblasts are involved in the phagocytosis of wear debris and may contribute to the development and progression of osteolysis. Using cell cultures, Vermes et al.[19] demonstrated that metallic particulate debris affected osteoblast function through two distinct mechanisms: a direct negative effect on cellular function by the phagocytosis itself, and an effect mediated through cytokines, which cause a downregulation of procollagen alpha-1 gene expression along with decreased cell proliferation. Moreover, this study demonstrated that osteoblasts stimulated by particulate debris produced interleukin-6 and prostaglandin E2, leading to the activation of osteoclast function. The addition of other exogenous growth factors to the cell cultures effectively reversed the suppressive effect of titanium particles on procollagen alpha-1 mRNA. This work points to the possibility of pharmacological intervention for the

WHAT'S NEW IN HIP ARTHROPLASTY

treatment and prevention of osteolysis.

Andersson et al.[20] reported a negative effect on human osteoblast function (a decrease in H^3-thymidine incorporation into deoxyribonucleic acid) when the cells were exposed to synovial fluid from hips undergoing revision surgery because of aseptic loosening. To our knowledge, this was one of the first studies to demonstrate a direct effect upon cellular function by the synovial fluid around loose total hip prostheses.

Bone resorption by osteoclasts can be a result of an imbalance in the regulation of cellular activities, differentiation, proliferation, or survival. Bi et al.[21] showed a thirtyfold increase in differentiation of cultured osteoclasts that were exposed to titanium particles. Particle phagocytosis did not affect cellular survival. The increased cellular differentiation resulted in measurably increased bone resorption. Neale et al.[22] demonstrated that phagocytosis of metallic particles resulted in a time and dose-dependent reduction of the osteoclast population and in bone resorption. The effects were more pronounced with cobalt-chromium and stainless-steel particles than with titanium particles.

A variety of agents such as alendronate, Lipitor (atorvastatin calcium), and bafilomycin-A have been studied in search of a pharmacological treatment for osteolysis. The exact mechanism through which these agents may have an inhibitory effect upon osteoclasts remains to be fully defined. Harris et al. reported on a novel inhibitor of osteoclast activity *in vitro,* a vascular endothelial growth-factor-neutralizing antibody (VEGF-NA). With use of an established mouse calvarial bone-resorption model, a macrophage cell line was activated with exposure to titanium particles. Bone resorption, concentrations of various bioactive cytokines, and gene expression of endothelial growth factor were quantitated. Production of cytokines was substantially greater when the cells were activated by the particles. Dose-dependent inhibition of bone resorption was the most intense (97%) with use of VEGF-NA. These data suggest that inhibition of angiogenesis may be an important way to develop pharmacological suppression of osteolysis.

Bearing Surfaces

Alternative bearing surfaces in total hip arthroplasty have been an area of intense investigation over the last five years. Bearing surfaces include hard-on-soft (metal-on-polyethylene and ceramic-on-polyethylene) and hard-on-hard (ceramic-on-ceramic and metal-on-metal) combinations. Improvements in the manufacturing, machining, sterilization, and storage of these materials have made these options increasingly attractive. However, controversies remain as to which combination is the most effective clinically.

Polyethylene

Metal-on-polyethylene is the most widely used bearing-surface combination. Improvement of the wear characteristics of polyethylene has been a major focus of research and development. Emphasis has principally been on controlling the amount of free radicals. The vast majority of polyethylene implants inserted in total hip arthroplasties over the last three decades were sterilized with gamma radiation in air. Gamma irradiation produces free radicals, which, when combined with air, lead to oxidative changes in the polyethylene, resulting in inferior wear characteristics. At the same time, gamma irradiation produces cross-linking of the polyethylene, resulting in improved wear characteristics. Moreover, long durations of shelf storage of the implant can result in more oxidative changes in the polyethylene when oxygen diffuses into the implant and reacts with residual free radicals in the material.

Recently, several polyethylene products have been introduced to increase cross-linking and to reduce oxidative degradation. These products differ with regard to the amount of radiation, the type of radiation (gamma or electron-beam), and whether the polyethylene is remelted prior to machining to eliminate residual free radicals. Some concerns have been raised with regard to alterations of the biomechanical properties of polyethylene with higher doses of radiation and with remelting. These changes can potentially result in inferior *in vivo* durability.

McKellop et al.[23] demonstrated, with simulator testing, that the packaging and sterilizing of polyethylene in a low-oxygen atmosphere leads to increased cross-linking, decreased oxidation, and improved wear characteristics. However, artificial aging with heating of the various polyethylene specimens resulted in inferior wear of the irradiated polyethylene regardless of whether it was done in air or in an inert environment. McKellop et al. cautioned that the advantages of radiation-induced cross-linking could be negated in the long term by *in vivo* oxidation of residual free radicals.

Muratoglu et al.[24] reported on the *in vitro* performance of one of the cross-linked polyethylenes. They demonstrated that the melt-annealing process effectively eliminated detectable residual radicals. While this polyethylene product showed no detectable volumetric wear over twenty million cycles in the hip simulator, there was a reduction in the yield strength, ultimate tensile strength, elongation, and crystallinity as compared with conventional polyethylene. However, these values fell within the limits set by the United States Food and Drug Administration. While these results are exciting, long-term *in vivo* studies are still necessary to determine whether the improved material properties of polyethylene that result from cross-linking will endure.

At the 2000 meeting of the American Association of Hip and Knee Surgeons, there was major controversy and extensive discussion following the presentation of the results of *in vitro* testing of cross-linked polyethylene. When the four most commonly used commercial cross-linked polyethylene products were tested, all four were found to be superior to the control polyethylene. However, more controversy was generated by the data on the effects of artificial aging. The

WHAT'S NEW IN HIP ARTHROPLASTY

wear rate of one particular product was substantially greater following aging in air at 80°C for three weeks. In fact, this product performed worse than the control. Moreover, among all of the samples tested, this cross-linked product showed the most prominent and extensive deleterious oxidative changes. The results of this study serve to further emphasize the wide range of differences among commercially available products. Testing methodologies need to be standardized since these products are all made differently and thus will respond to testing conditions differently. Differences *in vitro* do not necessarily reflect differences *in vivo,* underscoring the need for long-term clinical follow-up data to support more conclusively the use of these products.

Martell et al. reported improved clinical wear performance of cross-linked polyethylene after a minimum two-year follow-up in a well-designed prospective, randomized trial. The mean linear and volumetric wear rates of the conventional cups were 0.21 mm/yr and 94 mm^3/yr, respectively. These values were significantly lower ($p < 0.05$) for the cross-linked cups (0.14 mm/yr and 54 mm^3/yr, respectively). These authors also measured the wear rates *in vitro.* The ratio of volumetric wear observed *in vivo* (cross-linked/control = 0.57) closely matched the ratio observed with use of the wear simulator (cross-linked/control = 0.56). These findings further support the use of laboratory testing to validate the prediction of wear after *in situ* usage of a total hip prosthesis.

Cross-linking is not the only methodology available for decreasing polyethylene wear. Ritter et al. reported their experience with polyethylene articulations made by compression molding. In compression molding, a component is manufactured directly from polyethylene resin by applying heat and pressure with use of a mold that matches the geometry of the component. The number of free radicals and oxidative degradation of the polyethylene are expected to be low with this process. In a series of 378 total hip arthroplasties that were followed for nearly twenty years, these authors reported a 0.5% rate of pelvic osteolysis and a 3.2% rate of femoral osteolysis. The linear polyethylene wear rate was 0.05 mm/yr. Ritter et al. concluded that compression molding is an effective alternative to cross-linking.

Controversy remains regarding the clinical correlation between hip-simulator testing and the *in situ* use of total hip prostheses. Schmalzried et al. monitored thirty-one patients with a Step Activity Monitor (SAM) to measure their walking activity in real time. They found that (1) male subjects walked at higher speed, and spent more time doing so, than did female subjects; (2) male subjects had a greater rate of polyethylene wear; (3) a slower walking speed was associated with less wear; and (4) two million cycles of simulator testing may correspond to one year of *in situ* usage. Thus, laboratory testing of newer polyethylene for more than ten million cycles, rather than for the more traditional six million cycles, may be indicated. Moreover, a simple and relatively inexpensive device such as the Step Activity Monitor may be of value in identifying patients who may be at greatest risk for accelerated wear following total hip arthroplasty. Schmalzried et al.[25], in another study, reported a correlation between polyethylene wear and activity level. Their series comprised thirty-seven patients with a mean bone-mass index of 27.5. Liners made of conventional polyethylene or of Hylamer (DePuy-DuPont Orthopaedics, Wilmington, Delaware) were sterilized with gamma radiation in air. These authors found, *in vivo,* a linear wear rate of 0.14 mm/yr and a volumetric wear rate of 73 mm^3/yr. Regression analysis demonstrated the strongest correlation between male gender and increased wear. Other factors that significantly influenced wear included the patient's height ($p = 0.007$) and weight ($p = 0.04$) (correlated with male gender), the liner thickness ($p = 0.03$), and the hip-rotation center ($p = 0.015$). Pedometric data showed that the patients walked an average of 1.9 million cycles/yr. Combining the wear and pedometric data, Schmalzried et al. concluded that the mean volumetric wear of conventional polyethylene sterilized with gamma irradiation in an oxygen-rich environment is 30 mm^3/million cycles for a 70-kg patient. This value can serve as a target wear rate for hip-simulator studies when newer polyethylene materials are tested.

A critical question in clinical practice concerns the correlation between wear-rate measurements and the prediction of bearing-surface failure after total hip arthroplasty. Dowd et al.[26] analyzed the wear and clinical performance of forty-eight total hip prostheses with a single cup design and a 32-mm femoral head over a ten-year period. These patients were at risk for wear because the mean polyethylene thickness was only 4.9 mm and the mean age was fifty-six years. All cups were sterilized in ethylene oxide. The mean linear wear rate as measured on radiographs was 0.18 mm/yr. The slope of the wear rates at different time-intervals was relatively linear. Osteolysis was strongly correlated with wear ($p < 0.001$). No osteolysis was observed in hips with wear of <0.1 mm/yr. The most important conclusion was that future wear rates can be predicted accurately on the basis of wear rates in the early postoperative period.

Joint kinematics can influence function and durability after any reconstructive arthroplasty. Recently, Dennis et al. used established and validated fluoroscopic imaging techniques to evaluate joint kinematics in seven patients who were awaiting a revision total hip arthroplasty. They found that hip separation was greater in the patients who had a failed prosthesis (mean, nearly 10 mm) than in those who had a well-functioning one and were asymptomatic (mean, 3.6 mm). The principal locus of the separation was in the superior and lateral directions, which corresponded to the areas of maximal polyethylene wear on retrieval. Hip separation is theorized to contribute to cup failure by several mechanisms: (1) eccentric loading resulting in polyethylene wear, (2) impulse loading resulting in

WHAT'S NEW IN HIP ARTHROPLASTY

loss of fixation, (3) pumping of wear debris leading to migration of the particles and subsequent osteolysis, and (4) instability.

Ceramic

Clarke and Gustafson[27] reported that the wear rate of ceramic-on-polyethylene bearings was 50% of that of metal-on-polyethylene bearings in hip-simulator testing. In contrast, Oonishi et al.[28] reported that the mean linear wear rate was 0.05 mm/yr both for a gamma-irradiated polyethylene cup articulating against a ceramic femoral head and for the same polyethylene cup articulating against a metallic head. Thus, cross-linked polyethylene may negate the potential benefits of ceramic-on-polyethylene.

Two separate clinical studies on ceramic-on-polyethylene articulation were reported at the 2000 Hip Society meeting. Wroblewski et al. reported a linear wear rate of 0.03 mm/yr in a small series of cemented total hip arthroplasties with an articulation of ceramic and cross-linked polyethylene. The wear rate was fivefold less than that seen with traditional metal-on-polyethylene articulations. Ranawat et al. reported wear-rate measurements at a mean of 5.5 years in fifty-two pairs of patients; the only difference between the two groups was that one had a ceramic-on-polyethylene articulation whereas the other had a metal-on-polyethylene articulation. The linear wear rate in the ceramic-on-polyethylene group was 0.13 mm/yr compared with 0.17 mm/yr in the metal-on-polyethylene group ($p < 0.05$). It remains to be determined if the wear-rate differential will remain constant or become even greater with longer-term follow-up.

Most of the available data on the clinical efficacy of ceramic-on-ceramic articulation have been reported by European investigators. Improved cup fixation has been reported with use of porous-coated acetabular shells[29]. Additional improvements in the locking mechanism of the ceramic liner have decreased the frequency of chipping during impaction[30]. D'Antonio and Capello reported their experience in a multicenter investigational study in which 504 total hip arthroplasties performed over a two-year interval were randomized to either a ceramic-on-ceramic or a metal-on-polyethylene articulation. A major difference between the two groups was that 90% of the ceramic femoral heads were 32 mm in diameter while 83% of the metallic heads were 28 mm. Otherwise, the prosthetic design was identical in the two groups. At the time of a two to four-year follow-up, there was no difference in the clinical performance of the two types of articulation. Small osteolytic lesions were observed in the proximal femoral zones in the polyethylene group, whereas none were noted in the ceramic group. No ceramic fractures or failures of the locking mechanism were reported. Additional clinical trials of ceramic-on-ceramic articulations are ongoing in the United States. The short-term results have shown no apparent mechanical failures of the biomaterial, as previously reported.

Metal-on-Metal

Metal-on-metal articulations provide another hard-on-hard combination with a low rate of reported volumetric wear. Dorr et al.[31] found no osteolysis after fifty-six total hip arthroplasties that were followed for a mean of 5.2 years. Wagner and Wagner[32] also reported no osteolysis after seventy-five total hip arthroplasties that were followed for a mean of five years. However, one cup was revised because of loosening. In a separate study, Dorr reported his experience with a modular cup with use of metal-on-metal coupling. The particular cup design offered a modular polyethylene locking mechanism with a 3-mm-thick metal articulation surface machined into the polyethylene. Penetration of the polyethylene liner was initially 0.03 mm/yr from creep and settling, and subsequently it was 0.003 mm/yr. No osteolysis was observed. The reported complications of metal-on-metal articulations have been rare. Dorr et al.[31] reported disassociation of a modular liner and one case of metallosis due to impingement and recurrent dislocation.

Potential systemic effects of disseminated metallic wear debris are of concern; however, the clinical relevance remains undefined. Urban et al.[33] reported dissemination of wear debris to the paraaortic lymph nodes in 68% of twenty-eight patients. Moreover, they reported a 38% rate of metallic debris and a 14% rate of polyethylene debris in the liver and spleen. Lymphatic transport was the major mechanism of dissemination. The clinical effects of debris dissemination were essentially undetectable. In one patient, however, high concentrations of titanium particles in the liver and spleen resulted in a granuloma that required treatment. While there are case reports of malignant tumors arising in proximity to joint-replacement prostheses[34], a recent review of the available epidemiologic studies showed no causal link between total hip or knee arthroplasty and the development of cancer[35]. Metal hypersensitivity has also been a subject of debate. Hallab et al.[36] provided a comprehensive review of this subject. The prevalence of metal hypersensitivity is higher in patients with a prosthetic joint replacement than it is in the general population. Careful long-term follow-up is necessary to further establish the clinical impact of wear debris upon the immune and distant organ systems.

Complications

Infection

Infection remains the most feared complication following any prosthetic arthroplasty. Some interesting data were made available last year with regard to this particular complication in patients with the human immunodeficiency (HIV) virus. Lehman et al.[37] reported on a series of twenty-nine patients who were either HIV-positive or intravenous drug users at the time of a total hip or knee replacement. These patients had a total of forty-one joint arthroplasties. The overall rate of deep infection was 18% for HIV-positive patients; the rate was much higher (40%) in patients who both were HIV-

WHAT'S NEW IN HIP ARTHROPLASTY

positive and used intravenous drugs. The highest rate (66%) was seen in patients who were active intravenous drug users. Sullivan et al. reported the outcomes of twenty joint arthroplasties (in eleven knees and nine hips) in fifteen patients with HIV infection who were treated at a large tertiary-care center. In only one patient was the HIV infection due to intravenous drug use; most of the infections were in patients with hemophilia. Forty percent of the patients had died during the follow-up period; half had died within the first two years. The reoperation rate was alarmingly high (65%), with 70% of the reoperations done because of infection.

Thromboembolism

Thromboembolic disease remains the most frequent complication following total hip arthroplasty. At present, there is little controversy with regard to the need for routine prophylaxis. However, there is substantial disagreement with regard to which method is superior. Freedman et al.[38] presented data from a meta-analysis of fifty-two studies comprising nearly 11,000 total hip arthroplasties performed over a thirty-three-year period. All selected studies were prospective and randomized, and all utilized venography to document deep-vein thrombosis. All methods of prophylaxis were found to be superior to the use of a placebo. Overall, warfarin and low-molecular-weight heparin were more effective than the other agents (aspirin, a compression device, and fixed-dose heparin). Low-molecular-weight heparin and fixed-dose heparin were associated with a higher rate of bleeding complications. Freedman et al. concluded that the most effective, least risky prophylactic agent was warfarin while the least effective, most risky agent was fixed-dose heparin.

The efficacy of warfarin has been well established; however, its use is labor-intensive and can result in bleeding complications. Farber et al. studied the efficacy of in-hospital warfarin prophylaxis. Their protocol included administration of adjusted-dose warfarin until contrast venography was performed. Prophylaxis was discontinued if there was no deep-vein thrombosis, it was continued for six to twelve weeks if there was distal deep-vein thrombosis, and intravenous heparin therapy was initiated if there was proximal deep-vein thrombosis. Thromboembolism occurred in fourteen (0.73%) of 1920 patients following hospital discharge. Six patients (0.31%) had nonfatal pulmonary emboli, and eight (0.42%) had deep-vein thromboses. This protocol appeared to be effective while minimizing the risk of complications associated with continued warfarin prophylaxis following hospital discharge. Cost was also reduced. Bern et al. reported the results of a prophylactic protocol with use of low-fixed-dose warfarin. This was a novel protocol in that the patients received a 1-mg dose of warfarin starting seven days prior to surgery. This dose was continued after surgery, until discharge. These patients were compared with a group of patients who received adjusted-dose warfarin. Ultrasound did not reveal deep-vein thrombosis in either group. There was no difference in the estimated blood loss during surgery or in the transfusion requirements between the two groups. Elevation of prothrombin time was not observed in the low-dose group. This protocol appears to be effective and also would minimize the potential for complications and the need for monitoring after hospital discharge.

In contrast, Comp et al.[39] documented the need for prolonged prophylaxis after hospital discharge when enoxaparin was used. Nearly 1000 patients were enrolled in this multicenter, prospective, randomized study. All patients received injections of 30 mg of enoxaparin twice daily during hospitalization. Then the patients were randomized into a double-blind protocol, receiving either one 40-mg injection of enoxaparin or a placebo injection daily for three weeks. There was a significant difference ($p < 0.001$) in the overall rates of deep-vein thrombosis (8% in the enoxaparin group compared with 23% in the placebo group). There was also a significant difference ($p < 0.001$) in the rates of proximal deep-vein thrombosis (2.7% and 13%, respectively). A nonfatal pulmonary embolus developed in only one patient.

The most commonly used methods for the detection of deep-vein thrombosis are contrast venography and duplex ultrasound. Both methods have limitations. Colwell et al. reported the results of a new radioisotope test (AcuTect) that specifically identifies acute thrombi by detecting activated platelets. In their series of 100 patients, who also underwent ultrasound, sensitivity and specificity of the AcuTect scans were both 88% and accuracy was 79%. These results are preliminary and remain to be validated by other centers. However, this test may serve as an alternative method of detection, particularly of acute thrombi in patients with a history of deep-vein thrombosis.

Dislocation

A distinct subgroup of patients who have a dislocation for the first time many years after a successful total hip arthroplasty has been identified. Berry et al., in a review of the results of 25,465 primary total hip arthroplasties performed over a twenty-six-year period at the Mayo Clinic, found the overall dislocation rate to be 2.4%, with 0.6% of the dislocations occurring for the first time more than five years following the arthroplasty. The most common direction of dislocation was posterior (62%), and the median time to the first dislocation was 11.3 years. Women were more likely to have this complication. Other risk factors included episodes of subluxation, trauma, and the onset of cognitive or motor neurological impairment. There was also a correlation with polyethylene wear of >2 mm and with cup loosening and migration. An interesting finding was that 18% of the cups were initially placed beyond the recommended limits of cup position. In this study, 55% of the dislocations became recurrent and 30% of the recurrent dislocations required revision surgery.

Many different treatment options have been proposed

WHAT'S NEW IN HIP ARTHROPLASTY

for recurrent dislocation. Shapiro et al. reported on the use of a constrained liner in eighty-five total hip arthroplasties. The patients had had an average of four dislocations prior to revision with the constrained liner. Redislocation occurred in 2.4%. Toomey et al. reported on the use of liner exchange in fourteen hips with a modular cup; 79% had no more dislocations. Moreover, only one patient had recurrent instability following the liner exchange. This technique may be useful in carefully selected patients. Earll et al. reported the results of twenty-seven bipolar reconstructions for the treatment of instability and compared them with those of revisions performed with a liner-exchange technique similar to that reported by Toomey et al. No dislocation occurred following the bipolar revisions, whereas 55% of the hips with liner exchange had dislocation and 31% had recurrent instability. However, the group that had had bipolar revision had significantly ($p = 0.03$) lower Harris hip scores, principally because of persistent pain. Parvizi and Morrey[40] reported the results in twenty-eight hips that were revised with use of a bipolar prosthesis because of recurrent instability. This technique was successful in 81% of the hips, with 11% requiring additional surgery. The Harris hip scores were poor; the mean score was only 55 points at the time of final follow-up. This technique may be as effective as other options, but the patient must be made aware of the potential for a suboptimal functional outcome.

A new alternative to these methods is the use of larger femoral heads, especially those with the improved wear characteristics of cross-linked polyethylene. Bartz et al.[41] reported the effects of increasing head size with regard to impingement and posterior dislocation. They found a significant improvement ($p < 0.05$) in flexion prior to impingement and dislocation when the head size was increased from 22 to 28 mm. The difference in these flexion values between 28 and 32-mm heads was not significant. The principal source of impingement of the 22-mm heads was the stem neck on the cup edge, while that of the 32-mm heads was osseous impingement of the femur on the pelvis. Bartz et al. presented additional data at the 2001 meeting of the American Academy of Orthopaedic Surgeons. They reported that the use of 38-mm heads was associated with an increase in the range of flexion prior to dislocation. However, impingement was sensitive to the neck taper diameter. There was no advantage in using a 38-mm head instead of a 28 or 32-mm head when a stem with a larger neck diameter was used. It is therefore important for the surgeon to carefully evaluate the efficacy and risks of using larger heads when addressing recurrent dislocation.

Stress-Shielding

Adverse bone-remodeling as a result of stress-shielding remains a topic of concern. Engh et al.[42] demonstrated the inadequacies of routine radiographs for analysis of bone-remodeling. Interobserver agreement regarding the presence of bone loss was 73%. Agreement decreased to 66% when the investigators quantitated bone loss. Bone loss was not reproducibly recognized on routine radiographs until ≥70% loss had occurred as documented with dual-energy x-ray absorptiometry. Yamaguchi et al.[43] used sequential dual-energy x-ray absorptiometry scans to quantitate bone loss around fully and proximally coated stems at twenty-four to thirty months following surgery. With both stem types, the greatest amount of bone loss was observed in the proximal part of the femur at twelve to eighteen months. Greater bone loss in the distal zones (zones 3 and 6) was observed in association with the fully coated stems. There was no difference in the clinical outcome or the stability of fixation. The long-term clinical sequelae of stress-shielding remain to be fully established.

Practice Management and Outcome Measurement

The costs of total hip arthroplasty, particularly revision surgery, have continued to escalate. Two studies specifically evaluating the costs of revision total hip arthroplasty were presented at the 2001 meeting of the American Academy of Orthopaedic Surgeons. Lavernia et al. have been analyzing quality of life following total hip arthroplasty for the last five years. In a study in which they used the Quality of Well Being Index to analyze the results of fifty-three revisions at one to three years, they demonstrated that the mean cost per Quality Well Year was $11,977 at one year and $7955 at three years. These costs indicate that revision total hip arthroplasty is extremely cost-effective compared with medical interventions in other disciplines. Crowe et al. specifically analyzed the costs of fifty-one revision total hip arthroplasties, with stratification for complexity. The actual costs were then compared with the reimbursement received by the hospital. The hospital lost an average of $5400 for each revision operation. These authors concluded that the hospital continued to lose money despite improvements in cost containment over the last decade, which included the establishment of critical pathways, shortened length of stay, price control with regard to implants, and improved surgical techniques.

In the last decade, much discussion has focused on the use of patient-directed outcome measurement instruments such as the SF-36 and the WOMAC in the evaluation of patients who have had a total hip arthroplasty. In a study by Soderman and Malchau[44], a Harris hip score was assigned to 350 patients who had had a total hip arthroplasty and already had been assigned SF-36 and WOMAC scores. All three instruments were found to be valid, reproducible, and reliable. There was good interobserver reliability among the investigators who assigned the Harris hip scores. The correlation was especially good with regard to pain and function. Soderman and Malchau concluded that the Harris hip scale was as valid for outcome measurement as the SF-36 and the

WHAT'S NEW IN HIP ARTHROPLASTY

WOMAC. This finding is of some importance since many studies have provided only Harris hip scores as the clinical outcome measure. Valid comparisons of different series can therefore be made.

The two major organizations with focused interest in total hip arthroplasty and related disciplines are the Hip Society and the American Association of Hip and Knee Surgeons. The Hip Society routinely holds a spring meeting in conjunction with the annual meeting of the American Academy of Orthopaedic Surgeons. Its members also participate extensively in American Academy of Orthopaedic Surgeons symposia and Instructional Course Lectures and in meetings of regional orthopaedic societies. The American Association of Hip and Knee Surgeons has an annual meeting in the fall. Its members routinely conduct surveys, particularly with regard to practice-management issues such as prophylaxis for deep-vein thrombosis, management of infections, and cost analysis. Extensive information on scientific, social, and political issues is exchanged at these meetings. Members of both societies participate widely with other national and regional instructional meetings throughout the year. The requirements for and timing of scientific abstract submission for the American Association of Hip and Knee Surgeons is generally the same as that for the meeting of the American Academy of Orthopaedic Surgeons. The upcoming meetings for these organizations in 2002 will both be held in Dallas.

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WHAT'S NEW IN HIP ARTHROPLASTY

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