ORTHOPEDIC MANAGEMENT AND TREATMENT OF OSTEONECROSIS

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These recommendations for management are based upon personal observations of about 135 patients who have nontraumatic avascular necrosis, including 44 patients with dysbarism-related osteonecrosis. Only lesions affecting the juxta-articular or epiphyseal regions of bones will be considered, since intramedullary metadiaphyseal lesions are neither symptomatic nor disabling, and hence require no treatment. However, recognition of metadiaphyseal bone infarctions is important because the tendency in these patients to have coexistent epiphyseal lesions, or subsequently to develop them, is greater than in individuals without metadiaphyseal lesions.

The skeletal distribution of lesions in dysbaric osteonecrosis, in contrast to other illnesses associated with nontraumatic avascular necrosis, involves the humeral head more frequently than the femoral head. Despite the high incidence of symptomatic bends affecting knee joints, the epiphyseal regions of the distal femur and proximal tibia are rarely affected by dysbaric osteonecrosis — a circumstance possibly explained by extensive collateral circulation about the knee joint. To provide a rational approach to the medical and surgical treatment of asymptomatic and symptomatic lesions, it is helpful to consider that the evolution of nontraumatic *(e.g.*, dysbaric) osteonecrosis usually occurs in three stages and that the management is different for each.

STAGE I LESIONS

The patient is usually asymptomatic; routine roentgenograms are often normal, but tomography and radionuclide scintimetry suggest focal avascularity. Pathologically, there is no architectural distortion of the articular surface and only focal abnormalities are present.

Symptoms — such as shoulder or hip (groin) pain, muscle spasm, and joint stiffness — do not necessarily coincide with roentgenographic abnormalities; in fact, symptoms may be lacking altogether. It is extremely important to diagnose osteonecrosis at this early stage. The patient should not be exposed to further dysbaric phenomena until a diagnosis is established. In the meantime, if femoral-head lesions are suspected the patient should remain non-weight-bearing (crutch walking). If humeral-head lesions are suspected, he should avoid overhead lifting or performing heavy manual labor, including, especially, the use of pneumatic-type drilling equipment. Most commonly, the central third and middle portion of the humeral head and the anterosuperior quadrant of the femoral head are involved. Mechanical stress to these joints, particularly in the areas mentioned, should be eliminated.

Once the diagnosis is established, the patient should undergo a program of vocational rehabilitation. He should not be exposed to dysbaric phenomena or be allowed to continue participating in hard manual labor. Routine follow-up roentgenograms and, if necessary, tomograms should be performed at regular intervals — every three to six months. The patient should curtail physical activities to provide mechanical protection of the articular surfaces and, hopefully, to allow sufficient time for intrinsic revascularization of the necrotic lesion to occur.

STAGE II LESIONS

The patient is usually symptomatic with shoulder or hip pain, often with axillary nerve referral or groin pain, frequently with obturator nerve referral and muscle spasm. Radiological appearance is that of irregular radiolucencies, often with marginal densification and evidence of reossification without gross architectural complications — *i.e.*, without rupture of the osteochondral joint surface of the humeral or femoral head (Fig. 1). Diagnosis is essential at this stage if chondro-osseous rupture and irreversible damage are to be avoided.

In this stage there is no evidence of secondary subchondral fracture. The radiolucent crescent-line sign is negative.

Revascularization Procedures

There are currently no satisfactory extrinsic revascularization procedures for the humeral head. However, if tomography and intraosseous

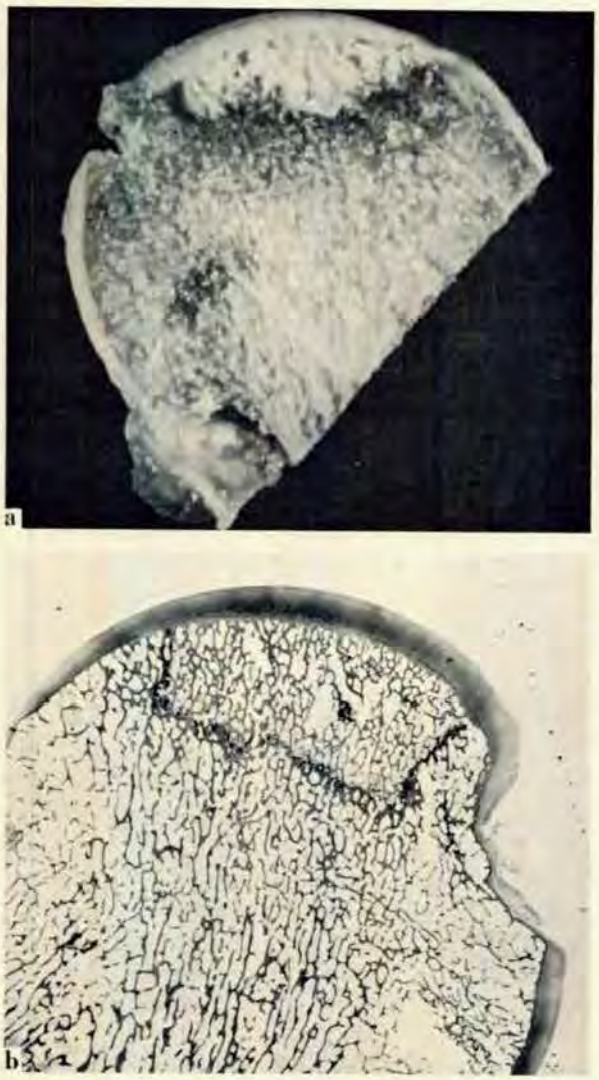

FIG. 1. Gross sagittal section of (*a*) L femoral head, showing Stage II osteonecrosis lesion in anterosuperior quadrant. Chalky necrotic subchondral bone (of toothpaste consistency) is separated from normal bone by dark zone of revascularization. (*b*) R femoral head, at level of fovea centralis, revealing well-demarcated Stage II lesions in superior portion of femoral head, with thickened marginal trabeculae and intertrabecular fibrosis and calcification without gross structural alteration of articular cartilage.

phlebography indicate that the femoral-head cartilage is still intact — *i.e.*, there is no evidence of secondary subchondral fractures — it is still possible, within certain limits, to revascularize segmental necrotic lesions from the cancellous region of the femoral neck. Extrinsic revascularization procedures are possible when the maximum thickness of the necrotic segment does not exceed 15 mm on A-P tomography. If greater than 15 mm, the intrinsic revascularization process will gradually cease and a necrotic area will remain in the subchondral bone (Wagner, 1971).

In an attempt to accelerate the intrinsic revascularization process, the necrotic area in the femoral head is excavated without dislocating the hip joint. Biplane roentgenograms are used to avoid injuring the intact articular cartilage. Wagner (1971) fills the excavated cavity with iliac bone grafts, whereas Bonfiglio and Bardenstein (1958) advocate introducing square-shaped autogenous tibial cortical bone pegs through round holes created in the femoral neck and head. Granulation tissue propagates into the femoral-head lesion through clefts remaining adjacent to the bone grafts.

Jameson (1972) modified the Judet musculo-osseous pedicle transfer (Judet, 1962) for osteosynthesis of femoral-neck fractures in an attempt to revascularize the head (Jones, 1971) (Fig. 2). The quadratus-femoris muscle provides vascularity for the cancellous bone of the intertrochanteric crest, which is introduced through an excavated hole into the femoral-head lesion. Meyers *et al.* (1972) treated 150 displaced femoral-neck fractures with the muscle-pedicle transplant technique and noted a marked reduction in the incidence of late segmental collapse of the head.

With necrotic lesions greater than 15 mm in maximum depth, nonsurgical management is used to protect the shoulder or hip mechanically by *1)* non-weight-bearing or bed rest, with or without traction; *2)* physiotherapy (deep heat and muscle-strengthening range-of-motion exercises); or *3)* muscle relaxants and analgesics. However, D'Aubigne *et al.* (1965) advocated temporary fixation of the acetabulum to the femoral shaft to bypass the head and relieve pressure on it to allow healing.

Boettcher *et al.* (1970) documented five patients treated conservatively by protected weight-bearing in whom the focal necrotic area was small. One patient experienced complete repair without collapse or degenerative change and was asymptomatic at a seven-year follow-up. The hips of the other four patients treated nonsurgically underwent progressive collapse.

Of 38 necrotic femoral heads repaired by drilling and bone-grafting techniques (Phemister,

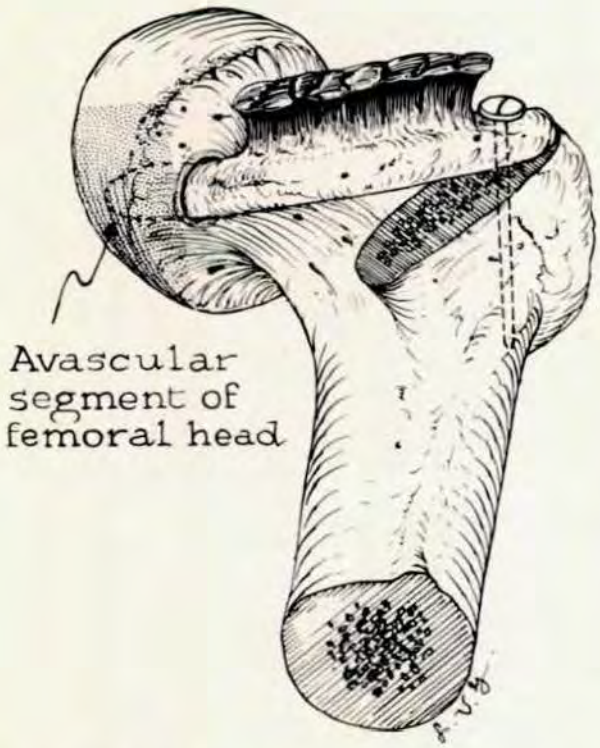

FIG. 2. Judet musculo-osseous pedicle transfer, as modified by R. M. Jameson (1972) — a procedure performed in attempt to revascularize a previously excised segmental defect in anteroinferior quadrant of femoral head, although most often used for lesions in anterosuperior quadrant. Viable cancellous bone from intertrochanteric crest is nourished by vessels supplying quadratus femoris muscle.

1949), six had a normal joint space with no collapse of the subchondral bone preoperatively. These hips had a higher frequency of good results than did those in which there was minimal or moderate preoperative collapse. Final results following bone grafting or musculo-osseous pedicle transfers will be improved if these procedures are performed before collapse occurs, and if the bone graft or viable bone pedicle is accurately positioned in the femoral head without injuring the articular cartilage.

STAGE III LESIONS

The patient is symptomatic. Roentgenograms — particularly external rotation projections of the shoulder and lateral projections of the hip — indicate architectural failure and structural collapse. Often a unipolar or bipolar subchondral fracture is apparent; the radiolucent crescent-line sign is positive (Fig. 3). Once a break has

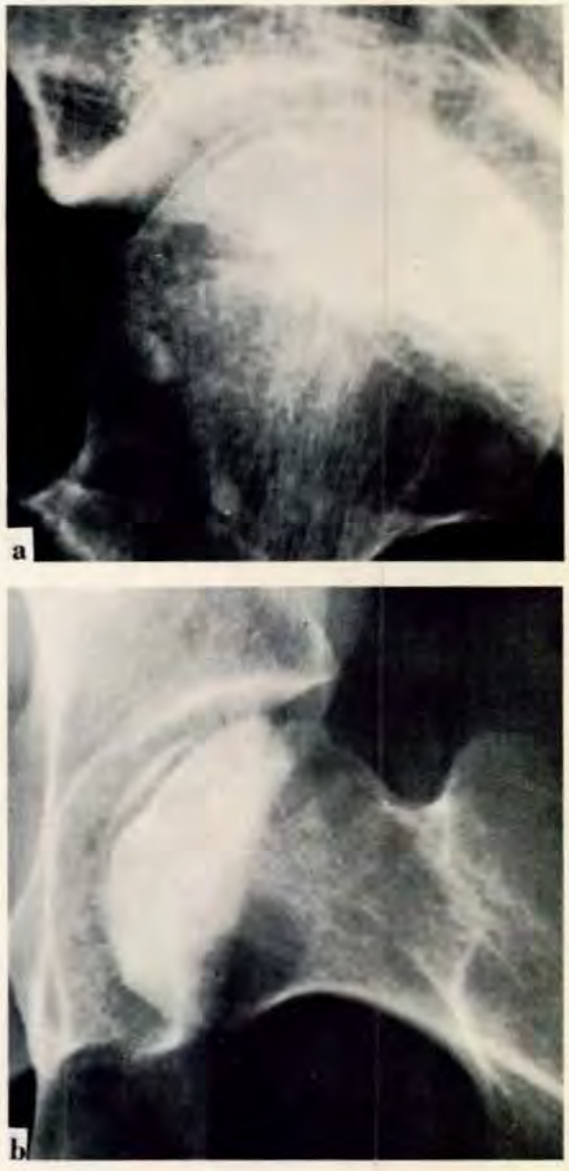

FIG. 3. Lateral roentgenograms of hips with early Stage III osteonecrosis lesions: (*a*) secondary subchondral fracture extending through necrotic bone in anterosuperior quadrant of femoral head in lesion with minimal articular incongruity; (*b*) another positive radiolucent crescent-line sign (translucent subcortical band sign) with dissection of subchondral bone.

occurred in the smooth spherical articular cartilage and subchondral bone, the necrotic lesion is advanced and irreversible. It will inevitably progress to further collapse, with articular incongruity and secondary degenerative changes. Given this damage, the humeral or femoral head is not salvageable (Fig. 4 and 5).

Histological studies indicate that the secondary subchondral fracture propagates through the preexisting necrotic bone and usually extends through the articular cartilage. The margin of the lesion at this stage is principally composed of calcified fibrous tissue interposed between thickened and dead trabeculae.

Once a subchondral fracture develops, osseous fragmentation and sequestrum formation are

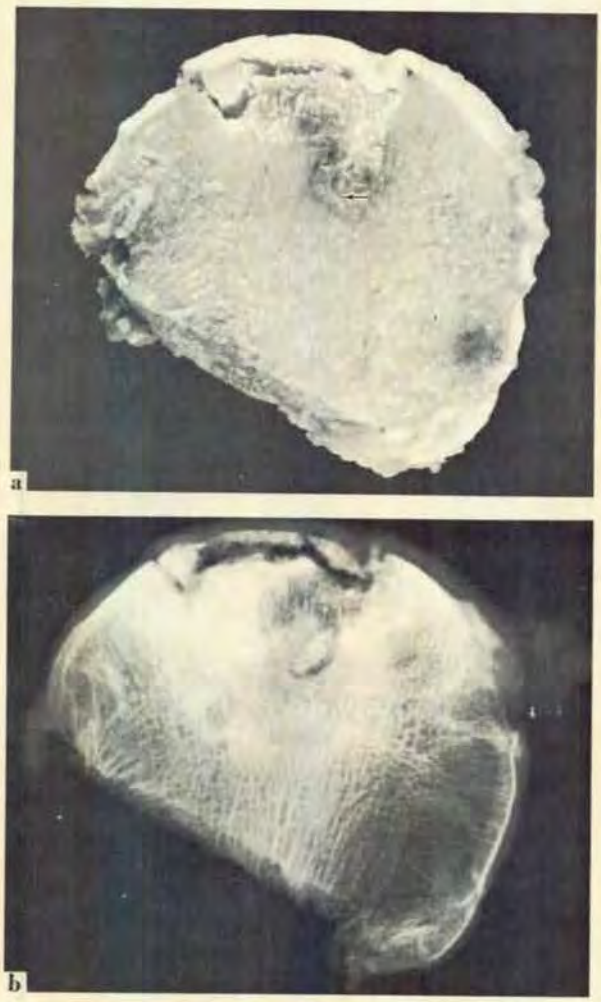

FIG. 4. (*a*) Gross sagittal section of R femoral head, revealing Stage III lesion with subchondral fracture extending through necrotic bone with minimal thinning of cartilage. Small fracture cleft beginning at apex of necrotic lesion is marked with arrow. (*b*) Roentgenogram of same section showing early sequestrum formation with marked osteonecrosis.

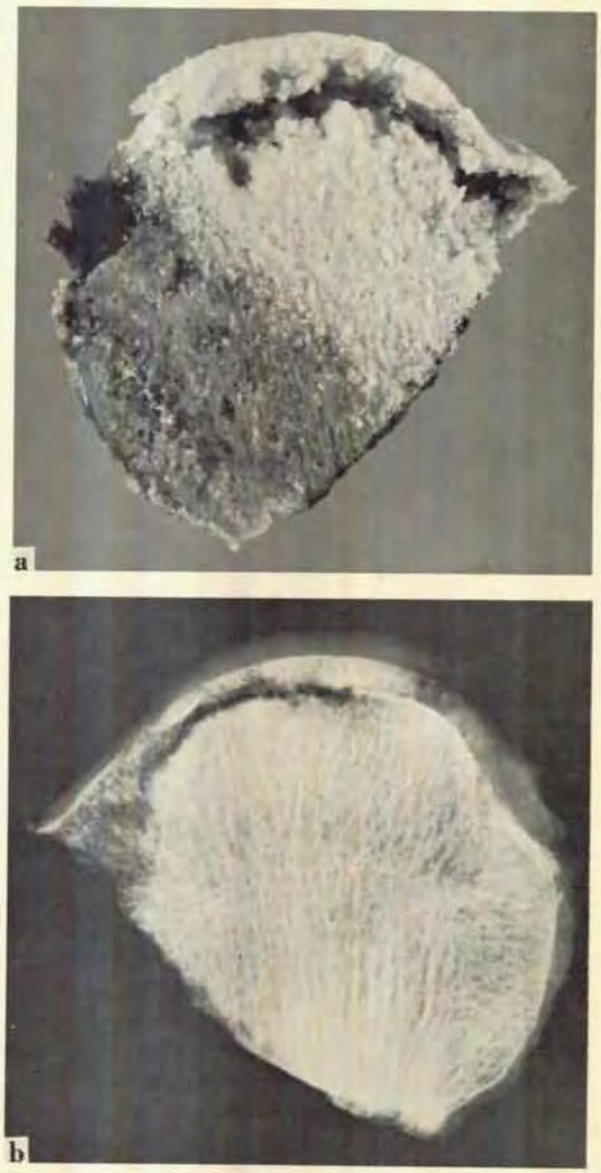

FIG. 5. (*a*) Gross sagittal section of L femoral head, showing large Stage III lesion and extensive subchondral fracture with complete detachment of overlying cartilage; (*b*) high-resolution roentgenogram of specimen showing semilunar fracture.

progressive (Fig. 6*a*), although the thickness of the articular surface is initially preserved. As subchondral collapse continues, there is subtotal joint destruction (Fig. 6*b*), with advanced

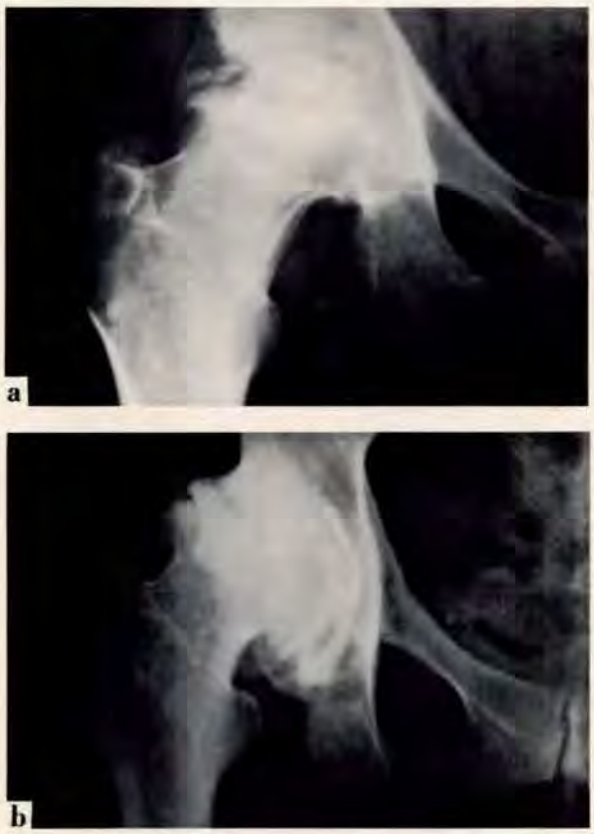

FIG. 6. (*a*) A-P roentgenogram of R hip, indicating Stage III lesion with sequestrum formation. There is central depression and collapse of superior weight-bearing cortex, with marginal osteophyte proliferation but fair preservation of joint space. (*b*) A-P roentgenogram of R hip, showing severe Stage III lesions. There are marked secondary degenerative changes involving the acetabulum as well as virtually complete obliteration of joint space, marked hypertrophic proliferation, and lateral subluxation of femoral head.

changes typical of degenerative arthritis — including a narrowed and incongruous joint space, diffuse hypertrophy with extensive marginal osteophytic proliferation, and large degenerative cysts on either side of the joint (glenoid and acetabulum). In prescribing treatment of Stage III lesions, several factors must be considered — the age, sex, occupation, and general health of the patient; his degree of pain, restriction of motion, deformity, and functional capacity; and the possible bilaterality of the lesions.

Shoulder Joint

Two principal surgical procedures are available for Stage III lesions of the shoulder: hemiarthroplasty with prosthetic replacement, and arthrodesis.

Hemiarthroplasty. In this procedure the humeral head is replaced with a metal prosthesis, which is maintained within the humeral shaft by a stem (Neer, 1963). However, this approach is not advised if there is significant arthritis of the shoulder joint (coxarthrosis) because the glenoid is not altered by the surgery. Satisfactory range of motion and muscle power are often regained following intensive physiotherapy, which is important in those laborers who are required to work with arms lifted.

Arthrodesis. Arthroplasty is not indicated when necrotic lesions of the humeral head are accompanied by degenerative changes of the glenoid or adhesive capsulitis and fibrous ankylosis of the shoulder joint. Arthrodesis — fixation of joint surfaces by fusion — is functionally superior under these circumstances, and a combined intra-articular and extra-articular procedure is preferred. The most serviceable position for glenohumeral arthrodesis allows sufficient scapulothoracic motion for the arm to fall to the side and traverse a range of motion of 90° abduction, 80° flexion, and 90° internal rotation (Gill, 1931).

Hip Joint

Four major surgical procedures are effective in the treatment of nontraumatic (*e.g.*, dysbaric) osteonecrosis of the hip joint: osteotomy, hemiarthroplasty, arthrodesis, and total hip replacement. Cup (mold) arthroplasty (Johnston and Larson, 1969) is now rarely indicated for osteonecrosis since the functional end result remains unpredictable. The principal reason is that any necrotic bone of the femoral head remaining beneath the cup may continue to die, resulting in progressive absorption, settling, and painful shortening of the femoral neck.

Osteotomy. Osteotomy (McMurray, 1935; and Pauwels, 1965) is designed to create a more satisfactory articulating surface between the femoral head and acetabulum, since more normal cartilage is brought into contact at weight-bearing areas. Romer and Wettstein (1971) per-

formed intertrochanteric osteotomies on 36 patients with idiopathic osteonecrosis. They concluded that the results were good in 65% of patients with unilateral hip disease and in 50% of those with bilateral necrosis of the femoral head. In their opinion the varus osteotomy usually has a better final result than the valgus osteotomy.

Osteotomy often relieves hip pain by producing more diffuse loading stresses on the femoral head. It is indicated for those patients having early Stage III lesions of dysbaric osteonecrosis with structural failure, and for young patients in whom arthrodesis may be undesirable. Pauwels's method of preoperative evaluation and the use of a compression device for internal fixation are essential in an osteotomy.

Arthrodesis. This procedure is indicated in young working men with unilateral involvement, since partial or total prosthetic-replacement arthroplasties are usually not performed in patients under 50 years of age. However, arthrodesis is difficult. The avascular femoral head does not contribute substantially to a solid fusion, so that fibrous rather than bony ankylosis often results. Arthrodesis is often the preferred treatment for younger patients, because a total hip arthroplasty may later be performed with satisfactory results.

Arthrodesis provides a stable and pain-free hip for the vigorous individual who must work while on his feet. Degenerative arthritis of the ipsilateral knee and low back complicates hip arthrodesis, especially as the patient becomes older. Of course, arthrodesis is contraindicated in individuals with bilateral hip disease, which is a frequent occurrence in those exposed to dysbaric phenomena. The possibility of subsequent involvement of the opposite hip should therefore be taken into account.

Hemiarthroplasty. The diseased femoral head is replaced with a metal ball, which is maintained in the shaft by a stem. The device was originally developed by the Judet brothers (1950); since then, several other devices have been used, including the Austin Moore, Thompson, and Eicher endoprostheses.

This procedure is indicated for those individuals with severe, extensive involvement of the femoral head when the acetabulum is normal. The prognosis in hemiarthroplasty is affected by acetabular cartilage deterioration resulting from unsatisfactory prosthetic ball and acetabular fit; imperfect sphericity on surface finish; the necessity for satisfactory acetabular subchondral support to prevent migration of the prosthesis; and variability in the prosthetic materials. The prognosis is further influenced by prosthetic loosening in the femoral shaft resulting from torque at the stem tip, a mismatch of the modulus of elasticity, unsatisfactory stem length, and associated systemic disease, particularly osteoporosis.

The reasons for failure of this procedure are important, since either the prosthesis loosens or sinks into the femur or it protrudes into the acetabulum, or both. The approach therefore has no place in present-day treatment of osteonecrosis when secondary degenerative arthritis is present (Fig. 6*b*). Salvati and Wilson (1972) evaluated 195 patients with noncemented femoral-head replacements for an average follow-up period of 9.6 years. They observed the best results in patients operated on for necrosis of the femoral head with intact acetabular cartilage.

Arthroplasty. Total hip replacement (both femoral-head and acetabulum) is indicated in those patients over 50 years of age in whom severe collapse of the femoral head is accompanied by secondary degenerative changes involving the acetabulum. Such changes include narrowed and incongruous joint spaces, with extensive osteophyte and cyst formation and lateral subluxation of the hip joint. Charnley (1970*b*), McKee and Watson-Farrar (1966), and Ring (1971) have developed this operation to its present usefulness. Results of total hip arthroplasty in patients with complicated Stage III osteonecrosis are very encouraging, since there is virtually complete relief of pain, restoration of stability, and good motion postoperatively. Hip pain is eliminated because all movement is between the insensitive surfaces of the prosthetic parts. Painful reactive sclerosis and pelvic migration of the femoral component are prevented, and the dimensions of a normal hip joint are often restored.

Methyl methacrylate is used for bonding the components. It prevents motion, loosening, and settling of the prosthesis. Furthermore, it distributes the pressure of superincumbent weight and abductor-muscle tension more evenly to the pelvis and femur, thus avoiding high stress points that may be painful. Combined prostheses are of two kinds. One is high friction — *e.g.*, the Tronzo and McKee-Farrar devices (Fig. 7), with metal-to-metal contact. The other is low friction — *e.g.*, the Charnley-Müller, Aufranc-Turner, and Charnley devices, which use a metal femoral component and a high-density polyethy-

FIG. 7. (*a*) A-P view of R hip showing McKee-Farrar total hip system installed; (*b*) McKee-Farrar total hip system with modified Thompson femoral component, a high-friction, metal-to-metal device. (Photographs courtesy of Zimmer USA, Warsaw, Indiana 46580.)

lene acetabular component, each securely fixed to the bone with methyl methacrylate.

Harris (1972) has introduced another total hip system in which the acetabular component is replaceable and may be installed in patients under 50 years of age, a previous contraindication to total hip replacement. Charnley (1970*a*) has found no significant untoward effects from Simplex P bone cement, a pharmacologically inert and insoluble polymer, in over 12 years of clinical application. Simplex P is compatible with tissues, and instances of sensitivity or tissue response to the cement have been extremely rare.

The prognosis in total hip-replacement arthroplasty is dependent upon the wear characteristics of the components, the adequacy of skeletal fixation, and the patient's tolerance of prosthetic debris. But currently there is every indication that a satisfactory total hip-replacement arthroplasty should last for approximately 20 to 25 years. The Ring and Sbarbaro total hip implants are not secured with bone cement and their longevity is yet to be established.

Results of total hip arthroplasty are very encouraging. The hip can be scored with respect to function, pain, stability, limp, and motion, according to the method of Harris (1969); a score of 100 is a perfect or normal hip. Coventry *et al.* (1972) reported a preoperative score of 45.0 and a postoperative score of 89.4 for 333 hips, the conditions of which were followed one year or longer.

SUMMARY

Treatment of nontraumatic (*e.g.*, dysbaric) osteonecrosis has been correlated with clinical, radiological, and pathological stages of progressive involvement of the shoulder and hip joints. There is minimal well-documented evidence to indicate that conservative nonsurgical methods result in spontaneous healing of Stage I and II lesions. Revascularization procedures are indicated for certain Stage II but not for Stage III lesions.

Arthrodesis and intertrochanteric osteotomy of the hip are indicated in patients under age 50 with Stage III lesions and unilateral hip disease, but postoperative rehabilitation is pro-

longed and the final functional results are uncertain. Hemiarthroplasty of either shoulder or hip joints is the treatment of choice when there is no significant arthritic involvement. Arthrodesis of the shoulder and total replacement of the hip are indicated in those individuals with severe Stage III lesions and severe secondary degenerative arthritis.

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