Current Management Options for Osteonecrosis of the Femoral Head: Part II, Operative Management

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Abstract

Osteonecrosis of the femoral head is a multifactorial disease that can result in significant clinical morbidity and affects patients of any age, including young and active patients. Late sequelae of femoral head osteonecrosis include femoral head collapse and subsequent degeneration of the hip joint. A high index of suspicion and improved radiographic evaluation allow orthopedic surgeons to identify this disease at an earlier stage. Current management options for hip osteonecrosis have results that vary according to patient population and disease stage. Modifications of older techniques, as well as emerging technologies, have led to the development of management strategies that may be able to alter the course of femoral head osteonecrosis.

Although technologic advances in implant design, bearing surfaces, and surgical technique have increased the survivorship of total hip arthroplasties (THAs), prosthesis longevity is still a significant concern for young, active patients with femoral head osteonecrosis. Hence, substantial emphasis has been placed on early identification and management of this disease. A high index of suspicion and improved radiographic evaluation allow identification of femoral head osteonecrosis at its early stages. Optimal management modalities would foster healing without sacrificing the structural integrity of the bone or the health of the overlying articular cartilage. Thus, patient symptoms could be managed while preserving the femoral head and maximizing posttreatment function. Although this ideal treatment has not been developed, recent advances in managing femoral head osteonecrosis may be able to prevent or delay progression of this disease and reduce its associated clinical morbidity. This review is Part II of a 2-part review, and will discuss operative management of osteonecrosis of the femoral head. Part I, which discussed diagnosis and nonoperative management, appeared in the September 2011 issue.

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Operative Management

Core Decompression

Core decompression was developed by Ficat and Arlet during their acquisition of biopsy specimens for histologic confirmation of the disease that caused idiopathic bone necrosis. This procedure anecdotally resulted in less hip pain. Later, core decompression was theorized to relieve the elevated intraosseous pressure within the femoral head and allow improved restoration of vascular inflow. It has been reported to be safe to perform the procedure on both hips simultaneously.[1] Clinical reports on using this technique vary widely. Most proponents agree that core decompression is likely most beneficial for Ficat stage I and II, especially compared with activity modification alone (Table).[2-8] Direct comparisons of the other nonoperative modalities (bisphosphonate use, extracorporeal shockwave therapy) with core decompression, or in combination with core decompression, have yet to be evaluated.

Structural and Cellular Supplementation of Core Decompression

Some investigators have proposed supplementing core decompression procedures with a nonvascularized or vascularized bone graft to improve the support of and possibly to enhance the repair of the femoral head. Alternatively, necrotic bone debridement and bone grafting may be performed through a window created in the femoral neck. Use of nonvascularized bone graft to support the femoral head is extensive; clinical success rates vary from 46% to 90% and radiographic success rates from 0% to 91%, depending on the study.[55] Bone morphogenetic protein has been added to the allograft bone used during core decompression, but this modification has had unconvincing results compared with those of core decompression with nonvascularized bone grafting alone.[55,56]

It has been reported that, when performed at specially equipped centers, vascularized fibular bone grafting and vascularized iliac bone grafting, in conjunction with core decompression, provide symptomatic relief and delay the need for THA in patients with Ficat stage II, III, or IV disease. These techniques are useful adjuncts to core decompression in more advanced cases of femoral head osteonecrosis (Table).[9-11] More recent reports indicate that use of vascularized iliac bone grafting may not be as promising as originally suggested.[13] In addition, a center-edge hip angle of 30° or less increases the risk for femoral head collapse and conversion to THA after vascularized fibular bone grafting by 5.5- and 7.5-fold, respectively.[12]

Trapdoor grafting, introduced in 1965, involves an open arthrotomy of the involved hip, dislocation of the femoral head anteriorly, followed by debridement of the necrotic bone from the femoral head, and packing the void with cancellous bone graft through a cartilage window in the femoral head. Combining trapdoor grafting with containment has shown favorable results in managing advanced femoral head osteonecrosis in a small number of very young patients with small- to medium-sized lesions (Table).[14,15]

Autologous bone marrow transplantation into the femoral head after core decompression was first attempted in 1997 as a biological alternative to bone grafting that may stimulate angiogenesis or osteoblast differentiation.[57] Results of a case–control, double-blind study of 10 Ficat stage I and II hips managed with autologous bone marrow transplantation after core decompression showed a significant reduction in pain and a 10% rate of progression to Ficat stage III after 2-year follow-up.[16] Short-term prospective analysis of this technique was promising and was supported by longer term studies.[58,59] Results of a prospective evaluation of 189 Ficat stage I and II hips managed with autologous bone marrow transplantation after core decompression with mean follow-up of 7 years showed excellent results for patients treated before collapse, with 9 of 145 (6.2%) hips progressing to THA. Results were less successful when management was initiated after collapse, with 25 of 45 (55.6%) hips requiring THA.[17] These intermediate-term prospective data were supported by longer term follow-up, where 94 of 534 (17.6%) Ficat stage I and II hips were converted to THA with mean follow-up of 13 years—suggesting that this procedure altered the course of femoral head osteonecrosis when implemented early (Table).[18]

Given the unpredictable nature of core decompression with or without nonvascular bone graft, as well as the donor-site morbidity associated with bone graft harvesting, porous tantalum rod implantation has been used after core decompression to provide consistent structural support to the femoral head. Results of a retrospective evaluation of 60 hips with osteonecrosis of the femoral head before radiographic collapse managed with core decompression and a porous tantalum rod demonstrated 68% survivorship at 4 years (Table).[19] However, results from another retrospective study on osteonecrotic hips in more advanced stages showed only modest results, with mean time to failure after procedure being less than 1 year.[20] Direct comparison with core decompression and other bone grafting techniques is required before a definitive recommendation can be made regarding this structural technique.

Articulated Hip Distraction

Articulated hip distraction has been proposed as a means to prevent femoral head collapse while allowing for remodeling by providing both arthrodiastasis and hip range of motion. Results of a retrospective review of 31 hips with 4.7-year follow-up revealed reduced pain in 78% of patients and no activity limitations after distraction in 50%; the rate of conversion to THA was 17%. In addition, articulated hip distraction had a 26% rate of minor complications with the external fixator. Furthermore, 91% survival at 5 years, 78% survival at 10 years, and 39% survival at 15 years were reported, so articulated hip distraction may delay the need for THA and may improve quality of life over the short term, but likely does not change the overall outcome of osteonecrosis of the femoral head.[60]

Osteotomy

Patients who are younger than 40 years, have a small necrotic segment in the femoral head, and maintain a mobile hip may be candidates for proximal femoral osteotomy. The goal of femoral osteotomy is to unload the necrotic, collapsing segment of bone from the primary weight-bearing area. Symptoms can be relieved by realigning the joint articulation, transferring the weight-bearing forces to an area of normal articular cartilage buttressed by healthy subchondral bone. Successful realignment through proximal femoral osteotomy can result in significant relief of pain and delay the need for THA. Options include rotational intertrochanteric or transtrochanteric osteotomies, valgus flexion or extension osteotomies, and varus osteotomies with or without flexion and extension. An osteotomy that is performed well and for the right indications can provide patient-reported quality-of-life outcomes similar to those achieved with THA.[61]

Preoperative planning for osteotomy requires high-quality imaging, including an anteroposterior radiograph of the pelvis, an oblique radiograph, a false-profile radiograph of the affected hip, anteroposterior radiographs of the affected hip in maximal abduction and adduction, and a true lateral radiograph. These allow the surgeon to evaluate the location and size of the necrotic segment on the femoral head. Studies have shown that cases with a combined Kerboul angle of more than 200° are more prone to failure after osteotomy, with subsequent collapse of the femoral head.[62] Some authors have recommended preoperative 3-dimensional computed tomography or magnetic resonance imaging for more precise assessment of the extent of the osteonecrotic lesion and for collapse prediction.[63]

Sugioka and colleagues developed the rotational transtrochanteric proximal femoral osteotomy for use in managing osteonecrosis.[21] This osteotomy is based on the finding that osteonecrosis most commonly affects the anterosuperior portion of the femoral head, with the posteroinferior aspect left intact. This allows for 80° to 90° anterior rotation of the proximal femur based on the vascular pedicle of the medial femoral circumflex vessels through 3 separate bony cuts. Osteotomies are created through the greater trochanter, the intertrochanteric region from superolateral to inferomedial, and through the femoral shaft starting from the proximal flare of the lesser trochanter. Successful rotational osteotomy in theory results in protection of the necrotic lesion from the shear forces that cause segment collapse and realignment of the subluxed femoral head with the acetabulum. This procedure can be technically demanding, and many reports initially showed good to excellent results in certain centers, and in Asian populations exclusively, though a prospective study has supported its use in Caucasian populations as well (Table).

Valgus flexion osteotomy is most useful in treating younger patients who have small anterolateral lesions with or without collapse. Indications include patients younger than 40 years who have no underlying systemic disease and who on physical examination demonstrate adequate hip abduction, internal and external rotation, and minimal flexion contracture. This osteotomy, in theory, unloads the necrotic portion of the femoral head by moving the anterolateral aspect of the head out of the weight-bearing area; corrects the adduction deformity common with anterolateral segment collapse with valgus realignment; and with the addition of flexion transfers the load to the intact posterior articular surface. Valgus flexion osteotomy is an option for managing small osteonecrosis lesions in young patients and may successfully delay collapse and the need for arthroplasty (Table).

In a small percentage of patients with osteonecrosis of the femoral head, the necrotic lesion occurs in the medial aspect of the femoral head, with preservation of the lateral column of bone and articular cartilage. When these cases are identified before segment collapse and the patient maintains at least 30° of abduction, a varus intertrochanteric osteotomy may be indicated. Precise location of the necrotic segment, either anterior or posterior on the femoral head, dictates whether flexion or extension is added to the osteotomy (Table).

Hip Resurfacing Arthroplasty

Recent advances in prosthetic designs have led to increased enthusiasm for resurfacing arthroplasty in the management of osteonecrosis of the femoral head. Hemiresurfacing arthroplasty is a bone-conserving procedure that preserves all the acetabulum, the viable portion of the femoral head, and the femoral neck. It is thought that, by providing a congruent femoral head surface to articulate against the acetabulum, the procedure relieves pain and restores function. However, hemiresurfacing may cause increased wear on the native acetabular articular cartilage and result in a high rate of pain and failure (Table).[37-39] Although it is still not entirely clear how much femoral head must still be viable after femoral head preparation during total hip resurfacing arthroplasty. This could affect implant fixation and increase the rate of femoral neck fracture. Hip resurfacing arthroplasty remains a more viable option, especially in active, younger patients. In addition, results of recent studies have demonstrated that total hip resurfacing arthroplasty has success rates similar to those of THA and, compared with THA, allows twice as many patients to maintain a high level of activity (Table).[40,41] Many surgeons prefer to avoid hip resurfacing arthroplasty in patients with osteonecrosis of the femoral head because of the 7% rate of revision to THA.[64,65] However, results from a case–control study involving 84 hips and a retrospective review of 1,000 hips support similarly excellent outcomes for osteonecrosis and other indications for hip resurfacing arthroplasty.[66,67]

The metal-on-metal bearing surface used in total hip resurfacing arthroplasty generates elevated levels of serum cobalt and chromium ions. However, the exact level of metal ions required for a pathologic response is difficult to determine.[68] The unknown long-term ramifications of these elevated ions levels, along with evidence that cobalt and chromium ions pass the placental barrier, prompt the recommendation that women of childbearing age should consider other bearing surfaces.[69] In addition, some patients may have, or develop, a type IV delayed hypersensitivity response resulting in the formation of a pseudotumor.[70-72] Hypersensitivity may develop in previously unresponsive patients, making screening difficult.[73]

Total Hip Arthroplasty

THA plays a significant role in the operative management of femoral head osteonecrosis, especially for patients with advanced disease. This procedure is often used as the primary treatment. In addition, THA can be a useful salvage procedure after other joint-preserving procedures (eg, core decompression, osteotomy, resurfacing) have failed. THA is associated with an increased rate of failure when used to treat patients with osteonecrosis versus other causes of joint degeneration (Table).[43,45-47] In addition, for young and otherwise healthy patients, the possibility of reduced prosthesis longevity is a significant clinical issue.[48] Therefore, although it should be considered a salvage procedure, THA remains a reasonable option in later stages of the disease for young patients with significant pain or functional limitations. In addition, results of a

Table. Operative Treatment Options for Femoral Head Osteonecrosis

Treatment	Literature	Study Design	Outcome	Recommendation
Core decompression	Ficat[2]	Review of 133 hips (Ficat I & II) at 9.5 years	Very good results in 90%; minimal disease progression in 79%	Recommended for Ficat I & II
	Mont et al[3]	Meta-analysis of 42 studies (>2000 hips)	Improved overall satisfactory results from 23% to 64% at 30 months	
	Stulberg et al[4]	Randomized clinical trial of 55 hips (all stages) managed with core decompression or conservative management	Improved outcomes in stage I (70% vs 20%), II (71% vs 0%), III (73% vs 10%)	
	Koo et al[5]	Randomized clinical trial of 37 hips (early stage) managed with core decompression or conservative management with minimum follow-up of 24 months	No significant difference between groups	
	Markel et al[6]	Retrospective review of 54 hips over 10 years	Successful results in 35% of patients	
	Smith et al[7]	Retrospective review of 114 hips with follow-up of 40 months	81% success in Ficat I (less favorable results in patients with crescent sign)	
	Fairbank et al[8]	Retrospective review of 128 hips with follow-up of 11 years	Successful in early diseases (88% Ficat I, 71% Ficat II); 27% success after femoral head collapse	
Vascularized bone grafting	Urbaniak et al[9]	Retrospective review of 103 hips (free fibula) at 5+ years	Successful outcomes in >80%; delayed need for THA by >5 years in 70%	Recommended as supplement to core decompression for Ficat II & III & possibly IV in centers capable of performing procedure Critical evaluation of acetabulum for hip dysplasia warranted
	Marciniak et al[10]	Retrospective review of 101 hips (free fibula) at 5 years	61% with symptomatic relief and no disease progression	
	Zhao et al[11]	Review of 226 hips (pedicled iliac bone block) at 12.5 years	6% required THA at 12.5 years; successful in 96% (Ficat II), 90% (Ficat III), 57% (Ficat IV); HHS score increased from 46 to 84	
	Roush et al[12]	Retrospective review of 200 hips (free fibula) with mean follow-up of 7.5 years	24% were converted to THA; center-edge angle of ≤30° correlated with 55% rate of progressive collapse and 45% rate of THA conversion, whereas center-edge angle of >30° correlated with 10% rate of progressive collapse and 6% rate of THA conversion	
	Chen et al[13]	Retrospective review of 33 hips (pedicled iliac bone block) over 5 years	76% required THA at mean of 74 months; in other 24%, THA was not required, HHS score increased from 62 to 80, all showed evidence of collapse	
Trapdoor grafting	Mont et al[14]	Review of 30 hips (23 patients, trapdoor, Ficat III & IV) with follow-up of 56 months	83% reported good to excellent results	Further research needed before routine use can be recommended, but trapdoor grafting may be beneficial in younger patients with Ficat III & IV
	Ko et al[15]	Review of 10 hips in 9 teenagers (trapdoor) with advanced osteonecrosis with follow-up of 4.5 years	Of 10 hips, 8 had good clinical results, and 2 had fair results	

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Treatment	Literature	Study Design	Outcome	Recommendation
Autologous bone marrow transplantation	Gangji et al[16]	Case–control, double-blind study of 18 Ficat I & II hips (10 managed with autologous bone marrow transplantation after core decompression & 8 managed with core decompression alone with follow-up of 2 years)	Significant reduction in pain and 10% rate of progression to Ficat III after bone marrow transplantation; 63% rate of progression to Ficat III after core decompression alone	Recommended for Ficat I & II as supplement to core decompression
	Hernigou & Beaujean[17]	Prospective evaluation of 189 Ficat I & II hips managed with autologous bone marrow transplantation after core decompression with mean follow-up of 7 years	Of 145 patients treated before collapse, 9 (6.2%) required THA; of 45 patients treated after collapse, 25 (55.6%) required THA	
	Hernigou et al[18]	Prospective evaluation of 534 stage I & II hips managed with autologous bone marrow transplantation after core decompression with mean follow-up of 13 years	94 hips (17.6%) were converted to THA	
Porous tantalum rod insertion	Veillette et al[19]	Retrospective review of 60 hips (tantalum rod, Steinberg I-III) with follow-up of 4 years	92% survivorship at 1 year; 82% survivorship at 2 years; 68% survivorship at 4 years improves to 92% when patients with chronic systemic disease are excluded	Further research needed before routine use can be recommended, but porous tantalum rod insertion may be beneficial in precollapse hips
	Nadeau & Séguin[20]	Retrospective review of 18 hips (tantalum rod, Steinberg III & IV) with follow-up of almost 2 years	78% without THA conversion at 1 year decreased to 45% at 2 years	
Rotational transtrochanteric osteotomy	Sugioka et al[21]	Review of 295 hips with follow-up of 11 years	Excellent results in 78% (investigators concluded collapse can be avoided when transposed intact area occupies 36% of acetabular weight-bearing area)	Moderately successful in patients younger than 40 with small lesion in anterosuperior portion of femoral head and good mobility; success and complications depend mostly on lesion size and possibly on body mass index
	Sugano et al[22]	Review of 41 hips at 6 years	Good or excellent results in 56%	
	Dean & Cabanela[23]	Review of 18 hips with follow-up of 5 years	17% had satisfactory outcomes; 83% showed evidence of femoral head collapse; 67% required THA	
	Iwasada et al[24]	Retrospective review of 48 hips with mean follow-up of 4 years	Satisfactory results in 62%; femoral head collapse in 6 hips in which ratio of intact posterior articular surface was <30%; bony complications in 16%	
	Yasunaga et al[25]	Histologic study of femoral head of 9 rats at 2.5 years	In 7 of 9 patients, creeping substitution in limited area; dead bone remained in all cases	
	Rijnen et al[26]	Prospective study of 26 hips (Caucasian population) evaluated at 8 years	17 hips converted to THA had radiographic survival rate of 54% after 1 year and clinical survival rate of 56% after 7 years	
	Atsumi et al[27]	Retrospective review of 35 hips with mean follow-up of 8 years	33 of 35 hips (94%) without further radiographic collapse and adequate living bone in weight-bearing area of femoral head; progressive joint space narrowing in 4 of 35 hips (11%)	
	Sugioka & Yamamoto[28]	Retrospective review of 46 hips with mean follow-up of 12 years	30 hips (65%) had no progression of collapse; 13 hips (28%) had changes consistent with osteoarthritis; none required THA	
	Atsumi et al[29]	Retrospective radiographic review of 28 hips with follow-ups of <6 months & 3 years & final follow-up	Progressive femoral head recontouring from 18% loss at <6 months to 8% loss at 3 years and 3% loss at final follow-up	

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Treatment	Literature	Study Design	Outcome	Recommendation
	Biswal et al[30]	Retrospective review of 60 hips with mean follow-up of 7 years	Of 50 hips, 10 (20%) had progressive collapse, 7 (14%) had progressive varus deformity, and 3 (6%) had femoral neck stress fractures	
	Ikemura et al[31]	Retrospective review of 27 patients (<20 years old) with mean follow-up of 14 years	Of 27 hips, 2 (7.4%) required THA; 25 (92.5%) without further intervention at final follow-up; 5 (18.5%) with progressive joint space narrowing but without collapse	
	Ha et al[32]	Retrospective review of 133 hips with follow-up of 4 years	Ficat III or higher, age over 40, body mass index ≥24, and combined necrotic angle ≥230° were statistically associated with risk for collapse	
Valgus flexion osteotomy	Scher & Jakim[33]	Prospective study of 46 Ficat III hips with follow-up of 65 months	Good to excellent results in 87% of hips with follow-up of 5 years; mean HHS score improved from 34 to 90	For patients younger than 40 with small anterolateral lesion but no underlying systemic disease and with adequate hip range of motion
	Gottschalk[34]	Review of 17 patients with follow-up of 3 years	8 patients had satisfactory clinical outcomes, 3 remained symptomatic, 5 required conversion to THA	
Varus intertrochanteric osteotomy	Mont et al[3]	37 Ficat II & III hips with follow-up of 11.5 years	76% had good or excellent results, HHS score improved from 38 to 89; most success in 20 patients who had not received corticosteroids	For isolated lesions in medial aspect of femoral head without segment collapse (patient must maintain 30° of abduction)
Hemiresurfacing arthroplasty	Siguier et al[35]	25 partial resurfacings (Ficat II-IV) at 43 months	76% had good or excellent results; 6 hips eventually required conversion to THA	Not recommended because of lack of long-term success as well as native acetabulum wear and groin pain
	Adili & Trousdale[36]	Review of 29 hemiresurfacings (mean patient age, 31.6 years) with follow-up of 34 months	HHS score increased from 48.1 to 79.3; THA conversion 93.5% at 1 year, 75.9% at 3 years	
	Grecula[37]	Meta-analysis of 451 hemiresurfacing arthroplasties performed between 1964 and 2000	Revision required for 83 complications, including pain, subluxation or migration of prosthesis, absorption of bone from femoral head, and proximal femoral fracture	
	Cuckler et al[38]	Retrospective review of 59 hemiresurfacings (Ficat III) at 4.5 years	Successful outcomes in 60%; HHS score improved from 51.4 to 80.6 at 1 year, but at 3 years there were 18 clinical failures (40%) based on presence of severe groin pain or conversion to THA	
	Amstutz & Le Duff[39]	Retrospective review of 54 hemiresurfacing arthroplasties with mean follow-up of 14 years	Survivorship was 80% at 5 years, 63% at 10 years, 36% at 15 years; some patients did not experience complete relief of pain; younger patients and those with intact acetabular cartilage survived longer	
Total hip resurfacing arthroplasty	Mont et al[40]	Review of THA vs hip resurfacing (30 patients in each group) with follow-up of 8 years (THA) or 7 years (hip resurfacing)	Similar success rates (90% for resurfacing, 93% for THA) and HHS scores (88 for resurfacing, 93 for THA), but more patients maintained a high level of activity with resurfacing (60%) than with THA (27%)	Recommended as salvage operation for young patients with large lesion; may allow for higher level

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Treatment	Literature	Study Design	Outcome	Recommendation
	Yu et al[41]	Retrospective review of 21 hips with follow-up of 2.7 years	HHS score increased from 35 to 90	of activity when compared with THA; long-term effect of serum metal ions remains unknown
Total hip arthroplasty	Piston et al[42]	Case series of 35 uncemented Ficat III-IV hips with follow-up of 7.5 years	All patients reported significant improvement in symptoms and returned to a high level of activity; revision rate was 6%, complication rate was 17%	Recommended as salvage operation for late-stage disease; successful despite significantly higher complication rate compared with THA for osteoarthritis
	Hartley et al[43]	Retrospective review of 55 primary uncemented THAs with follow-up of 10 years	21% required revision; of the patients who did not require revision, 93% reported little to no functional limitation after surgery, 86% reported no pain, and 80% were capable of ambulating unlimited distances	
	Fyda et al[44]	Retrospective review of 53 cemented THAs with minimum follow- up of 10 years	17.4% required revision (13% for aseptic loosening, 2.2% for recurrent dislocation, 2.2% for infection)	
	Kim et al[45]	Prospective study of 98 consecutive patients with mean follow-up of 9.3 years	No significant difference in mean HHS scores between hips managed with cemented arthroplasty (96) and hips managed with cementless implants (95); no aseptic loosening in either group, and both groups' overall revision rate was 2%; both groups had high rates of polyethylene wear and osteolysis	
	Radl et al[46,47]	Retrospective comparison of THA for osteoarthritis vs osteonecrosis with follow-up of 6 years	26% of osteonecrosis cases and 2% of osteoarthritis cases required revision; subsequent analysis found 10-year survival rates of 100% (patients without systemic disease) and 68% (subset with systemic disorders)	
	Ortiguera et al[48]	Matched-pair analysis of THA for osteoarthritis vs osteonecrosis in 188 hips with follow-up of 18 years	Revision rates were similar for osteonecrosis (18%) and osteoarthritis (19%); among patients younger than 50, those with osteonecrosis had more dislocations and need for revisions	
	Seyler et al[49]	Randomized clinical trial of 208 hips with follow-up of 7 years	Alumina-on-alumina and metal-on-polyethylene bearing surfaces performed equally in managing osteonecrosis and were comparable with management of osteoarthritis	
Total hip arthroplasty after osteotomy	Benke et al[50]	Retrospective review of 105 THAs with follow-up of 4.7 years in patients with previous osteotomy	82% of patients reported little to no pain related to hip, but 17% had operative complications, including difficulty in hardware removal and intraoperative femur fracture	Recommended as salvage operation despite increased complications
	Ferguson et al[51]	Retrospective review of 305 THAs after failed intertrochanteric osteotomy with minimum follow-up of 5 years	79% had good or excellent results; increased operative time and blood loss; 11.8% rate of perioperative complications, including difficulties in hardware removal and femoral shaft fracture; long-term evaluation of patient cohort showed, at mean follow-up of 10 years, 18% required revision, and probable loosening was evident in 19.5% of stems and 12.6% of cups, leading to cumulative probability of failure of 20.6% at 10 years	
	Breusch et al[52]	Review of 48 hips (45 patients) converted to THA with follow-up of 11 years	10-year survival of 94 and mean HHS score of 80	
	Kawasaki et al[53]	Comparison of 15 hips converted to THA after transtrochanteric rotational osteotomy and 16 matched control hips with THA for osteonecrosis	Operative time and blood loss were higher in patients with previous osteotomy, but postoperative HHS score, implant stability, and survival rates did not differ between treatment groups	
	Rijnen et al[54]	Retrospective evaluation of 22 patients who underwent THA after rotational osteotomy or core decompression and bone grafting with mean follow-up of 4 years	Significant increase in operative blood loss (from 787 mL to 1386 mL) and operative time (from 123 minutes to 161 minutes) with THA after rotational osteotomy; there was no difference in hospital stay or HHS score	

Abbreviations: HHS, Harris Hip Scale; THA, total hip arthroplasty.

randomized clinical trial support more than 92% survival at 7 years with either a metal-on-polyethylene or alumina-on-alumina bearing in the management of osteonecrosis of the hip.[49]

Prior proximal femoral osteotomy can make conversion to THA more difficult because of the added complexity of hardware removal, proximal femoral deformity leading to difficulty in prosthetic fit and fixation, and the potentially increased risk for intraoperative fracture and postoperative infection.[51-74,75] In recent years, authors of several studies have evaluated the impact of previous osteotomy on THA outcome (Table). Overall, the procedure involves significantly increased operative time and blood loss and has other perioperative complications, including femoral fractures.[50,53,54] However, THA has proved to be a procedure that can be performed successfully with good outcomes at long-term follow-up and is recommended as a salvage operation for patients with failed osteotomies.[50-53]

Horizons

Novel molecular and cellular options are being evaluated for management of osteonecrosis. Tissue-type plasminogen activator, plasminogen activator inhibitor type1, crosslaps, and anti-p53 antibody have been suggested as serum protein markers of osteonecrosis based on mass spectrometry and proteomic analysis.[76] Mesenchymal stem cells isolated and cultured from patients with osteonecrosis have the potential for both osteogenic and chondrogenic differentiation and could be used to induce healing of osteonecrotic lesions.[59,77,78] Adenoviral transduction of the vascular endothelial growth factor (VEGF), hepatocyte growth factor (HGF), and runt-related transcription factor 2 gene, *RUNX2* (formerly known as the core-binding factor α 1 gene, *CBFA1*), have been shown to lead to a significant increase in angiogenesis, bone remodeling, or osteoblastic differentiation in necrotic bone.[79-81] Similarly, compared with a control plasmid, VEGF plasmid implanted into a rabbit model of femoral head osteonecrosis demonstrated transfection of the VEGF gene, a significant increase in angiogenesis 2 to 4 weeks after transfection, and a significant increase in new bone formation at 6 to 8 weeks.[82,83] Also, bone marrow–derived stem cells expressing recombinant bone morphogenetic protein 2 resulted in femoral head regeneration in a rabbit model of femoral head osteonecrosis.[84] These early studies require clinical validation, but their potential for diagnosing and managing femoral head osteonecrosis may be significant and revolutionary.

Management of osteonecrosis remains controversial, especially for young and active patients. Clearly, early management should focus on preventing structural collapse. Improved diagnostic tools have made early disease detection possible, and many treatment modalities (operative and nonoperative) have favorably altered the natural progression of femoral head osteonecrosis. Some results have varied according to patient population, treating center, and disease stage. However, recent modifications of management techniques as well as new management strategies hold the potential to significantly improve clinical outcomes.

Authors' Disclosure Statement

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This paper will be judged for the Resident Writer's Award.