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Treatment of Osteonecrosis of the Femoral Head by Core Decompression, Bone Grafting, and Electrical Stimulation

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Abstract: Core decompression is one of the more popular procedures for the treatment of early stages of avascular necrosis (AVN) of the femoral head. However, the controversy regarding its safety and effectiveness continues. In an attempt to clarify the situation, we are reporting on a large series of cases performed by a single surgeon with long-term follow-up. This is a prospective study in which results have been evaluated using objective clinical parameters and quantitative radiographic measurements.

The classical core decompression, modified by using three decompression tracks and placing a loosely fitted cancellous graft into the larger central core, was performed on 406 hips with AVN between 1981 and 1995. Of these hips, 94 were also treated with electrical stimulation; 74 with direct current and 20 with capacitive coupling. Hips ranged from Stage I (pre-radiographic) to Stage IV (femoral head flattening without acetabular involvement). Results were determined by change in Harris hip score (HHS), extent of radiographic progression, and the need for total hip replacement (THR).

Five complications occurred after the 406 procedures: 2 fractures, both resulting from falls; 1 non-fatal pulmonary embolism; 1 femoral thrombophlebitis; and 1 pneumonia. There was a minimum 2- to 14-year follow-up on 297 of the hips. Of these, 107 (36%) required THR at a mean of 29 months. THR was performed in 26% of hips in Stage I; 34% in Stage II; 31% in Stage III (crescent sign); and 48% in Stage IV. Results were correlated with the size of the necrotic lesion. In Stages I and II THR was performed in 22%, 39%, and 40% of small (A), medium (B), and large (C) lesions, respectively. In hips not requiring THR, 39% were radiographically stable and the mean HHS improved by 10 points. No significant difference was noted in relation to etiology. No differences were noted between hips treated with or without supplemental electrical stimulation.

Core decompression with bone grafting, if carefully performed, has a very low complication rate. In cases treated before femoral head collapse, the outcome is significantly better than with symptomatic or conservative treatment. Results are correlated with both the stage of AVN and the size of the necrotic lesion.

Introduction

It is generally recognized that without specific treatment 70% to 80% of hips with clinically established avascular necrosis (AVN) will show radiologic and clinical progression. Accordingly, several prophylactic procedures have been used in the earlier stages of AVN to halt progression and encourage repair. Of these, perhaps the most frequently used to core decompression. This was described by Arlet and Ficat in 1964 [5]. By 1980 they had performed more than 800 cases [10,11]. This procedure has been used by several investigators and was popularized in the United States by Hungerford [12--14]; a complete review of the literature was recently published by Mont, Carbone, and Fairbank, 1996 [17]. Although the results reported in the literature have been somewhat variable, satisfactory clinical results are generally between two and three times greater in hips treated with core decompression than in those treated non-operatively [4,7,9--11,15--19,24,27,28].

After experiencing unsatisfactory outcomes in most of our patients treated with protected weight bearing alone before 1980, we began using a modified type of core decompression with supplemental bone grafting as our standard approach to the treatment of hips with earlier stages of AVN, which was later supplemented with electrical stimulation. By December 1995, this procedure had been performed on 406 hips, which form the basis of this report.

Materials and Methods

The technique as originally described by Arlet and Ficat [5] was modified as shown in Figure 1A.

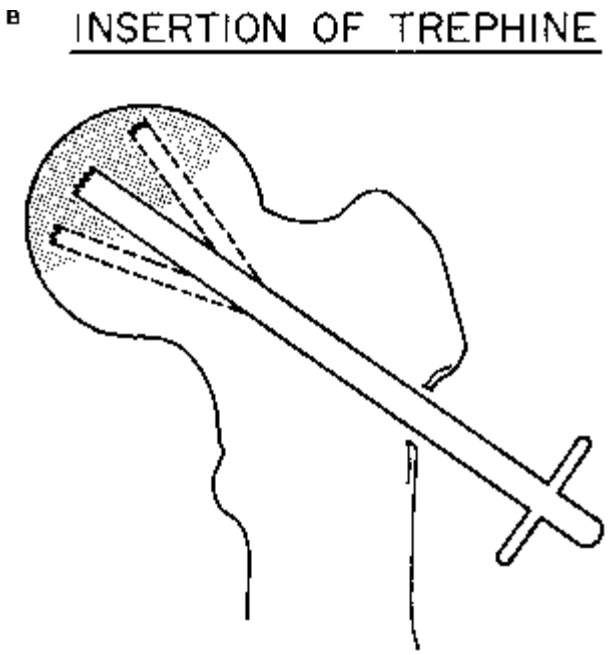

Fig. 1A. Schematic drawing of technique for performing core decompression.

Patients are placed on a fracture table with an image intensifier in place. The lateral femoral shaft is exposed through a small linear incision and a guide wire is inserted just below the flare of the greater trochanter into the center of the lesion. The cortex is opened with a conical reamer, and an 8-mm Michele trephine is inserted over the guide wire, which is taken to within 5 mm of the articular surface. Care must be taken to not perforate the joint. It is usually necessary to remove this core of bone in several sections as the material becomes impacted into the trephine. The bone taken from the intertrochanteric region is essentially normal. This is put aside to be used later for the graft. Tissue removed from the necrotic area is sent for histologic examination. Through the same opening in the cortex two smaller channels are made into the lesion using 6-mm or 5-mm Michele trephines. After it has been ascertained that the central core is patent to within 5 mm of the articular surface, the cancellous graft is thinned with a rongeur and then placed very loosely into the lesion (Figure 1B).

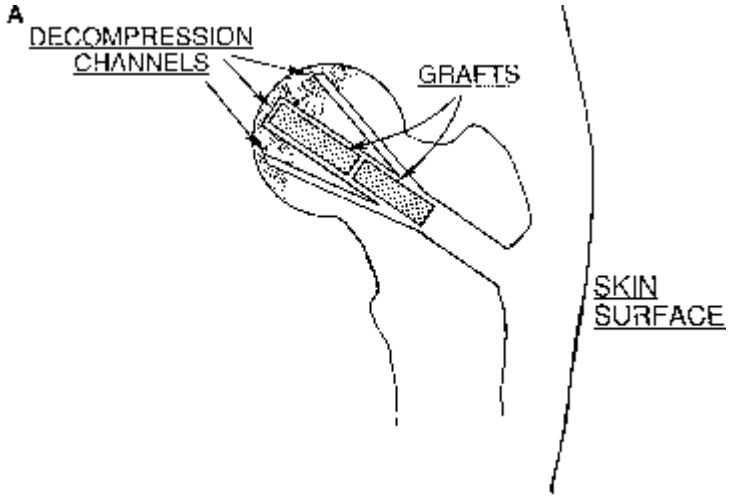

Fig. 1B. Schematic drawing of decompression channels showing central bone grafts in place.

The two smaller decompression channels are left open, and additional cancellous bone is placed at the cortical margin of the femur to promote healing of the surgical defect.

Patients are allowed partial weight bearing for three months using crutches. They are then allowed to walk without assistance but are urged to avoid undue stress to the hip for one year. They receive follow-up examinations every three months for the first year, every six months for the next, and yearly thereafter.

Immediately before surgery patients are evaluated clinically by the use of a Harris hip evaluation scale (HHS). Good quality anteroposterior (AP) and lateral X-rays are obtained. Magnetic resonance images (MRIs) are used to evaluate pre-radiographic lesions.

Post-operatively patients are evaluated by the HHS and by AP and lateral radiograms taken at 3, 6, 12, 18, and 24 months post-operatively, and either yearly or every two years thereafter. Early and late post-operative complications are noted. For those hips which require further surgery, the type of surgery and the interval between decompression and grafting and later reconstruction is noted. In virtually all cases in this series, hips which failed to respond to the primary procedure were treated with total hip replacement (THR) arthroplasty when clinically indicated.

Two groups of patients were treated with electrical stimulation in addition to the core decompression and grafting. One group of 74 hips received constant direct current (DC) stimulation to the necrotic segment by means of a cathode wire coiled about the graft and attached to an Osteostem® (Telectronics, Englewood, Colorado) or an Orthofuse® (DePuy, Warsaw, Indiana) [19--21]. A second group of 20 hips was treated with capacitive coupling (CC) by means of surface electrodes applied anteriorly and posteriorly to the skin directly over the femoral head and connected to a portable power unit [19,21,22].

In addition, we reviewed studies by Aaron [1--3], Bassett [6], Eftekhar [8], and others who used pulsing electromagnetic fields (PEMFs) to treat osteonecrosis without surgical intervention, although we did not use this technique ourselves.

Between July 1980 and December 1995, 406 hips in 285 patients with AVN were treated with core decompression and bone grafting. The entire group was evaluated to determine the incidence of post-operative complications. In 226 patients, 324 hips operated on before July 1992 were evaluated to determine the effectiveness of this procedure, because these had a minimum two-year follow-up. Of this group, five patients died and 16 could not be located for a two-year follow-up. These were excluded, leaving 297 hips in 205 patients as our primary study group. These were compared with 55 hips treated at our institution before 1980 by protected weight bearing alone and with published reports of other series.

Results

Patients ranged in age from 19 to 65 for a mean of 37 years, 166 (56%) were female and 131 (44%) were male. The follow-up time for the entire group was between one and 156 months with a mean of 46 months. This included patients who died or came to THR before the minimum two-year follow-up for inclusion in the study. The mean follow-up for patients not requiring THR was 62 months.

Etiologic factors were as follows: steroid 38%, alcohol 37%, both alcohol and steroid 15%, trauma 12%, idiopathic 10%. Hips were placed in the following stages according to the University of Pennsylvania system for staging [27,28]: Stage I, 62 hips (21%); Stage II, 133 hips (45%); Stage III, 13 hips (4%); Stage IV, 85 hips (29%); Stage V, 4 hips (1%).

Results in the entire group of 406 hips were initially evaluated regarding both the immediate post-operative and longer term complications. Outcome was evaluated only in the 297 hips with a minimum two-year follow-up. This was determined by the number of hips in each group which required THR arthroplasty, the clinical status as determined by a change in the HHS from the pre-operative to the most recent post-operative evaluation, and the change in the radiographic stage and extent of involvement as determined by the University of Pennsylvania system for evaluation and staging [25,26].

Complications

Of 406 hips which had undergone decompression and grafting, there were five complications: one pneumonia, one proximal femoral thrombophlebitis, one massive but non-fatal pulmonary embolism, and two fractures sustained in falls during the first month after surgery. One of these was a subcapital fracture and the other was an intertrochanteric fracture going through the hole in the lateral cortex. This is a much lower incidence of complications than some have encountered [7] but does not differ significantly from most reports.

Results of electrical stimulation

DC, CC, and PEMFs were evaluated separately and compared with decompression and grafting alone.

Direct current

On radiographic evaluation, hips treated with DC had a 70% incidence of progression with the mean progression being two-thirds of a stage. Control hips had a 79% incidence of progression with a mean change of one and one-third stages. Clinically, the electrically stimulated hips showed a mean improvement of five points on the HHS, with 64% of hips improved or

unchanged. Several control hips (43%) were either improved or unchanged, but the mean HHS dropped three points. Initially, 25% of hips treated with DC required THR as compared with 43% of hips treated without stimulation. However, on final evaluation, 41% of hips treated with DC required THR compared with 37% of hips with decompression and grafting alone. Thus, the addition of DC did not alter the final outcome.

Capacitive coupling

Clinically and radiographically 42% of the stimulated hips and 50% of the non-stimulated hips were either improved or unchanged. THR arthroplasty was performed on 25% of the stimulated hips and 20% of the nonstimulated hips. Thus, we could detect no effect of CC in this model.

Outcome

Because there were no differences between hips treated with DC or CC and those treated with decompression and grafting alone, these groups were combined for subsequent analysis of data. Outcome was determined by the clinical course, radiographic evaluation, and the incidence of THR. Correlation was made with stage, lesion size, and etiology.

Clinical evaluation

Hips were evaluated clinically by determining the change in the HHS from the pre-operative to the last post-operative visit. As anticipated, there was a significant difference between those hips which eventually requiring THR and those which did not. In hips requiring THR we found a mean pre-operative HHS of 63 (range, 25 to 100), and a mean post-operative score of 24 (range, 15 to 56). Thus, these hips lost 39 points. In hips not requiring THR, the mean pre-operative score was 74 (range, 32 to 100), the post-operative mean was 84 (range, 24 through 100), with a mean improvement of 10 points.

Radiologic evaluation

For radiographic evaluation we used a quantitative system of evaluation and staging developed at the University of Pennsylvania [25,26]. In simple terms, stages are defined as follows:

- Stage I. Preradiographic--diagnosis made on the basis of MRI and/or technetium scans.
- Stage II. Cystic and sclerotic changes on X-ray without evidence of collapse.
- Stage III. Crescent sign indicating subchondral collapse without loss of normal femoral head contour.
- Stage IV. Flattening of femoral head without radiographic involvement

of acetabulum.
- Stage V. Joint line narrowing and/or acetabular involvement.
- Stage VI. Advanced degenerative changes.

The *size* of the necrotic lesion is also indicated for Stage II through V as:

- A--Small (<15% involvement),
- B--Intermediate (15--30%),
- C--Large (>30%).

The majority of hips requiring THR showed radiographic progression. The mean stage pre-operatively was IIC (range, IA--VB) and progressed to a mean before THR of IVC (range, IIA--VC). In hips not requiring THR, the mean stage pre-operatively was IIB (range, IA--VC), with a mean post-operatively being IIC (range, IA--VI). 39% had no radiographic progression as compared with only 19% of non-operated controls. Hips requiring THR thus progressed two full stages, whereas those that did not require THR progressed only one-third of a stage.

Total hip replacement

Although many factors determined if and when THR is required, this serves as an important and perhaps unambiguous measure of outcome. The need for THR was, therefore, correlated with etiologic factors, stage, and lesion size.

THR was required in 107 of 297 hips, for an incidence of 36%. In our non-operative controls treated by protected weight bearing alone, 77% required THR. Of the 107 decompressed and grafted hips which required THR, 58% were replaced within two years after the initial procedure; 30% between two and five years; and 12% after five years.

Etiologic factors

THR was required in 41% of patients with alcohol-related avascular necrosis, 38% of those on corticosteroids, 46% of those in whom both steroids and alcohol were involved, 35% of post-traumatic AVN, and 33% of idiopathic AVN. The outcome for patients in whom both alcohol and steroids were implicated seemed somewhat worse than in the other groups, but none of these differences was statistically significant.

Relationship of stage to outcome

As anticipated, the outcome was generally worse in the more advanced stages of AVN. The results as determined by clinical course, radiographic progression, and need for THR were similar. The correlation between stage and THR is shown graphically in Figure 2.

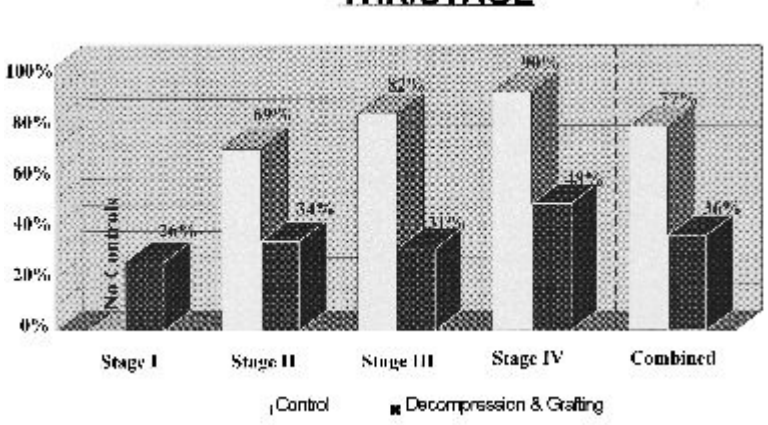

Fig. 2. Graph showing percentage of hips requiring total hip replacement arthroplasty by stage of AVN for both control and decompression and grafted hips.

The results of decompression and grafting are compared with 55 hips treated at our institution by protected weight bearing before 1980. (It should be noted that we are not indicating results for Stage I in these nonoperated hips because there were too few hips in this category for a valid comparison. Technetium scans were being used to evaluate hips with AVN at this time, because we did not begin the use of MRI until 1982.)

In virtually each stage, non-operative management led to twice the number of hips requiring THR as decompression and grafting. The outcome appeared even more striking when evaluated in terms of femoral head survival. The survivorship of femoral heads treated with decompression and grafting was essentially three times that of hips treated by limited weight bearing for the group as a whole, and for each stage. The mean follow-up time of hips treated conservatively was only 21 months as compared with a mean of 46 months for hips undergoing decompression and grafting. The results in Stage III showed hips with subchondral collapse that appear much closer to those in Stage II than in Stage IV. This group is quite small, however, and the difference between Stage III and Stage IV is not statistically significant. It is of interest that even after a certain amount of femoral head collapse, the outcome could be improved significantly by core decompression as compared with non-operative management. Although a large number of Stage IV hips were included, these were generally limited to hips with only a relatively small amount of collapse, and with minimal pain or disability.

Relationship of lesion size to outcome

Core decompression and other prophylactic techniques are of most value in the early stages of AVN before collapse has occurred. In this group we found a close correlation between lesion size and outcome.

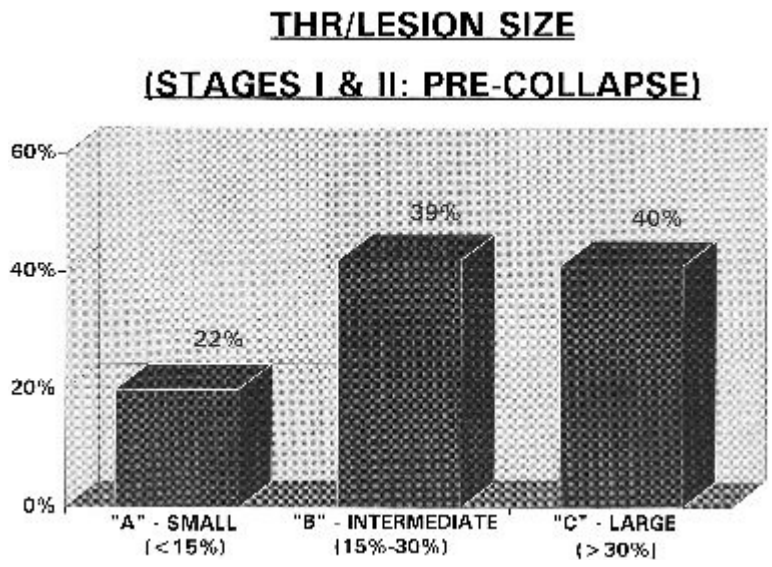

Fig. 3. Graph showing relationship between total hip replacement and size of the necrotic lesion for hips in Stages I and II, before femoral head collapse.

Figure 3 shows the results in hips with small A, intermediate B, and large C lesions in Stages I and II, before subchondral collapse. Hips with small lesions had a significantly better outcome than hips with intermediate or large lesions, but there was essentially no difference between these two groups.

The number of hips in Stage III was too few to be broken down by lesion size. In Stage IV, hips with advanced degrees of collapse or significant symptoms were generally not treated by this technique, and therefore it was not possible to evaluate the outcome based on lesion size.

Summary and Conclusions

If untreated, approximately 70% to 80% of hips with clinically established AVN show progression and most of these eventually require replacement arthroplasty. Accordingly, some method of prophylactic management is indicated in hips diagnosed in the earlier stages of AVN. Of the various treatment options, one of the more popular is core decompression. We have reported on 406 hips treated with a modified core decompression and supplemental cancellous bone grafting. Some also received electrical stimulation. Although we have personally had no experience with PEMFs in AVN, we felt that it would be of interest to make brief mention of this technique based on reports in the literature [2--4,6,8]. In contrast to the two types of electrical stimulation described earlier, this technique produces an electrical and a magnetic field in the area of bone being stimulated by the use of an externally applied coil. Few investigators have reported promising results using this technique in the treatment of AVN without operative intervention. Aaron [1] recently reported on 633 patients treated with PEMFs and observed for thirty-six months. These were compared with hips treated with core decompression and those on protected weight bearing. In Ficat I and II hips, the results of PEMF and core decompression were essentially equal, and both were superior to protected weight bearing. In

Stage III the results with PEMF were significantly better than either core decompression or protected weight bearing. The survival of the femoral heads in these three groups was 53%, 27%, and 10%, respectively.

Unfortunately, this device has not been released for general use in the United States by the Food and Drug Administration and further trials have been postponed. These results by a few investigators are certainly promising and should be kept in mind.

Our data demonstrate that core decompression and grafting is quite safe with an extremely low complication rate including only two transcervical fractures, both resulting from post-operative falls. Although by no means a panacea, the procedure appears to be effective as compared with protected weight bearing alone. For the entire series only 36% of treated hips required THR arthroplasty, as compared with 77% of controls. Viewed in terms of survivorship, this meant that in 64% of operated hips the femoral head was preserved, as compared with only 23% of controls. As expected, the results were better in hips with earlier stage lesions and in hips in which the area of necrosis was small. Neither DC nor CC improved the eventual outcome. PEMFs, as reported by other investigators, may be a promising technique which deserves further evaluation.

All hips treated here had both a decompression and cancellous grafting. No attempt was made to compare the results of core decompression with and without grafting. Our results, however, are similar to those reported by most other investigators regarding non-operative management and core decompression alone.

Core decompression with or without bone grafting is a simple, safe, and relatively effective method for treating early stages of AVN. Other methods of treatment are available, but most of these are more complicated and have a higher potential incidence of complications. Only if these are definitely shown to be more effective, would we advocate using these techniques rather than the technique described here. At this time, core decompression with bone grafting remains our standard approach to hips with early stages of AVN in most patients we encounter.

References

1. Aaron R, Abbott J: Osteonecrosis of the femoral head. SICOT, Amsterdam, Poster Session. August 1996.
2. Aaron RK, Lennox D, Bunce GE, et al: The conservative treatment of osteonecrosis of the femoral head: A comparison of core decompression and pulsing electromagnetic fields. *Clin Orthop* 249:209--218, 1989.
3. Aaron RK, Steinberg ME: Electrical stimulation of osteonecrosis of the femoral head. *Semin Arthroplasty* 3:214--221, 1991.
4. Abbott J: Avascular Necrosis of the Femoral Head: A Literature Review of Treatment Outcomes of PEMF, Core Decompression, and Non-Surgical Management. Hackensack, NJ, ElectroBiology, 1--49: March 1988.
5. Arlet J, Ficat RP: Forage-biopsie de la tete femorale dans l'osteonecrose primative. Observations histo-pathologiques portant sur

huit foranes. *Rev Rhum* 31:257--264, 1964.
6. Bassett C, Schink-Ascani M, Lewis S: Effects of pulsed electromagnetic fields on Steinberg ratings of femoral head osteonecrosis. *Clin Orthop* 246:172--185, 1989.
7. Camp JF, Colwell CW: Core decompression of the femoral head for osteonecrosis. *J Bone Jt Surg* 68:1313--1319, 1986.
8. Eftekhar N, Schink-Ascani M, Mitchell S, et al: Osteonecrosis of the femoral head treated with pulsed electromagnetic fields (PEMF). A preliminary report. In: Hungerford, D. (ed). *The Hip.* St. Louis, MO, Mosby, 306--330, 1983.
9. Fairbank AC, Bahtia D, Jinnah RH, Hungerford DS: Long-term results of core decompression for ischemic necrosis of the femoral head. *J Bone Jt Surg* 77-B:42--49, 1995.
10. Ficat RP: Idiopathic bone necrosis of the femoral head. *J Bone Jt Surg* 67B:3--9, 1985.
11. Ficat RP, Arlet J: Treatment of bone ischemia and necrosis. In: Hungerford DS (ed). *Ischemia and Necrosis of Bone.* Baltimore, Williams & Wilkins, 171--182, 1980.
12. Hungerford DS: Bone marrow pressure, venography, and core decompression in ischemic necrosis of the femoral head. In: Sledge CB (ed). *The Hip: Proceedings of the Seventh Open Scientific Meeting of The Hip Society.* St. Louis, C. V. Mosby, 218--237, 1979.
13. Hungerford DS: Core decompression for the treatment of avascular necrosis of the femoral head. *Semin Arthroplasty* 2:182--188, 1991.
14. Hungerford DS: The role of core decompression in the treatment of osteonecrosis. *AOA Symp Osteonecrosis* in press.
15. Kiaer T: Osteonecrosis profusion in core decompression. *AOA Symp Osteonecrosis* in press.
16. Markel DC, Miskovsky C, Sculco TP, Pellicci PM, Salvati EA: Core decompression for osteonecrosis of the femoral head. *Clin Orthop* 323:226--233, 1996.
17. Mont MA, Carbone JJ, Fairbank AC: Core decompression versus nonoperative management for osteonecrosis of the hip. *Clin Orthop* 324:169--178, 1996.
18. Mont MA, Hungerford DS: Current concepts review non-traumatic avascular necrosis of the femoral head. *J Bone Jt Surg* 77-A:459--474, 1995.
19. Robinson JJ, Springer JA: Success of core decompression in the management of early stages of avascular necrosis: A four-year prospective study. *Orthop Trans* 16:707, 1992--1993.
20. Steinberg ME: Core decompression of the femoral head for avascular necrosis: Indications and results. *Can J Surg* 38(Suppl 1):518--524, 1995.
21. Steinberg ME: Effects of electric and electromagnetic fields on bone formation, bone circulation and avascular necrosis. In: *Bone Circulation and Vascularization in Normal and Pathological Conditions.* Schoutens A, et al (ed). New York, Plenum Press, 1993.
22. Steinberg ME, Brighton CT, Bands RE, Hartman K: Capacitive coupling as an adjunctive treatment for avascular necrosis. *Clin Orthop* 261:11--18, 1990.
23. Steinberg ME, Brighton CT, Corces A, et al: Osteonecrosis of the femoral head: Results of core decompression and grafting with and

without electrical stimulation. *Clin Orthop* 249:199--208, 1989.
24. Steinberg ME, Hayken GD, Steinberg DR: The "conservative" management of avascular necrosis of the femoral head. In: Arlet J, Ficat RP, Hungerford DS (eds). *Bone Circulation.* Baltimore, Williams & Wilkins, 334--337, 1984.
25. Steinberg ME, Hayken GD, Steinberg DR: A quantitative system for staging avascular necrosis. *J Bone Jt Surg* 77-B:34--41, 1995.
26. Steinberg ME, Steinberg DR: Evaluation and staging of avascular necrosis. *Semin Arthroplasty* 2:175--181, 1991.
27. Stulberg BN, Bauer TW, Belhobek GH: Making core decompression work. *Clin Orthop* 261:186--195, 1990.
28. Warner JJ, Phillips JH, Brodsky GL, et al: Studies of nontraumatic osteonecrosis: The role of core decompression in the treatment of nontraumatic osteonecrosis of the femoral head. *Clin Orthop* 225:104--127, 1987.