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MINI-REVIEW

Osteonecrosis of the femoral head: Surgical perspective

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Summary Osteonecrosis of the femoral head (ONFH) has had a great socioeconomic impact on Asian populations. The etiology of the disease is not fully understood. Corticosteroid use is the most firmly established risk factor. Recent studies have pointed out the genetic basis of nontraumatic ONFH. The common fate of various contributing factors is microcirculation disturbance. In general, the treatment for early-stage ONFH is core decompression surgery with adjuvant measures such as various types of bone grafts. Hip replacement, either hemiarthroplasty or total hip replacement, can lead to good results. Recent studies have shed some light on non-operative treatments for early-stage disease, although long-term results are still lacking. The modes of treatment include shock wave therapy and oral administration of bisphosphonate, vitamin E, and vitamin K2. Advances in tissue engineering may make biological joint replacement possible in the near future.

1. Introduction

Osteonecrosis of the femoral head (ONFH) is a pathologic condition of the hip joint that was previously referred to as avascular necrosis (AVN). Disruption of the blood supply to the femoral head is commonly believed to cause bone necrosis and further hip joint destruction. As early as 1738, Munro first described a case of ONFH. Over 200 years later, Mankin reported on a series of 27 cases and named the disease AVN.[1] This brought the disease to the attention of orthopedic specialists and the literature on ONFH has been increasing since.

The socioeconomic impact of ONFH on society cannot be overemphasized. In the USA, ONFH accounts for 5–18% of total hip replacement (THR) surgeries annually.[2] Among the Asian population, ONFH plays a much more important role.

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In Taiwan, 46.3% of all THR surgeries are for ONFH.[3] The literature shows a high prevalence of the disease in Japan and Korea[4,5] compared to Caucasian populations. A case series of 647 hips in Hong Kong revealed that ONFH accounted for 45.6% of all hip replacements.[6] These data indicate that the disease is more prevalent in Asia and hence has been studied more thoroughly by Asian scientists and surgeons.

2. Etiology

Despite the general belief that ONFH stems from insufficient blood supply to the femoral head, the reason for such circulation disruption remains to be explored. ONFH can be categorized into three groups: trauma-associated ONFH, in which vessels supplying the femur head are torn during a traumatic event[7,8]; ONFH associated with known risk factors; and idiopathic ONFH. Known risk factors for ONFH include corticosteroid use, alcohol abuse, and coagulopathies such as Gaucher's disease, renal failure, and protein C/protein S deficiency. Corticosteroid use is ranked top for all possible etiologies. Approximately 5–25% of those who received intensive corticosteroid therapy (over 1 month) could develop ONFH.[9,10]

Numerous articles in the literature have revealed that many cases previously thought to be idiopathic ONFH were in fact related to genetic traits. Miyamoto et al reported that a recurrent mutation in the type II collagen gene caused pediatric ONFH (Legg–Calve–Perthes disease) in a Japanese family.[11] Liu et al discovered the gene responsible for hereditary primary ONFH in Taiwan.[12] Glueck et al[13] and Jones et al[14] also reported that heritable thrombophilia or hypofibrinolysis is often present in Western countries.

Regardless of the proposed etiology, current evidence tends to support the hypothesis that the common prelude to ONFH is microvascular thrombosis (Figure 1). Long-term intensive corticosteroid therapy or alcohol abuse can lead to the formation of fat emboli. Mutations in various genes, such as hypoxia-inducible factor 1-alpha,[15] NO synthase,[16] and factor V Leiden,[17] lead to microvascular disturbance.

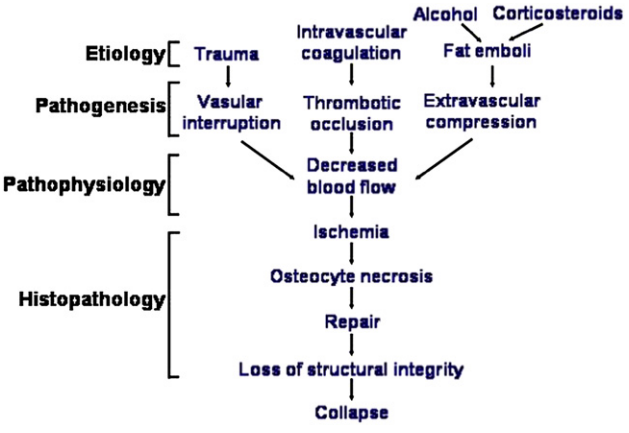

Figure 1 Etiology of osteonecrosis of the femoral head. The common pathway involves disruption of the microvascular circulation and subsequent ischemia at the femoral head.

According to these new findings, it is now more likely that ONFH is a common consequence of various disease entities.

3. Disease staging and diagnosis

The most popular staging system for ONFH is the Ficat system.[18] In Stage I disease, the patient has ONFH but plain radiographs show no abnormality. Stage II disease involves an osteonecrotic lesion with either higher radio-opaque density or a cystic appearance. The shape of the femoral head remains intact without collapse. When the disease progresses further to Stage III, there is osteochondral fracture of the femoral head which leads to the typical crescent appearance on plain radiographs. In Stage IV disease, there are secondary osteoarthritic changes in both the femoral head and the acetabulum. Many other staging or classification systems exist, but most of those are modifications of the original Ficat system.

The strategy for ONFH diagnosis is much the same as for other orthopedic pathologies. These include taking the patient's medical and family history, a physical examination, and subsequent imaging studies as indicated. A differential diagnosis is warranted if the patient has a medical history of corticosteroid therapy, alcohol abuse, or a family history of ONFH. As the disease progresses, the patient may present with a limping gait due to severe pain in the hip joint. A Patrick test should reveal positive signs (i.e., pain in the groin area). Plain radiographs remain the first-line screening tool. If these show no bone abnormality but ONFH is highly suspected, magnetic resonance imaging (MRI) is indicated. It has been demonstrated that MRI is the most sensitive and specific imaging modality for diagnosis of Stage I ONFH.[19] Scintigraphy is less sensitive and specific in detecting early-stage disease. Currently, scintigraphy can be performed on high-risk patients to delineate multifocal lesions in addition to femoral head lesions.

4. Non-surgical treatment

Over the past decades, efforts to search for non-surgical cures for ONFH have been ceaseless. Although a few reports have proposed the possibility of spontaneous resolution of early stage ONFH, current evidence indicates that without proper treatment, early-stage disease will inevitably progress to femoral head collapse in most cases.[20]

Lai et al[21] and Agarwala et al[22] reported possible benefits of bisphosphonates. In the study by Lai et al, only two of 29 femoral heads collapsed in the patients treated with alendronate, while 19 of 25 femoral heads collapsed in those without alendronate use. In an animal model, vitamin E was proposed to potentially prevent steroid-induced osteonecrosis due to its anticoagulant nature.[23] It has been reported that certain Chinese drugs enhance angiogenesis through *VEGF* gene transfer.[24] Wang et al compared two groups of patients with Stage I, II or III disease treated with extracorporeal shock waves or core decompression with nonvascularized bone grafting. The short-term follow-up results showed a better Harris hip score, pain relief and lesion regression in patients with early-stage disease in the shock wave group.[25] Ludwig et al[26] and Alves et al[27] also reported that high-energy shockwaves were beneficial.

Nevertheless, these non-surgical measures can only be used for cases in the early stage or the precollapse stage. Definitive results for long-term follow-up are still unavailable.

5. Surgical treatment

5.1. Early stage (Stages I and II)

For early-stage disease, core decompression is the mainstay of surgical treatment. After drilling a tunnel into the target part in the femoral head, the necrotic bone is removed and the circulation is rebuilt. Based on an animal model, Wang et al reported that core decompression may normalize femoral head circulation that has been compromised by methylprednisolone use.[28] In 1996, Mont et al reported good results compared with nonsurgical treatment for early-stage disease,[29] and in 2006 further confirmed the value of such a procedure after reviewing studies by other authors.[30] In the 1980s, core decompression was questioned as a dangerous and ineffective procedure.[31] A large amount of clinical evidence has since pointed to its safety and effectiveness, and there is now a consensus on this treatment for early-stage ONFH in developed countries.

In addition to simple decompression of the femoral head, a number of adjuvant measures can enhance bone healing. These include stem cell or bone morphogenic protein (BMP) injection,[32] tantalum rod insertion,[33] bone cement filling and bone grafting. The use of a tantalum rod may strengthen the mechanical structure of the head, but it may become troublesome in subsequent hip replacement. Stem cells and BMPs provide two key components of tissue engineering, but the critical third component—a scaffold to assure efficacy—is lacking. In 2009, a report from France claimed that cementing the femoral head leads to early pain relief,[34] but no similar results have yet been widely reproduced by others.

Bone grafting may be the most popular adjuvant at present. Autogenous bone grafts, including vascularized or nonvascularized, cancellous or strut (fibula), have all been reported, with various results.[35] In 2009, Chen et al proposed an autogenous bone grafting technique.[36] In this approach, the same small surgical incision as for core decompression is made and cancellous bone is taken from the trochanteric area along the drilling tract and then impactedinto the target site (Figure 2). The series showed better results compared with core decompression alone.

Sugioka's osteotomy, a rotational osteotomy of the proximal femur, is based on "turning" the good side of the head to take the burden of weight bearing.[37,38] In 2009, Atsumi et al reported a modified procedure of the original osteotomy with a high degree rotation to improve the clinical result.[39] Studies carried out by European and American surgeons, however, all revealed an inferior outcome. The divergence in outcomes between Japanese and Western series remains to be investigated.

5.2. Late stage (Stages III and IV)

The consensus on treatment for Stage IV ONFH is THR. For Stage III disease, the trend is also moving toward THR in most developed countries. However, many still believe that bipolar hemiarthroplasty plays a role.

5.2.1. Total hip arthroplasty

The current hot issue concerning THR is the bearing system.[40] Metal on polyethylene (PE) was the first widely accepted bearing surface to provide reliable longevity. Ceramic-on-ceramic systems have been used largely for young active patients owing to their low wear rates. With advances in modern materials engineering, new metal-on-metal surfaces with low wear rates and minimal osteolysis problems are expected in the future. At present, alternative bearing couples including ceramic on highly crosslinked PE and the above-mentioned bearings are gaining in popularity because the mean age of ONFH patients receiving THR is less than that of patients with primary osteoarthritis.[41]

Some have questioned the longevity of THR in ONFH patients. In a retrospective comparative study by Lee,[42] 12,466 THRs (ONFH group) and 18,515 THRs (primary osteoarthritis) showed a comparable 8-year survival rate, which was over 98% in both groups.

5.2.2. Bipolar hemiarthroplasty

The success rate for bipolar hemiarthroplasty in ONFH patients is variable. Amstutz et al,[43] Grevitt and Spencer[44] and Chan and Shih[45] reported satisfactory outcomes. They also emphasized the advantage compared to THR: hemiarthroplasty preserves more bone stock for young patients with a healthy acetabulum. Conversely, those against hemiarthroplasty argue that the procedure is associated

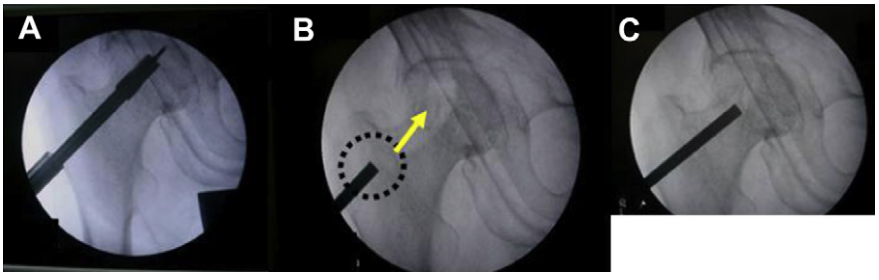

Figure 2 (A) Autogenous bone grafting technique proposed by Chen et al. Core decompression was carried out. (B) The autogenous bone grafting material was harvested from the trochanteric area using the same surgical wound. (C)The harvested material was then impacted into the lesion site.

with high acetabulum degeneration rates and protrusion problems.[46,47] In a series reviewed by Lee, the 8-year survival rate for 7407 bipolar hemiarthroplasties was not different from that for 12,466 THRs with a revision for any reason as the primary end point.[47] While it seems that most reports in the Western literature advocate THR for ONFH patients, the large series in Taiwan provides a reminder that bipolar hemiarthroplasty remains an option (Figure 3).

5.2.3. Other procedures

In 2003, Adili and Trousdale from the Mayo Clinic published results on resurfacing hemiarthroplasty for ONFH.[48] The procedure was designed as a time-buying surgery for bone stock preservation in young active patients. The survival rate at 3 years was 75.9% in their series. Sharma and Cheng reported a 4-year survival rate of 72.6% in 2007.[49] The indications for such a procedure are limited. The patient should be young, generally less than 30 years of age. The size of the femur should be large enough to support the implant. The effect of pain relief is unpredictable. Finally, the patient should fully understand that revision to THR is nearly inevitable.

6. Future prospects

Advances in basic research have brought hope for ONFH treatment. If technically possible, intervention can be made before the disease attacks. This may be achieved by avoiding risk factors for those with genetic problems, and modification of genes or translated proteins. The 1990s was the era heralding gene therapy, and now we are in the 21st century, the so-called age of regenerative medicine. Since gene manipulation has not yielded great success, regenerative medicine is emerging as the future hope for ONFH patients. A great deal of such research is under way. Tissue engineering of cartilage or bone could be used for biological reconstruction of destroyed joint structures.[50] There is still a long way to go before clinical application, yet the dream of biological joint replacement may be realized sooner than expected.

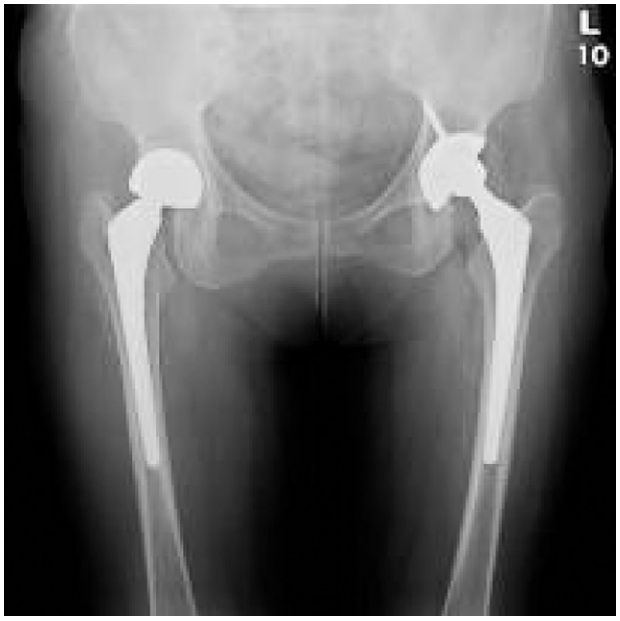

Figure 3 Plain radiograph of an ONFH patient who had left THR and right hemiarthroplasty. After 11 years, both implants were still surviving well and showing a comparable functional outcome.

7. Summary

ONFH has had a tremendous socioeconomic impact on the population of Taiwan and is the reason for nearly half of THR operations carried out annually. MRI is the best modality in detection of early-stage disease. A surgical approach remains the mainstay of treatment. For early-stage disease, core decompression may save the femoral head by rebuilding its microcirculation. Adjuvant procedures such as autogenous bone grafting improve the success rate. For late-stage disease, THR is the treatment of choice. Currently, alternative bearing couples are increasing in popularity because patients with ONFH are generally younger than those with other diseases. For those with an intact acetabulum, bipolar hemiarthroplasty may lead to comparable results. Studies since the 1990s have shed light on ONFH etiology. Various gene mutations have been identified as the cause of microvascular thrombosis. The trend is moving towards regenerative medicine. With advances in tissue engineering, biological joint arthroplasty may be feasible in the near future.

References

1. Mankin HJ. Nontraumatic necrosis of bone (osteonecrosis). *N Engl J Med*. 1992;326:1473—1479.
2. Vail TP, Covington DB. The incidence of osteonecrosis. In: Urbaniak JR, Jones Jr JP, editors. *Osteonecrosis: etiology, diagnosis, treatment*. Rosemont, IL: American Academy of Orthopedic Surgeons; 1997. p. III.43—III.49.
3. Lai YS, Wei HW, Cheng CK. Incidence of hip replacement among national health insurance enrollees in Taiwan. *J Orthop Surg Res*. 2008;3:42.
4. Fukushima W, Fujioka M, Kubo T, Tamakoshi A, Nagai M, Hirota Y. Nationwide epidemiologic survey of idiopathic osteonecrosis of the femoral head. *Clin Orthop Relat Res*. 2010;468:2715—2724.
5. Kang JS, Park S, Song JH, Jung YY, Cho MR, Rhyu KH. Prevalence of osteonecrosis of the femoral head: a nationwide epidemiologic analysis in Korea. *J Arthroplasty*. 2009;24:1178—1183.
6. Tang WM, Chiu KY. Avascular necrosis of femoral head: a short review. *APLAR J Rheumatol*. 2006;9:98—101.
7. Shih LY, Chen TH, Lo WH. Avascular necrosis of the femoral head—an unusual complication of an intertrochanteric fracture. *J Orthop Trauma*. 1992;6:382—385.
8. Chen CM, Chiu FY, Lo WH. Avascular necrosis of femoral head after gamma-nailing for unstable intertrochanteric fractures. *Arch Orthop Trauma Surg*. 2001;121:505—507.
9. Koo KH, Kim R, Kim YS, et al. Risk period for developing osteonecrosis of the femoral head in patients on steroid treatment. *Clin Rheumatol*. 2002;21:299—303.
10. Mont MA, Hungerford DS. Non-traumatic avascular necrosis of the femoral head. *J Bone Joint Surg Am*. 1995;77:459—474.
11. Miyamoto Y, Matsuda T, Kitoh H, et al. A recurrent mutation in type II collagen gene causes Legg—Calvé—Perthes disease in a Japanese family. *Hum Genet*. 2007;121:625—629.

12. Liu YF, Chen WM, Lin YF, et al. Type II collagen gene variants and inherited osteonecrosis of the femoral head. *N Engl J Med*. 2005;352:2294—2301.
13. Glueck CJ, Freiberg RA, Fontaine RN, Tracy T, Wang P. Hypofibrinolysis, thrombophilia, osteonecrosis. *Clin Orthop Relat Res*. 2001;386:19—33.
14. Jones LC, Mont MA, Le TB, et al. Procoagulants and osteonecrosis. *J Rheumatol*. 2003;30:783—791.
15. Hong JM, Kim TH, Chae SC, et al. Association study of hypoxia inducible factor 1alpha (HIF1alpha) with osteonecrosis of femoral head in a Korean population. *Osteoarthritis Cartilage*. 2007;15:688—694.
16. Koo KH, Lee JS, Lee YJ, Kim KJ, Yoo JJ, Kim HJ. Endothelial nitric oxide synthase gene polymorphisms in patients with nontraumatic femoral head osteonecrosis. *J Orthop Res*. 2006; 24:1722—1728.
17. Björkman A, Svensson PJ, Hillarp A, Burtscher IM, Rünow A, Benoni G, Factor V. Leiden and prothrombin gene mutation: risk factors for osteonecrosis of the femoral head in adults. *Clin Orthop Relat Res*. 2004;425:168—172.
18. Arlet J, Ficat P. Non-traumatic avascular femur head necrosis. New methods of examination and new concepts. *Chir Narzadow Ruchu Ortop Pol*. 1977;42:269—276.
19. Steinbery ME. Diagnostic imaging and the role of stage and lesion size in determining outcome in osteonecrosis of the femoral head. *Tech Orthop*. 2001;16:6—15.
20. Hernigou P, Poignard A, Nogier A, Manicom O. Fate of very small asymptomatic stage-I osteonecrotic lesions of the hip. *J Bone Joint Surg Am*. 2004;86-A:2589—2593.
21. Lai KA, Shen WJ, Yang CY, Shao CJ, Hsu JT, Lin RM. The use of alendronate to prevent early collapse of the femoral head in patients with nontraumatic osteonecrosis. A randomized clinical study. *J Bone Joint Surg Am*. 2005;87:2155—2159.
22. Agarwala S, Shah S, Joshi VR. The use of alendronate in the treatment of avascular necrosis of the femoral head: follow-up to eight years. *J Bone Joint Surg Br*. 2009;91:1013—1018.
23. Kuribayashi M, Fujioka M, Takahashi KA, et al. Vitamin E prevents steroid-induced osteonecrosis in rabbits. *Acta Orthop*. 2010;81:154—160.
24. Li JH, Wu YL, Ye JH, et al. Effects of blood-activating and stasis-removing drugs combined with VEGF gene transfer on angiogenesis in ischemic necrosis of the femoral head. *J Tradit Chin Med*. 2009;29:216—219.
25. Wang CJ, Wang FS, Huang CC, Yang KD, Weng LH, Huang HY. Treatment for osteonecrosis of the femoral head: comparison of extracorporeal shock waves with core decompression and bone-grafting. *J Bone Joint Surg Am*. 2005;87:2380—2387.
26. Ludwig J, Lauber S, Lauber HJ, Dreisilker U, Raedel R, Hotzinger H. High-energy shock wave treatment of femoral head necrosis in adults. *Clin Orthop Relat Res*. 2001;387:119—126.
27. Alves EM, Angrisani AT, Santiago MB. The use of extracorporeal shock waves in the treatment of osteonecrosis of the femoral head: a systematic review. *Clin Rheumatol*. 2009;28:1247—1251.
28. Wang GJ, Dughman SS, Reger SI, Stamp WG. The effect of core decompression on femoral head blood flow in steroid-induced avascular necrosis of the femoral head. *J Bone Joint Surg Am*. 1985;67:121—124.
29. Mont MA, Carbone JJ, Fairbank AC. Core decompression versus nonoperative management for osteonecrosis of the hip. *Clin Orthop Relat Res*. 1996;324:169—178.
30. Mont MA, Jones LC, Hungerford DS. Nontraumatic osteonecrosis of the femoral head: ten years later. *J Bone Joint Surg Am*. 2006;88:1117—1132.
31. Camp JF, Colwell CW Jr. Core decompression of the femoral head for osteonecrosis. *J Bone Joint Surg Am*. 1986;68:1313—1319.
32. Lieberman JR, Conduah A, Urist MR. Treatment of osteonecrosis of the femoral head with core decompression and human bone morphogenetic protein. *Clin Orthop Relat Res*. 2004;429: 139—145.
33. Veillette CJ, Mehdian H, Schemitsch EH, McKee MD. Survivorship analysis and radiographic outcome following tantalum rod insertion for osteonecrosis of the femoral head. *J Bone Joint Surg Am*. 2006;88(suppl 3):48—55.
34. Reuter N, Romier A, Hambourg Z, et al. Cementoplasty in the treatment of avascular necrosis of the hip. *J Rheumatol*. 2009; 36:385—389.
35. Yen CY, Tu YK, Ma CH, Yu SW, Kao FC, Lee MS. Osteonecrosis of the femoral head: comparison of clinical results for vascularized iliac and fibula bone grafting. *J Reconstr Microsurg*. 2006; 22:21—24.
36. Chen YT, Chen WM. *Core decompression combined with trochanteric cancellous bone grafting through a single 1.5cm wound*. San Francisco, CA, USA: American Academy of Orthopaedic Surgeons Annual Meeting; 2009.
37. Sugioka Y. Transtrochanteric anterior rotational osteotomy of the femoral head in the treatment of osteonecrosis affecting the hip: a new osteotomy operation. *Clin Orthop Relat Res*. 1978;130:191—201.
38. Yamamoto T, Ikemura S, Iwamoto Y, Sugioka Y. The repair process of osteonecrosis after a transtrochanteric rotational osteotomy. *Clin Orthop Relat Res*. 2010;468:3186—3191.
39. Atsumi T, Kajiwara T, Tamaoki S, Maeda A, Nakanishi R. Respherical contour with medial collapsed femoral head necrosis after high-degree posterior rotational osteotomy in young patients with extensive necrosis. *Orthop Clin North Am*. 2009;40:267—274.
40. Heisel C, Silva M, Schmalzried TP. Bearing surface options for total hip replacement in young patients. *Instr Course Lect*. 2004;53:49—65.
41. Selvarajah E, Hooper G, Inglis G, Woodfield T, Devane P. Cross-linked polyethylene wear in total hip joint replacements with 36mm ceramic heads. *J Bone Joint Surg Br*. 2010;92-B(Suppl I): 225.
42. Lee FT. *Epidemiologic study of avascular necrosis of femoral head and survival analysis of surgical treatments—Taiwan NHI database review*. Taiwan: China Medical University Repository; 2007.
43. Amstutz HC, Grigoris P, Safran MR, Grecula MJ, Campbell PA, Schmalzried TP. Precision-fit surface hemiarthroplasty for femoral head osteonecrosis. Long-term results. *J Bone Joint Surg Br*. 1994;76:423—427.
44. Grevitt MP, Spencer JD. Avascular necrosis of the hip treated by hemiarthroplasty. Results in renal transplant recipients. *J Arthroplasty*. 1995;10:205—211.
45. Chan YS, Shih CH. Bipolar versus total hip arthroplasty for hip osteonecrosis in the same patient. *Clin Orthop Relat Res*. 2000; 379:169—177.
46. Sanjay BK, Moreau PG. Bipolar hip replacement in sickle cell disease. *Int Orthop*. 1996;20:222—226.
47. Yamano K, Atsumi T, Kajiwara T, Hiranuma Y, Tamaoki S, Asakura Y. Bipolar endoprosthesis for osteonecrosis of the femoral head: a 12-year follow-up of 29 hips. *J Bone Joint Surg Br*. 2004;86-B(Suppl II):150—151.
48. Adili A, Trousdale RT. Femoral head resurfacing for the treatment of osteonecrosis in the young patient. *Clin Orthop Relat Res*. 2003;417:93—101.
49. Sharma V, Cheng EY. Is there a role for resurfacing hemiarthroplasty? *Semin Arthroplasty*. 2007;18:211—215.
50. Ikada Y. Challenges in tissue engineering. *J R Soc Interface*. 2006;3:589—601.