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ORIGINAL PAPER

Treatment of nontraumatic osteonecrosis of the femoral head using bone impaction grafting through a femoral neck window

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Abstract Nontraumatic osteonecrosis of the femoral head (non-ONFH) is a disorder that can lead to femoral head collapse and the need for total hip replacement. Various head-preserving procedures have been used for this disease to avert the need for total hip replacement. These include various vascularised and nonvascularised bone grafting procedures. We examined the effect of bone-grafting through a window at the femoral head-neck junction known as the "light bulb" approach for the treatment of osteonecrosis of the femoral head with a combination of demineralised bone matrix (DBM) and auto-iliac bone. The study included 110 patients (138 hips; 41 females, 69 males; mean age 32.36 years, range 17–54 years) with stage IIA–IIIA nontraumatic avascular necrosis of the femoral head according to the system of the ARCO (Association Research Circulation Osseous). The bone grafting procedure is called "light bulb" procedure in which the diseased bone was replaced by a bone graft substitute (combination of DBM and auto-iliac bone).The outcome was determined by the changes in the Harris hip score, by progression in radiographic stages, and by the need for hip replacement. The mean follow-up was 25.37 months (range 7–42 months). All data were processed by a statistics analysis including Cox risk model analysis and Kaplan-Meier survival analysis. Pre- and postoperative evaluations showed that the mean Harris hip score increased from 62 to 79. Clinically, 94 of 138 hips (68%) were successful at the latest follow-up, and radiological improvement was noted in 100% of patients in stage IIA, 76.67% of patients in stage IIB and 50.96% of patients in stage IIC and IIIA cases. Excellent and good results according to the Harris score were obtained in 100% of cases in stage IIA, 93.33% in stage IIB and 59.62% in stages IIIA and IIC stage, with a survivorship of 85% in stages IIA and IIB and 60% in stage IIIA and IIC cases. Cox risk model analysis showed that the clinical success rate correlated with both pre-operation stage and the necrotic area of the femoral head. The complications included ectopic ossification, lateral femoral cutaneous nerve lesion and joint infection. This procedure may be effective at avoiding or forestalling the need for total hip replacement in young patients with early to intermediate stages of osteonecrosis of the femoral head. Therefore, it may be the treatment of choice particularly in nontraumatic osteonecrosis of the femoral head of pre-collapse stage with small and middle area (<30%, or the depth of collapse <2 mm).

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Background

Non-traumatic osteonecrosis of the femoral head (ONFH) is a poorly understood condition commonly seen in young patients. Various head-preserving procedures have been used for this disease to avert the need for total hip replacement (THR). These include core decompression, various types of osteotomies, and different methods of nonvascularised and vascularised bone grafting. None of these methods have been found to be universally successful, but all have been attempted in an effort to forestall the need for THR, because THR in these young patients is not attractive and is associated with inferior long-term outcome [2]. Between January 2004 and July 2007, we treated 110 patients with 138 painful hips using a nonvascularised bone

grafting procedure in which the femoral head was evacuated through a window made at the femoral head–neck junction and replaced by a combination of demineralised bone matrix (DBM) and auto-iliac bone known as the "light bulb" procedure. We assessed the outcome of this procedure with an average follow-up of two years.

Materials and methods

Patients

There were 41 women (60 hips) and 69 men (78 hips) who had a mean age of 32.36 years (range 17–54 years) at the time of surgery. The presumed risk factors included the use of steroids in 76 patients (99 hips) with an average methylprednisone intake of 5,061.10±6,816.06 mg (150 mg–45,000 mg) over a duration of 107.13±333.07 days (range 3 days to 5 years); excessive intake of alcohol in 23 patients (27 hips) with an average daily intake of 318.75±88.39 ml (250–750 ml wine/day) in a period of 14.86±7.46 years (range 2–30 years). The remaining 11 cases (12 hips) were classified as having idiopathic ON because no specific risk factors could be identified. The diagnosis of femoral head osteonecrosis was made using anteroposterior (AP) and frog lateral radiographs or MRI scans. Images were obtained in coronal and sagittal sections. The diagnosis of osteonecrosis on MRI scans was based on bandlike abnormal signals, on bandlike hypointense zones on T1-weighted images, and on matching hyperintense zones on short tau inversion. Anteroposterior and frog lateral radiographs were taken when the patient entered the study and every year thereafter. All radiographs were graded according to the system of the Association Research Circulation Osseous (ARCO). The patients were classified according to the system of ARCO into stage IIA (four hips), stage IIB (31 hips), stage IIC (33 hips) and stage IIIA (71 hips). In 28 patients, the procedure was done bilaterally under the same anaesthetic.

Surgical technique

The procedure was done with the patient lying in the lateral decubitus position. An approximately 7-cm incision was made over the greater trochanter for an anterolateral approach to the hip (Watson-Jones approach), which was used to preserve the blood supply to the femoral head. The fascia lata was split in the direction of the skin incision and the anterior gluteus medius was detached. The anterior joint capsule was spilt longitudinally along the femoral head between the gluteus medius muscle and tensor muscle of fascia lata in order to expose the head-neck junction.

An approximate 1.0 cm×1.5 cm bone window was made at the femoral head–neck junction using osteotomes. This cortical window segment was saved in normal saline-wrapped gauze for later use. A mushroom-tipped burr was used to curette a cavity to the subcartilage bone lamella in the femoral head using the window as an entrance, and all of the dead bone was removed. The volume of cavity was measured by saline and the sclerotic bone was perforated using an electric drill until bleeding bone was encountered. In this study, the cavity was filled with an auto-iliac bone (cortical bone and cancellous bone) combination of demineralised bone matrix (DBM, containing bone morphogenic protein, BMP). The material was packed into the cavity with a layered approach and the cortical segment was replaced and fixed with one 3-mm absorbable pin. After surgery, all patients followed a strict rehabilitation and training program. Patients were maintained at toe-touch weight-bearing with two crutches for 12 weeks and were advanced to approximately 50% weight-bearing for the second 12 weeks using a cane or crutch in the opposite hand. They began full weight-bearing as tolerated at six months postoperative. Higher impact loading activities (such as running) were begun at 12 months postoperative.

Assessment

All patients were prospectively followed-up clinically and radiographically by one of the authors (Wang) every three months during the first year and every six months for the second year. The clinical follow-up consisted of the determination of preoperative and postoperative serial Harris hip scores, and serial AP and frog lateral radiographs were used for the radiographic follow-up. All radiographs were analysed by three of the authors on a consensus basis. On the serial postoperative radiographs, consolidation of the impacted graft and collapse or progression of collapse and osteoarthritis (OA) were determined. Excellent, good, fair and poor results were defined as Harris hip score over 90, 80–89, 70–79 and below 70, respectively. Clinical failure was defined as a Harris hip score below 80 points or if the patients need further surgical procedure such as THA or osteotomy for any reason. A radiographic failure was defined as the onset or the progression of collapse or progressive OA.

Statistical analysis

All statistical analyses were completed using SPSS Statistical Software (SPSS for Windows, release 10.0; SPSS Inc., Chicago, IL). Means, standard deviations and frequencies were calculated for general demographic and routine clinical data. We used Cox risk model analysis and Kaplan-Meier

survival for multivariate analysis. *P* values of less than 0.05 were considered statistically significant.

Results

The mean duration of follow-up was 25.37 months (range 7–42 months). The operation time (unilateral) lasted for an average time of 2.3 hours with a blood loss of approximately 115 ml. The preoperative Harris hip score for the entire group was 62.65 (±10.97) points. The average postoperative score of all hips was 79.50 (±13.42) points at the most recent follow-up or just before conversion to a total hip implant. The clinical success rate for hips with an ARCO stage IIA is 100%; for stage IIB early, 93.33%; and for stages IIIA and stage IIC, 59.62% (Table 1).

At review according to our criteria, 58 of 138 hips (42.02%) were radiological failure. During follow-up, radiological failure was seen in alcohol-induced ONFH (70.37%) and steroid-induced ONFH (36.37%). Thirteen hips with a progressive collapse needed a THA (9.5%). The remaining 45 hips were stable. The rate of radiological failure was 23.33% in stage IIB, 48.48% in stage IIC, and 49.02% in stage IIIA, respectively (see Table 2).

Kaplan-Meier survival analysis indicated a survivorship of 85% in stages IIA and IIB and 60% in stages IIIA and IIC two years after operation. Cox risk model analysis revealed that the pre-operation stage was an independent risk factor for clinical efficacy ($P<0.01$; relative risk=14.27; 95% CI= 2.14–35.58) and radiographic efficacy ($P=0.003$; relative risk=8.19; 95% CI=1.32–24.67).

No complications were seen during the operation; however, the postoperative complications included ectopic ossification in seven hips, joint infection in three hips and lateral femoral cutaneous nerve lesion in six hips.

Discussion

ONFH, a relatively common disease in younger, active patients, seemingly has a wide range of aetiologies and a poorly understood pathogenesis. Symptomatic ONFH typically progresses with collapse and incongruity of the joint. The effective treatment for ONFH is supposed to alleviate pain and maintain shape of the femoral head so as to prevent any deterioration of the function of the hip joint.

Therefore, it is worthwhile investigating methods that restore sphericity of the femoral head and revascularise the necrotic bone to minimise the risk of collapse. Various bone grafting procedures including structural and non-structural bone grafting and vascularised or non-vascularised bone grafting have been developed with an aim at directly influencing the pathological process, delay or prevent the collapse of the femoral head, and avert the occurrence of secondary osteoarthritis [2, 13, 18]. Vascularised bone grafting (such as pedicled iliac bone block with gluteus medius muscle, quadratus femoris or sartorius), which has inconsistent long-term success rates, supplies a source of viable bone, improving the healing potential by providing circulating stem cells and growth factors [3, 10, 15]. Hasegawa et al. [7] reported that there was 61% success in stage II patients at ten years; while Baksi et al. [4] found that there was 100% success in stage I, 92% in stage II and 80.4% in stage III with radiographic success in 81.3% of stage II and 70.1% of stage III at 16 years. Aldridge et al. [1] reported survival rates of 67.4% at two years and 64.5% at five years with vascularised fibular bone grafting. Marciniak et al. [11] reported that 61% and 42% of patients had not received hip replacement at five and eight years postoperatively, respectively. Zhang et al. [20] reported that there was 79% success rate at two years.

The vascularised bone grafting is characterised by a prolonged operation, complicated techniques, major trauma

Table 1 Clinical results

ARCO stage	Aetiological factor				Harris scores		Results		
	Hips (rate)	Steroids	Alcohol	Idiopathic	Preoperation	Follow-up	Excellent	Good	Rate (excellent plus good)
IIA	4 (2.89%)	1	3	0	74.94 (±1.98)	90* (±0.00)	3	1	100%
IIB	30 (21.74%)	27	3	0	68.92 (±8.66)	79.61* (±17.44)	26	2	93.33%
IIC	33 (23.91%)	25	3	5	59.66 (±13.11)	73.91* (±17.95)	16	2	54.55%
IIIA	71 (51.45%)	46	18	7	58.10 (±11.19)	77.92* (±15.04)	6	38	61.97%
Total	138	99 (71.7%)	27 (19.6%)	12 (8.7%)	62.65 (±10.97)	79.50* (±13.42)	51	43	68.12%

ARCO Association Research Circulation Osseous

* $P<0.05$

Table 2 Radiographic results

ARCO stage	Corticosteroid (n = 99)	Alcohol (n = 27)	Idiopathic (n = 12)	Rate of failure	THR (rate)
IIA (n = 4)	0	0	0	0	0
IIB (n = 30)	5	2	0	23.33%	2 (6.67%)
IIC (n = 33)	10	5	1	48.48%	3 (9.09%)
IIIA (n = 71)	21	12	2	49.3%	8 (11.3%)
Total	36 (36.37%)	19 (70.37%)	3 (25%)	42.02%	13 (9.5%)

ARCO Association Research Circulation Osseous, *THR* total hip replacement

and a significant number of complications; therefore, many researchers began to introduce non-vascularised bone grafting [6, 9, 16]. There are three major methods for non-vascularised bone grafting: Core depression (CD) procedure via the lateral side of the greater trochanter of the femur, the trapdoor procedure via cartilage of the femoral head, and the "light bulb procedure" through a window at the femoral head–neck junction. These surgical procedures mainly harvest bone graft from the iliac bone or other parts of the patient. The CD procedure was initiated by Phemister et al. and the success rate varied from 30% to 71% to 90% [5]. Steinberg et al. reported that 36% of patients needed THR 30 months postoperatively, and the success rate varied according to preoperative staging and size of necrosis [19]. The trapdoor procedure was initially reported by Judet et al. and further described in detail by Meyers, who achieved remarkable clinical effects [8]. Mont et al. [12] reported success rates of 83% and 33% in stage III and stage IV patients, respectively. Since this technique destroyed the integrity of joint cartilage on the femoral head and aggravated the injury to the femoral head, the cartilage failed to heal after the operation [14]. Rosenwasser et al. initially brought forth the concept of the "light bulb procedure", in which the necrotic lesion was replaced by the bone grafting via the window on the femoral head–neck junction without any damage to the joint cartilage [17]. The clinical success rate was 81% at 12 years. Mont et al. reported that there was a 86% success rate at four years, and all patients had marked improvement in Harris hip score [13].

In our study, we replaced the necrotic bone with the light bulb procedure, and had overall success rates of 68%, including 93.33% in stages IIB and 59.62% in stages IIC and IIIA. No radiographic progress was shown in 57.98% of the patients, and the rate in stage IIB was 76.67%, which decreased to 50.96% in stages IIC and IIIA. Our results showed that the clinical success was not exactly consistent with the radiographic success. Though a proportion of patients witnessed slight radiographic progression (collapse or collapse worsening), their Harris hip score had significant improvement, which was in agreement with the results of other researchers [4]. Consequently, the clinical success rate was 85% in stages IIA and IIB, and 60% in stages IIC and IIIA which took up 84.62% of all patients receiving THR. In addition, 90% of these hip replacement operations had been done within 1.5 years.

The prognosis of the patients correlates to preoperative stage, aetiology, age and gender of the patients, etc. [3]. Cox risk analysis showed that preoperative stage and necrotic lesion area were the major risk factors of success. The patients at pre-collapse stage (II) as well as moderate and small necrotic lesion area (<30%, or collapse <2 mm) (A and B) had significantly better prognosis than those at post-collapse stage (IIIC) or large necrotic lesion area (>30% or collapse >2 mm). The survival analysis showed that there was 85% success rate in stages IIA and IIB, with 60% at stages IIC and IIIA.

We applied non-vascularised bone grafting with cortical bone, cancellous bone and DBM (containing BMP) of autologous iliac bone by gradually compacting, which was characterised by the following advantages of simple surgical technique, low incidence of complication and a short duration of operation. This procedure provided strong structural support for the femoral head, amended the morphology of the femoral head to a certain extent and averted the further collapse of the femoral head. Besides, the light bulb procedure improved the healing process of the femoral head by cancellous bone and the induction activity of DBM.

Conclusions

In summary, this procedure may be effective at avoiding or forestalling the need for hip replacement in young patients with early stage of osteonecrosis of the femoral head. Therefore, it may be the treatment of choice particularly in nontraumatic osteonecrosis of the femoral head of the pre-collapse stage with small and middle area (<30%, or the depth of collapse <2 mm).

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