Management of nontraumatic osteonecrosis of the femoral head using impaction bone grafting via a light bulb window through a safe surgical dislocation approach

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Purpose
The aim was to appreciate the clinical and radiological results of impacted bone graft via bone window on the head-neck junction for treatment of nontraumatic avascular necrosis of femoral head through a safe surgical dislocation approach.
Patients and methods
A total of 33 hips in 26 patients were managed with femoral head osteonecrosis by impaction of autogenous iliac bone graft via bone window on the head-neck junction (light bulb) through a safe surgical dislocation approach. There were eight females and 18 males, with a mean age of 29.06 years (ranging from 14 to 46 years) with stage II and III avascular necrosis of the femoral head according to Association Research Circulation Osseous (ARCO). The results were studied based on variations in the Harris hip score and progress in radiographic stages.
Results
These 26 patients were followed up from 24 to 48 months (mean: 33.9 months). The mean Harris hip score was 82.78 (range from 66 to 95) after last follow-up when compared with 60.45 (range from 41 to 85) preoperatively. The clinical success for ARCO stage II was 75% (100% in stage IIA, 83.3% in stage IIB, and 50% in stage IIC) and for ARCO stage III was 43.5% (70% in stage IIIA, 60% in stage IIIB, and 0% in stage IIIC), whereas the overall radiographic progression was found in 15 of 33 hips (45.4%), where nine of them (27.3%) progressed to radiographic failure (femoral head collapse) and required total hip arthroplasty.
Conclusions
Impaction of autogenous bone graft through a safe surgical dislocation via a bone window creates a mechanical and biological condition for graft incorporation, and therefore, it may be the treatment of choice in nontraumatic osteonecrosis of the femoral head at the precollapse stage (stage II and early III), especially with a small-sized lesion, with a better outcome in idiopathic type.

Keywords:
femoral head, impaction bone graft, light bulb technique, osteonecrosis

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Introduction

Osteonecrosis of the femoral head (ONFH) is a disorder that commonly affects young patients and leads to femoral head collapse with further need for total hip arthroplasty (THA). It gives a great challenge to orthopedic surgeons with unclear natural history [1,2].

THA in young adults has a great risk of multiple revisions owing to osteolysis and loosening [3].

The concept of using hip-preserving surgery to treat ONFH and to defer THA has been widely accepted [4–7].

Head-preserving procedures include core decompression, nonvascularized and vascularized bone grafting, and different types of osteotomies with lack of universal success [8,9].

The idea of nonvascularized impaction bone grafting is to excise the necrotic tissue and fill the defect by corticocancellus bone chips, which provide mechanical structural support for the articular cartilage and stimulate osteoinduction process of healing [10].

The aim of this prospective study was to describe the technique and the results of using nonvascularized impaction bone grafting in the treatment of nontraumatic ONFH, where the graft was inserted through a window at the head-neck junction (light bulb procedure), which was done through a safe surgical hip dislocation approach [11].

Patients and methods

After IRB approval was obtained, each patient signed an informed consent form, after discussing the advantages and disadvantages of the procedure with each patient and his or her family. A total of 26 consecutive patients (33 hips) with nontraumatic ONFH were prospectively managed between May 2011 and June 2015 at Mansoura University Hospital. There were 18 males (23 hips) and eight females (10 hips), with a mean age of 29.06 years (range from 14 to 46 years).

The diagnosis was done based on clinical and radiological evaluation, and also preoperative Harris hip score was recorded. The preoperative radiological studies included a plain radiography of both hips (anteroposterior and frog lateral positions) and MRI of both hips.

Radiological staging was based on the Association Research Circulation Osseous (ARCO) for ONFH, with special attention to the quantitation of the lesion (area involved and length of the crescent):

(1) A: minimal involvement (<15%).
(2) B: moderate involvement (from 15 to 30%).
(3) C: extensive involvement (over 30%) [12].

Our study included 26 patients (33 hips): 16 hips without femoral head collapse (ARCO II), which were subclassified into stage IIA (four hips), stage IIB (six hips), and stage IIC (six hips), and 17 hips with positive crescent sign (ARCO III), which were also subclassified into stage IIIA (10 hips), stage IIIB (five hips), and stage IIIC (two hips) (Table 1).

We excluded patients above 50 years and patients with ONFH with osteoarthritis (OA) of the hips (ARCO IV).

Table 1 Patient's data and clinical results

Hips	Sex	Age	Risk factors	ARCO stage	Follow-up (months)	Preoperative HHs	Postoperative HHs
1	♂	33	Idiopathic	IIC	27	68	82
2	♂	26	Steroids	IIIA	40	70	94
3	♀	18	Idiopathic	IIIB	24	65	88
4	♂	38	Smoking	IIIB	42	58	82
5	♂	42	SLE, Hepatitis C, steroids	IIC	28	55	78
6	♀	26	Idiopathic	IIA	37	75	95
7	♂	33	Idiopathic	IIB	32	72	91
8	♀	14	SLE, steroids	IIIC	30	49	68
9	♂	32	Multiple sclerosis, steroids	IIIC	38	44	66
10	♂	21	Idiopathic	IIC	28	63	84
11	♀	23	Idiopathic	IIB	40	69	92
12	♂	22	Steroids	IIIB	31	57	78
13	♂	35	Hepatitis C	IIIA	42	65	85
14	♀	14	SLE, steroids	IIIA	38	85	74
15	♂	40	Gout	IIIA	29	69	82
16	♂	21	Idiopathic	IIIA	35	73	90
17	♂	46	Smoking	IIA	48	72	93
18	♀	28	Steroids	IIIA	27	58	73
19	♂	19	Multiple sclerosis	IIB	36	66	90
20	♂	35	Idiopathic	IIA	44	59	94
21	♀	23	Idiopathic	IIIB	31	48	83
22	♂	36	Steroids, smoking	IIC	29	41	66
23	♂	24	Smoking	IIIA	43	62	76
24	♀	28	Steroids	IIA	30	65	92
25	♂	35	Idiopathic	IIIA	24	71	94
26	♂	38	Smoking	IIC	34	57	82
27	♂	43	Idiopathic	IIB	26	56	84
28	♂	22	Steroids	IIIB	40	42	72
29	♂	14	Idiopathic	IIIA	28	64	83
30	♀	29	SLE	IIC	33	46	74
31	♂	40	Gout	IIIB	31	44	78
32	♀	25	Idiopathic	IIIA	42	54	88
33	♂	36	Steroids, smoking	IIIB	34	53	81

ARCO, Association Research Circulation Osseous; HHS, haris hip score; SLE, systemic lupus erthrimatosis.

We studied the risk factors associated with ONFH, which included the use of steroids in 2 patients (a dose of more than 2 g prednisone per months for at least 3 months) [13], systemic lupus erythematosus in three patients, tobacco abuse (more than 20 cigarettes per day) [14] in six patients, gout in two patients, multiple sclerosis in one patient, hepatitis C in two patients, and six patients considered as idiopathic owing to lack of apparent risk factors. Five patients had more than one risk factor.

Operative technique

On a lateral decubitus position of the patient, a surgical hip dislocation approach as described by Ganz *et al*. [11] was done to preserve the femoral head blood supply (Fig. 1).

The femoral head was dislocated, and the whole femoral head and the acetabulum were carefully inspected, where the necrotic area and its overlying cartilage were identified. An ~2×2 cm window was created at the femoral head-neck junction using osteotomies, and preservation of this window segment in normal saline-wrapped gauze was done to be reused at the end of the procedure.

The necrotic bone in the femoral head was debrided and removed by a combined use of a mushroom-tipped burr and bone curettes entered through the window.

The necrotic bone was totally debrided till oozing of the fresh blood from the sclerotic zone, which was perforated by a pneumatic drill.

The cavity was filled with autogenous iliac bone graft (cortical and cancellous bone), which was obtained from ipsilateral iliac bone.

The graft was packed tightly inside the cavity with a layered approach and a hammering technique using a bone graft impactor introduced through the window until the normal spherical shape of the femoral head was obtained. Care was taken to avoid accidental head penetration. The window segment was put back and locked with one 3-mm absorbable pin. The hip was reduced, and the capsule closed. The greater trochanter was fixed by two cancellous screws.

Postoperative rehabilitation program was followed up by all patients with avoidance of weight bearing for 3 months, which gradually increased in the next 3 months to reach full weight bearing at 6 months postoperatively.

Assessment

Each patient was scheduled for follow-up visits at 3, 6, 12, and 24 months after surgery and every year after 24-month visit. Clinical follow-up visit included documentation of preoperative and serial postoperative Harris hip scores and postoperative complications and serial anteroposterior and frog lateral radiographs. Analysis of all radiographs were done by the three authors independently, and they provided comment on graft incorporation, joint space, development and/or progression of collapse, and OA.

Clinical failure means that a Harris hip score less than 80 points or the patient underwent THA. Radiological failure means that development and/or progression of collapse or OA.

Patients were clinically graded into excellent, good, fair, and poor based on the Harris hip score of 90, 80–89, 70–79, and below 70, respectively.

Statistical analysis

SPSS version 21 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) was used for data analysis. The data normality was tested first with Shapiro–Wilk test. Qualitative data were described using number and percentage. χ^2-Test was used for assessing the association between categorical variables. Continuous variables were presented as mean±SD. The two-paired groups were compared with paired *t*-test. Analysis of variance test was used for comparison of means of more than two groups, and in-between group comparison was tested by post-hoc least significant difference test. Spearman's correlation was used for correlation between ordinal data.

Level of significance

The threshold of significance was constant at 5% level (P) for all previously mentioned statistical tests done. When the probability of error is more than 5% ($P>0.05$), the result was considered nonsignificant, significant when the probability of error is less than 5% ($P\leq0.05$), and highly significant when the probability of error is less than 0.1% ($P\leq0.001$). The smaller the P value obtained, the more significant are the results.

Results

The mean follow-up period was 33.9 months (range from 24 to 48 months). According to ARCO grading system, the overall clinical success (excellent and good Harris hip scores) was found in 22 (66.6%) of 33 patients. The mean preoperative haris hip score (HHS) was 60.45

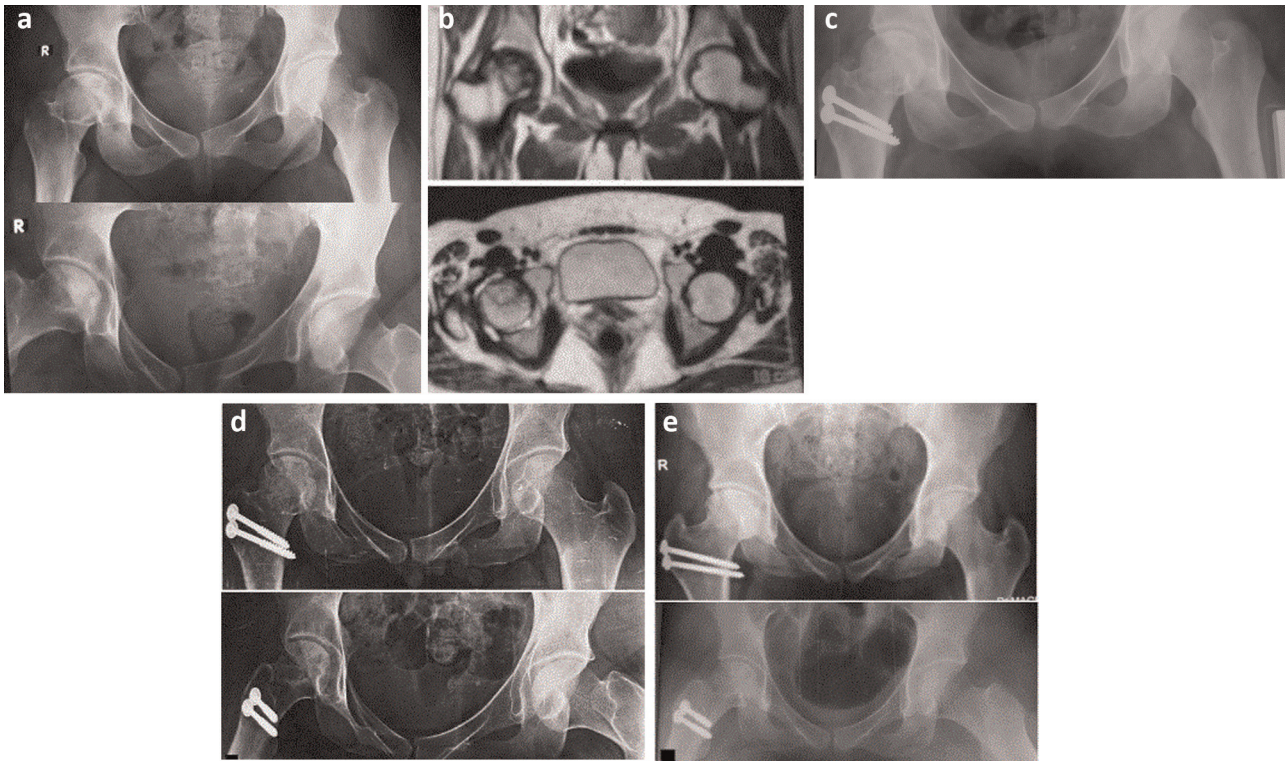
Figure 1

Operative technique. (a) Kocher–Langenbeck incision. (b) Anterior margin of the gluteus maximus was indicated by the perforans vessels position. (c) Fascia lata and gluteus maximus is divided. (d) Trochanteric bursa and gluteus medius were exposed. (e) Incision of the trochanteric bursa and fascia over gluteus medius. (f) Identification of the posterior border of gluteus medius and posterior-superior tip of the greater trochanter. (g) Develop the interval between gluteus medius and piriformis tendon and mark the site of digastric trochanteric osteotomy. (h) Mobile trochanter is flipped anteriorly with exposure of the hip capsule. (i) Femoral head was seen after Z capsulotomy. (j) Femoral head was dislocated and exposing the area of segmental collapse. (k) A window was created at the femoral head- neck junction and removal of necrotic bone with a curette. (l) A small-sized osteotome and burr were used to debride the necrotic bone. (m) Autogenous iliac bone graft was used to fill the cavity. (n) Impaction of the graft and closure of the precreated window.

(range from 41 to 85), which improved to a mean postoperative value of 82.78 (range from 66 to 95) at the last follow-up (statistically highly significant, $P \leq 0.001$) (Table 1 and Fig. 2).

The clinical success for ARCO stage II was 75% (100% in stage IIA, 83.3% in stage IIB, and 50% in stage IIC) with an increasing improvement rate of 27.5, 29.8, and 29.1%, respectively, whereas for ARCO stage III was

Figure 2



Radiologically demonstrated case. (a) Two views radiographs of 28 years old female patient of right hip osteonecrosis with history of steroid therapy. (b) MRI shows stage II large C lesion on the RT hip. (c) Early postoperative radiographs. (d) Follow-up radiograph at 3 months postoperatively. (e) One-year follow-up with graft incorporation and no collapse of the femoral head. RT, right side.

Table 2 Clinical and radiological results

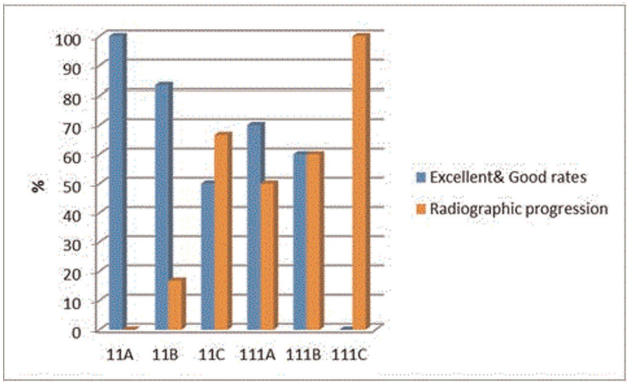
		Final Harris hip score scale					
Arco stage	Hips	Excellent	Good	Fair	Poor	Excellent and good rates [*n* (%)]	Radiographic progression [*n* (%)]
IIA	4	4	0	0	0	4 (100)	0
IIB	6	3	2	1	0	5 (83.3)	1 (16.7)
IIC	6	0	3	2	1	3 (50)	4 (66.6)
IIIA	10	3	4	3	0	7 (70)	5 (50)
IIIB	5	0	3	2	0	3 (60)	3 (60)
IIIC	2	0	0	0	2	0	2 (100)
Total	33	10	12	8	3	22 (66.6)	15 (45.4)

43.5% (70% in stage IIIA, 60% in stage IIIB, and 0% in stage IIIC), with improvement rate of 20, 33.4, and 30.5%, respectively (Table 3 and Fig. 3).

The overall radiographic progression was found in 15 of 33 hips (45.4%), where nine of them (27.3%) progressed to radiographic failure (femoral head collapse) and required THA, while the other six hips (18.2%) showed variable degrees of secondary impingement of the hip and narrowing of hip joint space (OA hip) and was well tolerated clinically.

The rate of radiographic progression for stage II was 31.25% (IIB was 16.7%, stage IIC was 66.6%) and for stage III was 58.8% (stage IIIA was 50%, stage

Figure 3



Correlation between clinical success and radiographic progression.

Table 3 Relation between ARCO stage and Harris hip score scale

ARCO stage	Pre-Harris hip score	Post-Harris hip score	Paired *t*-test	Improvement rate (%)
IIA	67.75 (7.18)	93.50 (1.29)	P=0.005*	27.5
IIB	59.66 (11.39)	85 (7.69)	$P \leq 0.001^{**}$	29.8
IIC	55 (10.13)	77.66 (6.74)	$P \leq 0.001^{**}$	29.1
IIIA	67.10 (8.67)	83.90 (7.76)	$P=0.001^{*}$	20
IIIB	54.40 (8.38)	81.80 (4.14)	$P=0.001^{*}$	33.4
IIIC	46.50 (3.53)	67 (1.41)	$P=0.046^{*}$	30.5

ARCO, Association Research Circulation Osseous.

IIIB was 60% and stage IIIC was 100%) (Table 2, Fig. 3).

Absence of risk factors (idiopathic cases) had a highly statistically significant correlation ($P \leq 0.001$) with the mean postoperative HHS.

Minimal complications were encountered at graft donor site, including minimal pain and hypothesia at the anterolateral aspect of the proximal thigh in 9% of hips.

Discussion

ONFH is a relatively common disorder that affects young adults with unclear natural history, and it is symptomatic in 60% of cases and progresses to radiological changes that eventually become symptomatic, with 70–80% of cases requiring THA [1,15].

Nonoperative treatment is indicated in small and early lesion, with 90% failure rate [16]. Hip-preserving surgeries are widely accepted treatment for ONFH in young adults with high risk of failure [1,17]. The aim of hip-preserving surgeries is to preserve the hip function by reconstruction of the blood supply and promoting repair of necrotic bone and to provide mechanical support of the subchondral bone to maintain the shape of the femoral head [18].

Hip-preserving surgeries varied from core decompression surgery to osteotomy to vascularized and nonvascularized bone grafting, with each procedure having its advantage and disadvantages [2,3]; core decompression decreases pain by lowering the elevated pressure inside the femoral head and stimulating bone regeneration by restoring the compromised intraosseous circulation [1]. However, it does not preserve the shape of the femoral head owing to incomplete structural regeneration [19]. So, it should be combined with vascularized or nonvascularized bone graft or electrical stimulation to enhance bone repair [20]. Although vascularized bone graft has a long-term success by providing a better source of viable bone and a good healing power [21] as supported by Aldridge *et al*. [22], and Marciniak *et al*. [23], with survival rate of 64.5% and 61% at 5 years, respectively.

Vascularized bone graft is a complicated procedure surgery with long operative time associated with a lot of complications, so it brought the attention toward nonvascularized bone grafting techniques [24,25]. Nonvascularized bone grafting techniques were done either through a core decompression tract (Phemister technique) [26] or through a window in the articular cartilage (trapdoor procedure) [27] or through a window at the femoral head-neck junction (light bulb procedure) [28].

The most important preliminary step is to remove the necrotic tissue totally till reaching the hardening zone and bleeding surface was seen, and then autologous corticocancellous bone graft was impacted into the cavity to promote induction of the osteogenesis and provide mechanical support of the femoral head cartilage to prevent its collapse [29].

The clinical success of Phemister technique varied from 36 to 90% compared with a range of 71–90% for the trapdoor technique with potential destruction of the integrity of the cartilage of the cartilage of the femoral head and failure of postoperative cartilage healing, whereas the clinical success in light bulb technique varied from 68 to 87% where the articular cartilage was protected against damage [30].

The overall clinical success in our study was 66.6% including 75% in stage II and 58.8% in stage III, which is comparable to other researchers using the light bulb technique [30,31].

The clinical success (excellent to good rates) ratio correlates with the stage of the disease (75% in stage II and 58.8% in stage III) and the size of the lesion (stage A better than stage B and stage B better than C) (Table 2), which means high failure rate occurred with

large-sized lesions. This is consistent with other studies [30,31] (Tables 2 and 3, Fig. 3).

Although the radiographic progression ratio is high (45.4%) (13.24% in stage II and 58.8% in stage III) only 27.3% required THA and osteogenesis 66.6% of them were large-sized lesions, where the remaining cases (18.2%) had a good HHS with mild radiographic changes, and this is consistent with other research studies5[21,30].

Location of the femoral head necrotic area had a close relationship with the clinical failure rates, and this was supported by Lieberman *et al*. [5] in their systemic review, where they concluded that high clinical failure rates of 45% (41 out of 91 cases) in cases when necrotic area exceeds the corresponding weight bearing area by 60% and a low clinical failure rate of 4.5% (one out of 22 cases) when the necrotic area was not exceeding the corresponding weight bearing area by 30%. This was supported by Wei Zuo and colleagues where they raised the relation between the necrotic segment and the lateral column involvement, where they classified the disease type into C, M, and L types, where the necrotic area did not involve the lateral column with 1.7% surgical failure rate and L2 and L3 types in cases with lateral column involvement with surgical failure rate of 38.9% and 39% in L2 and L3 types, respectively. This was consistent with our study as all clinical failures showed involvement of the lateral column [32].

Although with high potential complications occurred in the donor site of iliac bone graft [33], minimal complications occurred in our study.

We preferred the technique of surgical hip dislocation approach because it allows us to visualize almost 360° of the femoral head together with complete access of the acetabulum [11], and we considered it as superior to other approaches of the hip, as it avoids extensive detachment of the Tensor fascia lata and Gluteus medius from their origin to visualize the acetabulum in anterior, lateral, and anterolateral hip approach [34]. Moreover, it avoids the tenotomy of the external rotators with further compromising and interruption of the anastomosis between the inferior gluteal and deep branch of the medial femoral circumflex artery with the posterior approach [35].

Limitations of our study are the relatively small number of patients with different etiologies of osteonecrosis and the need for longer follow-up.

Conclusion

Impaction of autogenous bone graft through a safe surgical dislocation via a bone window creates a mechanical and biological condition for graft incorporation. Consequently, it may be considered the treatment of choice in non- traumatic ONFH at the precollapse stage (stage II and early III), especially with a small-sized lesion, with a better outcome in idiopathic type.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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