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El-Sayed Mohamady Ibrahim
Orthopedic Surgery, Faculty of Medicine, Banha University, Banha, Egypt

Mohsen Ahmed Mashhoor
Orthopedic Surgery, Faculty of Medicine, Banha University, Banha, Egypt

Islam Mustafa Cortam
Orthopedic Surgery, Faculty of Medicine, Banha University, Banha, Egypt

Emad Sanad
Orthopedic Surgery, Faculty of Medicine, Banha University, Banha, Egypt

Corresponding Author:
El-Sayed Mohamady Ibrahim
Orthopedic Surgery, Faculty of Medicine, Banha University, Banha, Egypt

Impaction bone graft for acetabular bone defect in total hip arthroplasty

El-Sayed Mohamady Ibrahim, Mohsen Ahmed Mashhoor, Islam Mustafa Cortam and Emad Sanad

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Abstract
Background: The number of total hip arthroplasty (THA) surgeries is growing annually Acetabular bone defects are frequently encountered in THA, and the reconstruction can be challenging for surgeons, especially in large defects.
Patient and Method: This is a prospective study conducted on 20 patients which were indicated for primary or revision total hip Arthroplasty THA with acetabular defect and needed acetabular reconstruction by impaction bone graft IBG. The age of the studied patients ranged from 19 to 73 years. There were 12 (60%) males and 8 (40%) females. 12 (60%) operations were performed for the right side and 8 (40%) were for the left side.
Results: The postoperative mHHS ranged from 69.2 to 87.1. Regarding the radiological graft incorporation to host bone, 6 (30%) patients achieved partial incorporation while 14 (70%) patients achieved complete incorporation. No patients developed loosening of cup radiolucent line more than 2 mm or acetabular migration more than 5 mm. Postoperative complications involved initial loosening of screws in 1 (5%) patient, temporary sciatic palsy in 1 (5%) patient who was resolved spontaneously, and dislocation in 1 (5%) patient.
Conclusion: Impaction Bone Graft for acetabular reconstruction in THA can achieve satisfactory results with high rate of radiological graft incorporation and low complication rate. Factors associated with favorable graft incorporation include primary THA, autografts, cementless cups, reduced defect size, and decreased thickness of the graft layer.

Keywords: Bone graft, impaction, bone defect, acetabular, total hip arthroplasty

Introduction
Total hip arthroplasty (THA) is one of the most clinically successful and cost effective interventions in health care of the last century [1]. However, despite the continuous improvement in surgical technique and implant development, the overall revision THA (rTHA) rate remains unchanged [2].
Osteolysis and loosening are still significant complications of THA. Additionally, the loss of bone stock is a critical issue that can negatively affect the outcomes of revision surgery [3]. Acetabular defect due to gradual bone loss occurs with deferent hip pathologies and also is one of the reasons for revision hip surgeries [4].
The degree of bone deficiency can be determined by preoperative X-rays and computed tomography (CT), the latter being more accurate, whereas magnetic resonance imaging (MRI) is an adjunctive tool to assess both bone and soft tissues. Final assessment is made intra operatively [4].
The most widely used classifications of acetabular bone defects are the American Academy of Orthopedic Surgeons (AAOS) Classification [5]. and the Paprosky Classification [6].
Identifying the appropriate method of acetabular reconstruction depends on properly classifying acetabular bone loss and evaluating the patient thoroughly [7].
Various strategies can be utilized for acetabular reconstruction in case of acetabular deficiencies, including bulk allografts, bone cement, augments, rings, or cages. Another option is using large cups; however, bone stock can be compromised further by the use of large implants [8].

Impaction bone grafting (IBG) is a reliable biological and mechanical method to restore acetabular bone-stock deficiency [9]. Femoral head autograft or fresh-frozen allograft is morselized into small cancellous pieces, which are then impacted into the defect before inserting the primary or revision acetabular components [10]. The impacted graft can restore the bone loss, form a durable scaffold for the acetabular implant, incorporate into the host bone, and undergo gradual remodeling [11].

This prospective study conducted to assess the clinical and radiological outcome achieved with Impaction Bone Graft for Acetabular Defect in Total Hip Arthroplasty.

2. Patients and Methods

This is a prospective study that conducted on 20 patients which were indicated for primary or revision total hip Arthroplasty THA with acetabular defect and needed acetabular reconstruction by impaction bone graft IBG between (2022 and 2024). All patients performed in the orthopedic department, Benha University and El helal insurance hospital, Menofia. Institutional review board and written informed consent obtained from all patient prior to conducting the study.

a) Inclusion criteria

- All patients indicated for total hip replacement whatever primary or revision
- Generally, fit for major operations
- With cavitary or small segmental acetabular defect that could be treated by IBG
- No other limitations such as age, sex, etc.

b) Exclusion criteria

- Bad general conditions who will be unfit for major operations
- Patients with major hip issue which are not indicated for total hip replacement such as perfuse infection or complete muscles paralysis or metastatic tumors etc.
- Patients with major segmental bone defect whereas on the femoral or acetabular sides.

c) Method

Operative steps

the patients were on lateral decubitus with anterior and posterior supports the posterior hip approach was utilized in all cases, and in revision cases, the incision was usually extended proximally and distally to define tissue planes more easily to release scars and to facilitate extensile exposures when needed. The femoral head and neck were resected in primary cases, and the existing prosthesis was removed in revision cases. Extended trochanteric osteotomy (ETO) was needed in most revision cases for stem extraction and better debridement preparation of the proximal femur before insertion of the femoral stem. The true floor and the transverse acetabular ligament (TAL) were identified after osteophytes removal. A Steinmann pin was then inserted in the posterior wall and ischium to protect the posterior soft tissues, including the sciatic nerve. Excision of the hypertrophied labrum and remnants of the anterior capsule was then performed.

Assessment for the acetabular defect: 360` Exposure of the acetabulum only possible through posterior hip approach and by the use of 3 bone leavers with the Steinmann pin Identification of the correct placement of the cup and the site of the acetabular defect before reaming were done.

The acetabulum was prepared with gouges and reamers to expose sufficient cancellous bone while maintaining subchondral plate at the periphery of the acetabulum for better mechanical support to the socket. The correct size of the acetabular component or the acetabular reconstruction augment, ring, or augmented dual-mobility cup that achieved maximum bony contact was determined before the sizing of the defect. With the trial cup in place, the defect was assessed, and the proposed position of IBG was determined using the trial components.

Impaction bone graft IBG

The autogenous head of the femur was used as the IBG in primary cases. In revision cases, one or two cryopreserved allogeneic femoral head was used. First, the femoral head was soaked in 5% povidone–iodine solution for 30 min and cut into morselized pieces of 0.5–1-cm diameter. In allogenic grafts, the morselized bones were soaked in a 10% hydrogen peroxide solution for 15 min. The morselized bones were then washed with saline. The morselized bones were then mixed with 2-g vancomycin. After bone bed preparation, the morselized bones were placed into the defect and well impacted using the cup impactor tool,

This was followed by the insertion of the acetabular cup with or without acetabular reconstruction construct, in uncemented acetabular components, cup stability was achieved by press-fit fixation, and we preferred to add supplemental screws to increase the stability of the acetabular cup. Femoral preparation will be done, followed by insertion of well fit femoral stem either cemented or cementless, then head will be inserted to the stem. A suction drain was applied, the capsule and muscles were reattached, and the wound was closed. Further operative details were being documented including: operation time, intraoperative blood loss or complications and postoperative.

d) Post-operative

- On the 1st postoperative day, AP pelvis X-ray was obtained to evaluate the cup position, correction of the center of rotation, offset restoration, filling the cavitary defects with bone graft, and improvement in leg-length discrepancy.
- AP X-ray of the femur up to the distal extent of the stem was obtained to assess the stem position within the medullary canal and the reduction of the trochanteric osteotomy.
- All the patients received postoperative antibiotic for 15 days.
- All the patients received thrombo-prophylaxis for 35 days.
- All the patients were being instructed for partial weight bearing for 6 weeks progressed to full weight bearing as tolerated. Where trochanteric osteotomy was done, full weight bearing was postponed to 12 weeks postoperatively.

e) Follow up

- The follow-up visits were being scheduled at 2 weeks, 6 weeks, 3 months, 6 months and 1 year for:

a) Post operative complications were managed by more visits as needed

b) Radiological evaluation by plain X-ray (Pelvis, AP, lateral views) and CT scan (at 6 months or 1 year visits) to show:
- any signs of loosening
- Impaction graft incorporation
- heterotrophic ossification
- any signs of bone on growth in cementless prosthesis

c) Clinical or functional outcomes of all cases were be evaluated again and compared using modified Harris hip score (mHHS) 6 months to 1-year post operatively.
- Graft incorporation was indicated by the continuation of trabecular lines from the graft into the host bone without resorption or fracture. Graft incorporation was classified at the last follow-up X-ray into complete incorporation, partial or early incorporation, no incorporation, or indistinct
- Additionally, graft consolidation was determined when the interface between the graft and normal bone was not identifiable with similar bone density.
- The graft layer thickness in the three DeLee and Charnley acetabular zones was measured at the widest graft layer in each zone, in the immediate postoperative X-rays with correction for magnification, Then, the overall mean graft layer thickness in all zones was calculate.

Statistical Analysis

Statistical analysis was done by SPSS v26 (IBM Inc., Armonk, NY, USA). Shapiro-Wilks test and histograms were used to evaluate the normality of the distribution of data. Quantitative data were presented as mean and standard deviation (SD). Comparison between pre and postoperative data was performed by paired t-test while comparison between partial and complete incorporation was performed by unpaired student t-test. Qualitative data were presented as frequency and percentage (%) and were analyzed using the Chi-square test or Fisher's exact test when appropriate. A two tailed P value ≤ 0.05 was considered statistically significant.

3. Results

This prospective study was conducted on 20 patients that were indicated for total hip arthroplasty with acetabular defect. The age of the studied patients ranged from 19 to 73 years with a mean± SD of 52.75±15.4 years. There were 12 (60%) males and 8 (40%) females. 12 (60%) operations were performed for the right side and 8 (40%) were for the left side (Table 1).

Table 1: Baseline characteristics of the studied patients.

		n=20
Age (years)	Mean± SD	52.75±15.4
	Range	19 - 73
Sex	Male	12 (60%)
	Female	8 (40%)
Affected side	Right	12 (60%)
	Left	8 (40%)

The indications for surgery were acetabular erosion by bipolar HAP in 6 (30%) patients, failed DHS with acetabular erosion in 1 (5%) patient, displaced acetabular fracture in 1 (5%) patient, fracture neck of femur & protrusio acetabuli in 2 (10%) patients, loose cemented THR in 3 (15%) patients, loose cementless THR in 4 (20%) patients, OA & protrusio acetabuli in 1 (5%) patient, and post-infection erosion (2nd stage with spacer) in 2 (10%) patients (Table 2)

Table 2: Indications of surgery of the studied patients.

	n=20
Acetabular erosion by bipolar HAP	6 (30%)
Failed DHS with acetabular erosion	1 (5%)
Displaced acetabular fracture	1 (5%)
Fracture neck of femur & Protrusio acetabuli	2 (10%)
Loose cemented THR	3 (15%)
Loose cementless THR	4 (20%)
OA & Protrusio acetabuli	1 (5%)
Post-infection erosion (2nd stage with spacer)	2 (10%)

The postoperative mHHS ranged from 69.2 to 87.1 with a mean± SD of 77.07±4.63. The findings were poor in 2 (10%) patients, fair in 14 (70%) patients, and good in 4 (20%) patients. Regarding the mHHS improvement, 8 (40%) patients had improvement of 21–50, and 12 (60%) patients had improvement of > 50 (Table 3).

Table 3: Postoperative mHHS of the studied patients.

		n=20
mHHS	Mean± SD	77.07±4.63
	Range	69.2 - 87.1
mHHS findings	Poor	2 (10%)
	Fair	14 (70%)
	Good	4 (20%)
mHHS improvement	21–50 points	8 (40%)
	> 50 points	12 (60%)

Intraoperative complications involved acetabular perforation with reaming in 1 (5%) patient, fracture of greater trochanter in 1 (5%) patient, and iatrogenic acetabular defect in 1 (5%) patient who was treated by conversion of the cup to augmented dual-mobility cup with flanges fixed by screws. Postoperative complications involved initial loosening of screws in 1 (5%) patient, temporary sciatic palsy in 1 (5%) patient who was resolved spontaneously, and dislocation in 1 (5%) patient (Table 4).

Table 4: Intra and postoperative complications of the studied patients.

		n=20
Intraoperative complications	Acetabular perforation with reaming	1 (5%)
	Fracture of greater trochanter	1 (5%)
	Iatrogenic acetabular defect	1 (5%)
Postoperative complications	Initial loosening of screws	1 (5%)
	Temporary sciatic palsy	1 (5%)
	Dislocation	1 (5%)

Regarding the radiological graft incorporation to host bone, 6 (30%) patients achieved partial incorporation while 14 (70%) patients achieved complete incorporation. No patients developed loosening of cup radiolucent line more than 2 mm or acetabular migration more than 5 mm. (Table 5).

Table 5: Radiological graft incorporation to host bone of the studied patients

	n=20
Partial incorporation	6 (30%)
Complete incorporation	14 (70%)

4. Case Presentation

Case 1

Male patient 65years old diabetic & hypertensive. patient has right acetabular erosion by bipolar HAP prepared for revision total hip arthroplasty. According to the AAOS classification patients had acetabular defect type IIA. Acetabular reconstruction using augment was done. The graft type was allograft. The cup was cemented dual mobility cups. The duration of surgery was 3 h. The blood transfusion was needed. the preoperative LLD the patients had shortening of the operated limb of 1 cm. The postoperative LLD was within 0 cm. The preoperative mHHS was 46. The postoperative mHHS was 71. No complication was reported intraoperative or postoperative. No loosening of cup was reported.

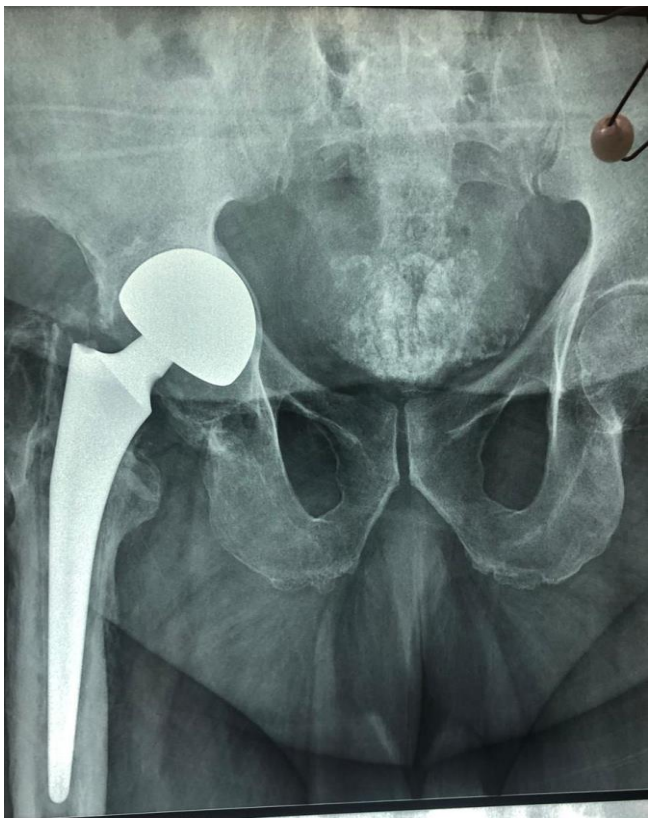

Fig 1: Preoperative x ray

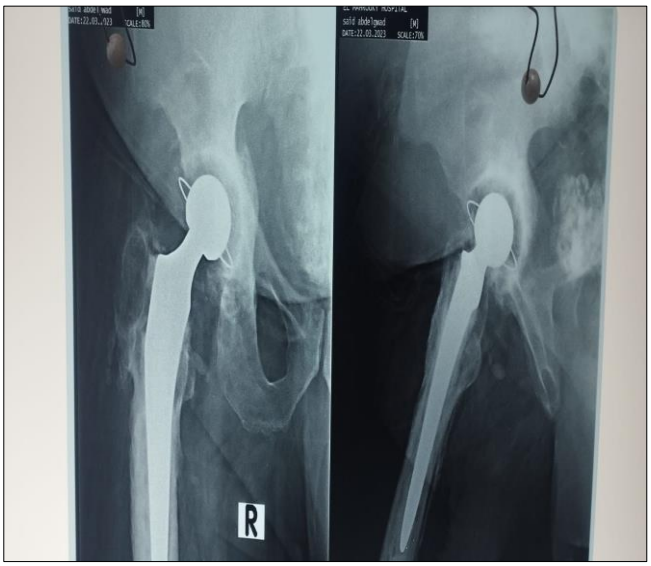

Fig 2: postoperative x ray

Case 2

Male patient 65years old hypertensive. patient has Left displaced acetabular Fracture by prepared for total hip arthroplasty. According to the AAOS classification patients had acetabular defect type IIB. Acetabular reconstruction using augment was done. The graft type was allograft. The cup was cemented dual mobility cups. The duration of surgery was 2.5 h. The blood transfusion was needed. the preoperative LLD the patients had shortening of the operated limb of 3 cm. The postoperative LLD was within 1 cm. The preoperative mHHS was 54. The postoperative mHHS was 78. No complication was reported intraoperative or postoperative. No loosening of cup was reported.

Fig 3: Preoperative x ray

Fig 6: postoperative x ray.

4. Discussion

Cavitary deficiencies can be managed with IBG alone; however, IBG in segmental or combined acetabular deficiencies usually requires supplementary implants such as metal mesh, rings, or cages to close peripheral defects and convert the non-contained into contained defects. [12]

Despite good reported clinical results with IBG for acetabular deficiencies, failure of graft incorporation,

insufficient cement mantle, and inadequate stability may lead to cup loosening, migration, or subsidence [13].

In the study The age of patients ranged from 19 to 73 years with a mean±SD of 52.75±15.4 years. There were 12 (60%) males and 8 (40%) females. 12 (60%) operations were performed for the right side and 8 (40%) were for the left side. The acetabular reconstruction was performed in conjunction with primary THA in 5 (25%) patients, while 15 (75%) patients had revision THA.

Abu-Zeid M., *et al*. [14] conducted a study to report the functional and radiological results of acetabular reconstruction using impaction bone grafting (IBG) in patients with acetabular bone deficiency undergoing primary or revision THA. The study includes 50 patients with a mean age of 46.7 ± 15.3 years. The mean body mass index (BMI) was 28.7 ± 3.7 (range 22–35) kg/m^2. Twenty-three (46%) operations were done for the right side and 27 (54%) were for the left side. the THA was primary in 14 (28%) patients and revision in 36 (72%) patients.

Rohe, S., *et al*. [15] conducted a study to determine the cup survival after biological restoration of acetabular defects in THA. the Mean age of the 82 patients at the index operation was 70.3 ± 9 years. All patients had a previous operation of the hip, 22.6% had two, 6.8% three, 3.4% four and 1.1% five previous operations.

The indications for surgery were acetabular erosion by bipolar HAP in 6 (30%) patients, failed DHS with acetabular erosion in 1 (5%) patient, displaced acetabular fracture in 1 (5%) patient, fracture neck of femur & protrusio acetabuli in 2 (10%) patients, loose cemented THR in 3 (15%) patients, loose cementless THR in 4 (20%) patients, OA & protrusio acetabuli in 1 (5%) patient, and post-infection erosion (2nd stage with spacer) in 2 (10%) patients.

Abu-Zeid M., *et al*. [14] showed that The indications for primary THA were protrusio acetabuli (n = 8), femoral neck fractures associated with protrusio acetabuli (n = 4), and femoral head fracture-dislocation (n = 2). The indications for revision THA were aseptic loosening of THR (n = 24), aseptic loosening of bipolar hemiarthroplasty (n = 6), septic loosening of THR (n = 4), and recurrent dislocation after THR (n = 2). The four patients with septic loosening were treated by two-stage revision arthroplasty.

Rohe, S., *et al*. [15] showed that the Indication for index revision surgery was aseptic loosening (81.6%), aseptic loosening in presence of osteolysis by wearing of the PE-inlay (8%), periprosthetic fractures (4.6%) and septic loosening (5.8%). Femoral head allografts from our bone bank were used in all cases. 25 patients (44.8%) had a solid structured bulk graft, 18 (32.2%) cortico-cancellous bone chips and 13 (23%) were treated with a combination of bulk and cortico-cancellous bone grafts.

The trochanteric osteotomy was

The preoperative mHHS ranged from 0 to 65.6 with a mean±SD of 19.55±25.26. The postoperative mHHS ranged from 69.2 to 87.1 with a mean±SD of 77.07±4.63. The findings were poor in 2 (10%) patients, fair in 14 (70%) patients, and good in 4 (20%) patients. Regarding the mHHS improvement, 8 (40%) patients had improvement of 21–50, and 12 (60%) patients had improvement of > 50. By Comparison of mHHS pre and postoperative The mHHS was significantly improved after the acetabular defects grafting.

Abu-Zeid M., *et al*. [14] showed that the mean HHS increased significantly to 76.6 ± 6.1 (range 60–87) at the last follow-up visit, p < 0.001. The results were good in 12 (24%) patients, fair in 30 (60%) patients, and poor in 8 (16%) patients. Regarding the HSS improvement, 30 (60%) patients had improvement of 21–50, and 20 (40%) patients had improvement of > 50.

Intraoperative complications involved acetabular perforation with reaming in 1 (5%) patient, fracture of greater trochanter in 1 (5%) patient, and iatrogenic acetabular defect in 1 (5%) patient who was treated by conversion of the cup to augmented dual-mobility cup with flanges fixed by screws. Postoperative complications involved initial loosening of screws in 1 (5%) patient, temporary sciatic palsy in 1 (5%) patient who was resolved spontaneously, and dislocation in 1 (5%) patient.

Abu-Zeid M., *et al*. [14] showed that Intraoperative complications included iatrogenic acetabular defect (n = 1) treated immediately by conversion of the cup to augmented dual-mobility cup with flanges fixed by screws, greater trochanteric fracture (n = 1), and acetabular perforation with reaming were no affection of cup stability (n = 1). Postoperative complications included sciatic nerve traction palsy (n = 2), which was resolved spontaneously in 4 weeks.

Rohe, S., *et al*. [15] showed that 46 of 56 patients had no further operation (82%). 10 patients (18%) had complications after the cup exchange and bone grafting while some occurred in the same patient: 6 aseptic cup loosening (2 press fit cups, 2 jumbo cups, 2 revision cages), 4 periprosthetic infections, 2 recurrent dislocations, 1 periprosthetic fracture and 1 major limb amputation of the thigh on both sides.

The patients' satisfaction was moderate in 2 (10%) patients and high in 18 (90%) patients.

In agreement with our result Abu-Zeid M., *et al*. [14] showed that patient satisfaction was graded as high (very satisfied) in 44 (88%) patients, moderate (Somewhat satisfied) in 4 (8%) patients, and low (Somewhat dissatisfied) in 2 (4%) patients.

Rohe, S., *et al*. **(15)** showed that an allogenic bone reconstruction of the acetabulum can lead to satisfactory biomechanical results.

Özdemir *et al*. [17] reported favorable long-term outcomes of cemented primary THA combined with IBG in patients younger than 25 years with acetabular bone deficiencies.

Significant improvement in HHS was reported by van Egmond *et al*. **(18)** with a 10-year survival rate of 88% in patients with large acetabular defects reconstructed with IBG and a cemented cup.

Buttaro *et al*. [19] reported 90.8% cup survival after using IBG, metal mesh, and cemented cup in patients with cavitary uncontained acetabular defects in revision THA, with a mean follow-up of 36 months.

Schreurs *et al*. [20] reported 96% and 84% cup survival at 10 and 15 years of follow-up, respectively, in patients undergoing acetabular revision with IBG and cemented cups.

van Haaren *et al*. [21] evaluated the outcomes of using IBG for large deficiencies and reported a high rate of failure, but the used graft in all patients was allograft not autograft.

Mozafari *et al*. [22] reported 96.5% rate of complete graft incorporation in patients with dysplastic hips with over 30% acetabular bone defect who had impaction autograft and cementless THA, with a mean follow-up of 93.3 months.

De la Torre-Escuredo *et al*. [23] reported that using combined IBG with trabecular metal augments yielded satisfactory outcomes in young adults with extensive acetabular defects. There was no significant difference in abduction angle or cup migration at the last follow-up compared to the immediate postoperative radiograph. Similarly, Gill *et al*. [24] reported no failure after using IBG combined with trabecular metal augments in 15 acetabular defects of Paprosky types 2B and 3A.

Regarding the radiological graft incorporation to host bone, 6 (30%) patients achieved partial incorporation while 14 (70%) patients achieved complete incorporation. No patients developed loosening of cup radiolucent line more than 2 mm or acetabular migration more than 5 mm.

Abu-Zeid M., *et al*. [14] showed that Regarding the radiological graft incorporation to host bone, 35 (70%) patients had complete incorporation, and 15 (30%) patients had partial incorporation. Partial incorporation was noticed in Delee and Charnley zone 3 ($n = 12$) and zone 2 ($n = 3$). Graft consolidation was confirmed in 28 (56%) patients.

This study has some limitations, including the absence of a control group, and the wide diversity of cases such as using autograft or allograft and primary or revision THA. We were unable to separate primary and revision THA cases due to the relatively small number of patients. Additionally, we did not quantify the amount of bone graft intra- or postoperatively. Also, multivariable analysis was not performed when assessing the factors affecting the rate of HHS improvement. Finally, the follow-up period was relatively short and inadequate to exclude late complications such as component loosening. However, it was long enough to assess IBG incorporation and its influencing factors.

5. Conclusion

Impaction Bone Graft for acetabular reconstruction in THA can achieve satisfactory results with high rate of radiological graft incorporation and low complication rate. Factors associated with favorable graft incorporation include primary THA, autografts, cementless cups, reduced defect size, and decreased thickness of the graft layer.

6. Conflict of Interest

Not available

7. Financial Support

Not available

8. References

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