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Original Research

Both Acetabular and Femoral Reconstructions With Impaction Bone Grafting in Revision Total Hip Arthroplasty: Case Series and Literature Review

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ABSTRACT

Background: Extensive bone loss on femur and acetabulum posed a big challenge to orthopedists in total hip revision surgeries. Impaction bone grafting (IBG) as a valuable bone preservation technique could effectively address this problem. Either IBG revision on the femoral or acetabular side was well studied, while its use on both sides in one operation was not. The aim of this study is to present the outcomes of IBG on both femoral and acetabular sides at first-time hip revision.

Methods: We retrospectively reviewed 8 patients (mean follow-up of 5.8 years) undergoing first-time revision with IBG on both acetabular and femoral sides at our institution. The Paprosky classification system was used to classify bone defects. Freeze-dried allografts and cemented prostheses were used in all patients. Postoperative complications and rerevision rates were reported.

Results: Five patients presented a Paprosky type IIC acetabular defect, 3 with a type IIIB, IIIA, and IIC defect, respectively. Three patients presented with a type IV femoral defect, 3 with a type IIIB defect, and 2 with a type II defect. Two patients developed complications, while one had an intraoperative femoral fracture and one had delayed wound healing. At the latest follow-up, no patient had rerevisions or operations related to the prosthesis.

Conclusions: IBG in combination with cemented prosthesis is a profitable biological reconstruction revision technique that could provide satisfying midterm outcomes. We first propose the use of blood clots mixed with bone grafts for potential bone incorporation enhancement, while its specific effects need to be verified in further studies.

Introduction

Reconstruction of proximal femur and acetabulum has long been one of the most challenging problems in revision hip arthroplasty [1]. Multiple techniques have been used in dealing with this issue, including jumbo cup, reinforcement rings, and antiprotrusio cage, etc. on the acetabular side and proximally porous-coated uncemented stem and tapered stem, etc. on the femoral side [2,3]. However, the majority of them fail to address bone stock preservation and may consequently lead to deteriorative bone storage that can make future revision a knotty problem.

Impaction bone grafting (IBG), since its first use in acetabular reconstruction in January 1978 by Slooff et al. and femoral reconstruction in April 1987 by Gie et al., has proven to provide surprisingly satisfying outcomes [4,5]. Not only initial stability is achieved as many other revision techniques do, but more importantly, hip reconstruction is accomplished by repairing bone defects. Favorable outcomes have been reported during the past decades, as the 20-year survival rate was up to 98.8% on the femoral side and 87% on the acetabular side with aseptic loosening as the end point [6,7].

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Though IBG revision on either femoral side or acetabular side has been largely reported in the literature, its use on both the acetabular and femoral sides at first-time hip revision is poorly studied. As the result of one-side-only IBG revision could be unavoidably influenced by the other side, to clarify the independent efficacy of IBG in revision hip arthroplasty, there is a need to analyze the outcomes of IBG revision performed on both sides.

Material and methods

Between October 2013 and November 2018, 8 patients (2 males, 6 females; mean age 64 years; range, 51 to 74 years) undergoing IBG revision on both the acetabular and femoral sides at our institution were collected. Approval of this study was obtained from our institution's internal review board. Patients' digital medical records were reviewed to collect demographics, clinical characteristics, and operative data. Detailed radiographic examination was conducted, and the Paprosky classification system was used to classify femoral and acetabular bone defects [8,9]. Two senior fellows in the field of arthroplasty reviewed the preoperative radiographs and clinical data to reach a consensus about the failure mechanism. Any disagreements were resolved by discussion with and arbitration by our senior attending surgeon (Xinzhan Mao). Initial diagnosis was posttraumatic avascular necrosis in 3 patients, primary avascular necrosis in 4 patients, and unknown in one patient. The indications for revision total hip arthroplasty were all aseptic loosening of the acetabular and femoral components.

All patients routinely received prophylactic first-generation cephalosporin (1 gram, once) and tranexamic acid (1000 mg, once) 30 minutes preoperatively. Five patients were operated on the left hip and 3 on the right hip under general anesthesia. All surgeries were performed through a standard posterolateral approach by one surgeon. Postoperatively, intravenous first-generation cephalosporin was given for 24 hours. Low-molecular-weight heparin (4000 IU qd) was given to all patients for thromboembolic prophylaxis during hospital stay and substituted by aspirin (100 mg qd) or rivaroxaban (2.5 mg Bid) after discharge for 35 days in total. Straight leg raise exercise was started on the second postoperative day, and partial weight bearing was allowed after drainage tube removal. Follow-up visits after surgeries were planned in the first, third, and sixth postoperative months and annually thereafter. Without using clinical scores to assess patients' functional outcomes, we preferred to record more specific self-reported complaints. Major complications defined as deep venous thrombosis and pulmonary embolus, as well as implant-related complications such as periprosthetic joint infection, dislocation, and periprosthetic fractures were recorded. The average follow-up was 5.8 years (range, 3.6 to 8.6 years). Telephone interview was made at the latest follow-up if the patient could not make the visit in person.

Bone grafts were taken from freeze-dried femoral heads (XKC, Beijing, China), which were irradiated at about 25 kGy. Intraoperatively, it was soaked in iodine complex for 15 minutes, then washed with pulsatile lavage. Bone cortex was completely removed, and the cancellous substance was morselized manually with rongeur, yielding cancellous bone chips from 4 mm to 8 mm. Prepared bone chips were mixed with 1 gram of vancomycin powder (GENTLE PHARMA CO., Yunlin, China) per femoral head and fresh autologous coagula obtained from the wound (Fig. 1). The X-change revision instruments system (Stryker Howmedica, Newbury, UK) was used to impact grafts in all revisions. The X-Change revision mesh (Stryker Howmedica, Newbury, UK) and Simplex cement (Stryker Howmedica Osteonics, Rutherford, NJ) were used in all cases (Fig. 2).

Results

The clinical characteristics of the patients are listed in Table 1. All of these patients underwent their first-time revision. Stryker Exeter stem was cemented into the impacted graft bed in 7 patients, and a Link SP II long stem was used in one patient. Exeter X3 RimFit Acetabular Cup was used in all cases.

On the acetabular side, there was one case presenting a type IIIB defect, one case with a type IIIA defect, 5 cases with a type IIC defect, and one case with a type IIB defect. On the femoral side, there were 3 cases presenting a type IV defect, 3 cases with a type IIIB defect, and 2 cases with a type II defect. Uncontained bone loss on both the acetabular and femoral sides was identified in 4 patients. In total, 4 out of the 8 patients were revised with IBG in combination with metal mesh on both the acetabular and femoral sides, 2 with metal mesh used on the femoral side, and 2 with IBG only (Table 1; Fig. 3). Extended trochanteric osteotomy was performed in one patient. The average duration of operation (incision to close time) was 6.3 hours (range, 4.8-10 hours), with mean intraoperative hemorrhage of 600 ml.

Two patients developed complications. One patient who had intraoperative femoral fracture was treated with allograft struct wires fixation, which postponed her weight-bearing activity to start at the sixth postoperative week. One patient had delayed wound healing and was cured by prolonged antibiotics. At the latest follow-up, no patient had rerevision or operations related to the prosthesis (Fig. 4). All patients were mobile without using support for walks. Pain of the hip was not reported. Only 3 patients complained mild hip discomfort after walking a long distance.

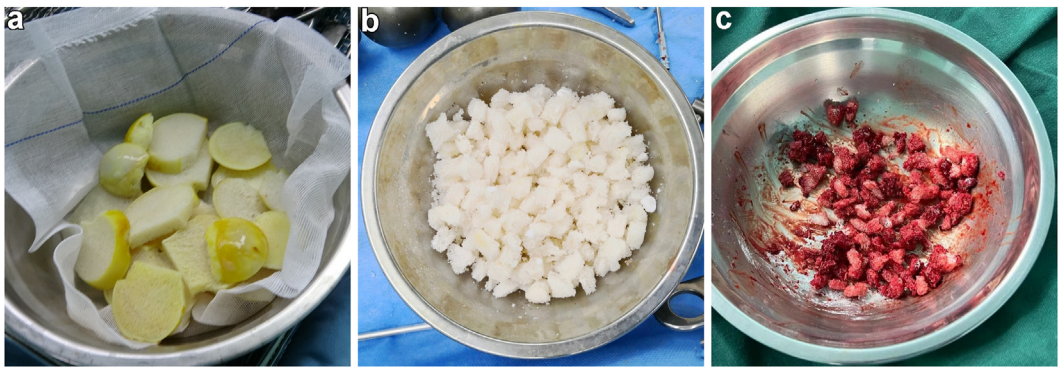

Figure 1. Intraoperative photographs of the preparation process of bone grafts. (a) Washed allografts. (b) Manually morselized bone chips. (c) Bone chips mixed with vancomycin and blood clots.

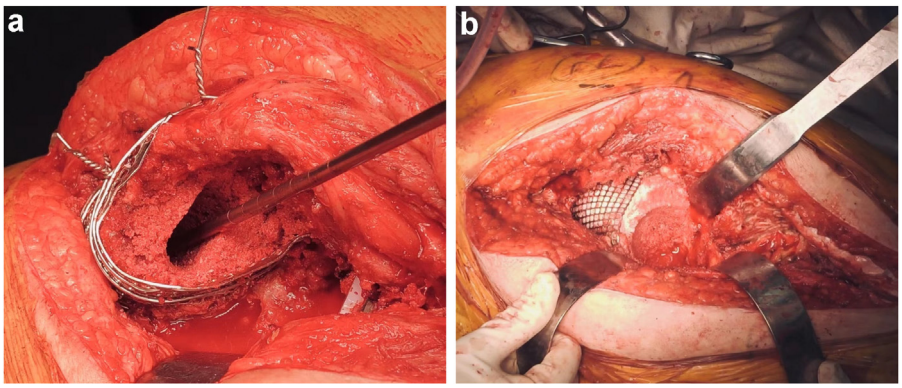

Figure 2. Intraoperative photos of reconstructed (a) femoral canal and (b) acetabular bed.

Discussion

Regarding people's increasing life expectancy and the rising number of revisions performed in young patients, the situation where orthopedists perform repeated revisions on the same patient will become inevitable. In hip revision arthroplasties, extensive bone deficiency is one of the most challenging problems [10]. Patients who are expected to undergo repeated revisions would experience cumulative bone loss and increasingly worse outcomes in later revisions if the bone defects were not preserved at the first-time revision. Although there are varying revision techniques, very few of them provide benefits for replenishing the loss of bone stock but IBG.

IBG on either femoral or acetabular side has been well studied in the literature. Comba et al. reported that 30 patients who underwent IBG revision on acetabular side had 7-year survival free of aseptic revision rating up to 96% and survivorship free of rerevision for any reason rating 89% [11]. Similarly, Morita found 94.7% survivorship free of aseptic revision and 90.8% survivorship free of rerevision for any reason in their cohort of 66 patients undergoing IBG revision on acetabular side with mean follow-up of 6.6 years [12]. Regarding IBG revision on femoral side, both midterm and long-term outcomes were reported in the literature. Buttaro et al. retrospectively reviewed 15 hips that had proximal femoral reconstructions with IBG and metal mesh and found the survivorship was 100% at 1 year and 86.6% at 6 years [13]. Heyligers et al. reported a 15-year survivorship of 100% in a cohort study of 33 femoral reconstructions with IBG [14].

To date, our study is one of the first to focus on IBG reconstruction of both the acetabulum and femur at the first-time hip arthroplasty revision using freeze-dried allografts. Though favorable outcomes of IBG revision on either the femoral side or acetabular side was commonly agreed, the outcome of first-time IBG revision on both sides is largely unknown. Stroet et al. studied 33 patients undergoing IBG revision on both the acetabular and femoral sides in a consecutive retrospective study. They reported a 10-year survival rate of 97% and 15-year survival rate of 90% with the end point of rerevision for aseptic loosening [15,16]. While around half of their patients had one or multiple prior revisions, the results could be inevitably biased, therefore hard to conclude the independent efficacy of IBG at the first-time revision. In our study, patients with an average follow-up of 5.8 years did not undergo rerevision or any operations related to the implants. This result is in accordance with the midterm outcomes of femoral or acetabular IBG hip revisions reported in the literature and is relatively better. All of our patients were freely mobile with no significant hip discomfort. Although several female patients complained of mild hip pain when the weather changed, it may not be related to the implants [17].

The option of impaction bone grafts can either be fresh frozen or freeze-dried allografts. Fresh-frozen allogenic bone used to be the standard source for grafting. However, the scarcity of supply and difficult storage has limited its extensive use [18]. Irradiated freeze-dried allograft, with easy storage and similar mechanical nature, is suggested to be a good alternative. To address the concern of contamination of freeze-dried allografts, cobalt-60 source of gamma radiation is applied [19]. Generally, 10 to 35 kGy gamma irradiation is applied to sterilize bone graft [20]. Debate exists on the application of proper radiation doses. Lower doses may add to the concern of insufficient sterilization, while higher doses may produce unacceptable strength of bone allografts. Dux et al. found that the commonly used 30 kGy doses of gamma radiation could alter the failure processes of cancellous bone resulting in increased microfracture, reduced amounts of cross-hatching type diffuse damage, and increased residual strain, which would make bone tissue more brittle [21]. In an in vivo study, Hernigou et al. found

Table 1
Demographic data of all cases.

Case	Age	Gender	Laterality	Revision date	Paprosky (femoral side)	Paprosky (acetabular side)	Follow-up (y)
1	51	Female	Left	2013	II	IIC	8.6
2	74	Female	Left	2014	IV	IIB	7.9
3	65	Female	Left	2015	IIIB	IIIB	6.8
4	60	Female	Right	2016	IIIB	IIIA	6.1
5	72	Female	Left	2017	IV	IIC	4.5
6	58	Male	Right	2017	II	IIC	4.6
7	62	Male	Left	2018	IIIB	IIC	3.6
8	68	Female	Right	2018	IV	IIC	4.2

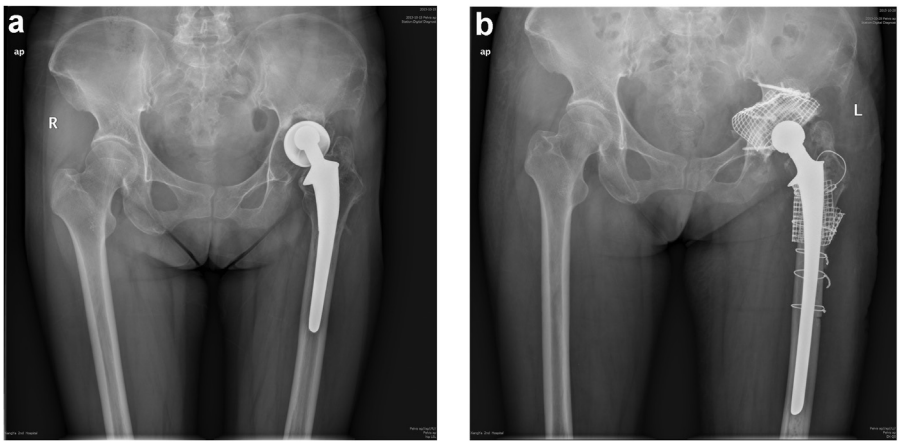

Figure 3. (a) Preoperative and (b) postoperative radiographs of case one.

the incidence of mechanical complication was as low as 5.5% in patients implanted with allografts irradiated at 25 kGy, which was not significantly different from nonirradiated grafts [22]. On top of these reports, Zhang et al. found minimal change in the strength of iliac crest wedges irradiated at 20 to 25 kGy dose [23]. These studies demonstrate that the irradiation doses on the grafts used in our study are acceptable and would not make mechanical impairment. In addition to vancomycin, we mixed bone grafts with blood clots obtained from patients' wounds, which we thought could enhance allograft remodeling. Lu et al. reported that fresh autologous coagula could promote angiogenesis in their ectopic bone allograft implantation model in comparison with freeze-dried allografts implanted alone [24]. Angiogenesis is believed to be pivotal for greater osteoblast differentiation and bone matrix synthesis, which can further improve consolidation of impacted grafts with the receptor bed [25]. Promotion of allograft angiogenesis may thereafter intensify bone incorporation. To our knowledge, there are no studies discussing the effect of fresh autologous coagula on allografts in hip revisions. Further in vivo studies and longer follow-ups are needed to clarify long-term effects on graft incorporation of this treatment.

There are several potential limitations of this study. First, we have a limited number of patients, which may weaken the reliability of our results. As we collect more samples in recent years, we will report more robust results and verify present outcomes in future research. Second, patients' self-reported complaints were used instead of patient-reported outcome measures. Although patient-reported outcome measures are helpful in evaluating patients' function recovery, we believe patients' complaints can reflect their satisfaction more directly. Third, not all patients have scheduled radiographic follow-ups, as some of them live in remote areas and it is not convenient for them to come back frequently. However, all patients do report high satisfaction at the latest follow-up, which implies that the in vivo prostheses function well.

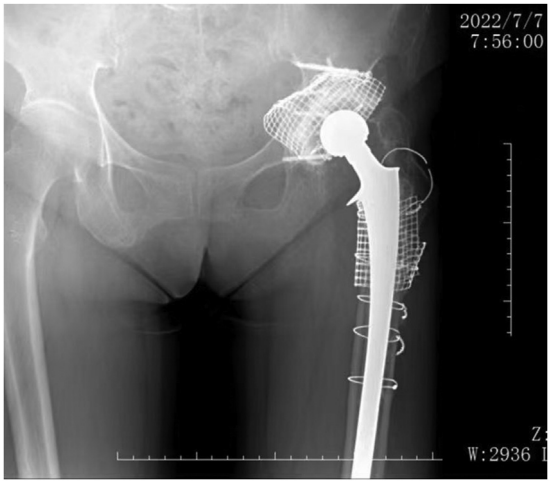

Figure 4. Eight-year follow-up radiograph of case one.

Conclusions

In conclusion, this study represents one of the first reported articles on the application of impaction bone grafting revision using freeze-dried allografts on both the acetabular and femoral sides of reconstruction. Our result reveals that impaction bone grafting in combination with cemented prostheses is a profitable biological revision technique and could provide satisfying midterm outcomes. Besides, we first propose the use of blood clots mixed with bone grafts, which may help enhance the process of bone incorporation, though its specific effects need to be verified in further studies.

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Conflicts of interest

The authors declare there are no conflicts of interest.

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Author contributions

L.X. substantially contributed to acquisition, analysis of data and drafting the paper. H.L. and X.H. conducted data interpretation and revised the manuscript. S.J., W.Z., J.P., and X.W. contributed to research design and revising the paper. X.M. supervised the study. All authors have read and approved the final submitted manuscript.

References

[1] Gamradt SC, Lieberman JR. Bone graft for revision hip arthroplasty: biology and future applications. Clin Orthop Relat Res 2003;417:183–94.

[2] Mancino F, Cacciola G, Di Matteo V, De Marco D, Greenberg A, Perisano C, et al. Reconstruction options and outcomes for acetabular bone loss in revision hip arthroplasty. Orthop Rev (Pavia) 2020;12:8655.
[3] Sheth NP, Nelson CL, Paprosky WG. Femoral bone loss in revision total hip arthroplasty: evaluation and management. J Am Acad Orthop Surg 2013;21:601–12.
[4] Gie GA, Linder L, Ling RSM, Simon JP, Slooff TJJH, Timperley AJ. Impacted cancellous allografts and cement for revision total hip arthroplasty. J Bone Joint Surg Br 1993;75:14–21.
[5] Slooff TJJH, Huiskes R, van Horn J, Lemmens AJ. Bone grafting in total hip replacement for acetabular protrusion. Acta Orthop 1984;55:593–6.
[6] Schreurs BW, Keurentjes JC, Gardeniers JWM, Verdonschot N, Slooff TJJH, Veth RPH. Acetabular revision with impacted morsellised cancellous bone grafting and a cemented acetabular component: a 20- to 25-year follow-up. J Bone Joint Surg Br 2009;91:1148–53.
[7] Wilson MJ, Hook S, Whitehouse SL, Timperley AJ, Gie GA. Femoral impaction bone grafting in revision hip arthroplasty 705 cases from the originating centre. Bone Joint J 2016;98:1611–9.
[8] Ibrahim DA, Fernando ND. Classifications in brief: the Paprosky classification of femoral bone loss. Clin Orthop Relat Res 2017;475:917–21.
[9] Telleria JJM, Gee AO. Classifications in brief: Paprosky classification of acetabular bone loss. Clin Orthop Relat Res 2013;471:3725–30.
[10] Astore F, Molho NM, Piccaluga F, Comba F, Slullitel PA, Buttaro MA. Impaction bone grafting for severe femoral Bone Loss. JBJS Essent Surg Tech 2022;12:e20.00043.
[11] Comba F, Buttaro M, Pusso R, Piccaluga F. Acetabular revision surgery with impacted bone allografts and cemented cups in patients younger than 55 years. Int Orthop 2009;33:611–6.
[12] Iwase T, Ito T, Morita D. Massive bone defect compromises postoperative cup survivorship of acetabular revision hip arthroplasty with impaction bone grafting. J Arthroplasty 2014;29:2424–9.
[13] Buttaro MA, Comba F, Piccaluga F. Proximal femoral reconstructions with bone impaction grafting and metal mesh. Clin Orthop Relat Res 2009;20:331–9.
[14] Heyligers IC, Schreurs BW, Van Haaren EH. Femoral revision with impaction bone grafting and a cemented polished tapered stem. Oper Orthop Traumatol 2014;26:156–61.
[15] Verspeek J, Nijenhuis TA, Kuijpers MFL, Rijnen WHC, Schreurs BW. What are the long-term results of cemented revision THA with use of both acetabular and femoral impaction bone grafting in patients younger than 55 Years? Clin Orthop Relat Res 2021;479:84–91.
[16] te Stroet MAJ, Rijnen WHC, Gardeniers JWM, van Kampen A, Schreurs BW. Satisfying outcomes scores and survivorship achieved with impaction grafting for revision THA in young patients. Clin Orthop Relat Res 2015;473:3867–75.
[17] Shulman BS, Marcano AI, Davidovitch RI, Karia R, Egol KA. Nature's wrath—the effect of weather on pain following orthopaedic trauma. Injury 2016;47:1841–6.
[18] Pierannunzii L, Zagra L. Bone grafts, bone graft extenders, substitutes and enhancers for acetabular reconstruction in revision total hip arthroplasty. EFORT Open Rev 2016;1:431–9.
[19] Nguyen H, Morgan DAF, Forwood MR. Sterilization of allograft bone: effects of gamma irradiation on allograft biology and biomechanics. Cell Tissue Bank 2007;8:93–105.
[20] Nguyen H, Morgan DAF, Forwood MR. Sterilization of allograft bone: is 25 kGy the gold standard for gamma irradiation? Cell Tissue Bank 2007;8:81–91.
[21] Dux SJ, Ramsey D, Chu EH, Rimnac CM, Hernandez CJ. Alterations in damage processes in dense cancellous bone following gamma-radiation sterilization. J Biomech 2010;43:1509–13.
[22] Hernigou P, Delepine G, Goutallier D, Julieron A. Massive allografts sterilised by irradiation. Clinical results. J Bone Joint Surg Br 1993;75:904–13.
[23] Zhang Y, Homsi D, Gates K, Oakes K, Sutherland V, Wolfinbarger L. A comprehensive study of physical parameters, biomechanical properties, and statistical correlations of iliac crest bone wedges used in spinal fusion surgery: IV effect of gamma irradiation on mechanical and material properties. Spine (Phila Pa 1976) 1994;19:304–8.
[24] Lu H, Meng H, Lu S, Qin L, Zhao B, Wang A, et al. Freeze-dried and irradiated allograft bone combined with fresh autologous coagula promotes angiogenesis in an ectopic bone allograft implantation model. Connect Tissue Res 2018;59:233–44.
[25] Moreira DC, Sá CN, Setúbal Andrade MG, Bório dos Santos Calmon de Bittencourt TC, de Almeida Reis SR, Pithon MM, et al. Angiogenesis and osteogenesis at incorporation process of onlay bone graft. J Oral Maxillofac Surg 2013;71:2048–57.