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A Review and Description of Acetabular Impaction Bone Grafting: Updating the Traditional Technique

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Restoring acetabular bone loss in revision hip arthroplasty is a major challenge for the orthopaedic surgeon. This paper discusses the traditional cemented technique of impaction bone grafting as applied to the acetabulum, as well as the evolution of the technique to employ uncemented implants. Some of the recent published literature regarding these techniques is reviewed and the personal experiences of the senior author with these techniques are also reported.

Key Words: Total hip arthroplasty, Bone grafting, Bone cement, Acetabulum, Reoperation

INTRODUCTION

"…All reconstructions will eventually fail whether they are synthetic or biological. As surgeons our role is to prolong the time to failure, and to make sure that when failure occurs, further reconstruction is possible. Bone grafts restore bone for future surgery…"[1)]

Managing loss of both femoral and acetabular bone stock is a common issue for the revision hip surgeon. The aim of this review is to discuss the use of impaction bone grafting (IBG) in the light of current implants and techniques with a particular focus on the acetabulum. Technical considerations are provided by the senior author (S.S.).

Although there are various classifications to describe bone defects in both the femur and pelvis, these commonly require the surgeon to differentiate between contained and uncontained defects, with the aim of allowing the restoration of structural integrity, upon which the success of any revision surgery rests.

The key features of the technique of acetabular IBG include restoration of bone stock with all its inherent benefits, providing a stable acetabular component and restoration of an anatomical hip center.

While acetabular IBG was first described by Slooff et al.[2)] in 1984, it has undergone modification and evolution over time, not least by advances in instrumentation and surgical technique.

As its name implies, the procedure requires the impaction of cancellous bone chips (which are invariably allograft) into a contained bone defect. Impaction is achieved through careful employment of various impactors, and is an essential part of the success of the technique. Morcellisation of the bone graft allows adaptation to any shape of (contained) defect and various studies have demonstrated good

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histological incorporation of the graft bone, with difficulty in histological differentiation of donor and host bone at 83 months post-surgery[3]. According to some authors, cementation of a polyethylene acetabular component into the graft bed, rather than the use of uncemented components, results in superior outcomes. Bone cement does not appear to have any detrimental effect on bone graft healing and incorporation, and the grafted bone morsels along with polymethyl methacrylate (PMMA) cement form a biological composite at the wide bone cement interface. Any potential benefit of bone graft substitutes has not clearly been demonstrated in the literature[4].

INDICATIONS, CONTRA-INDICATIONS, ALTERNATIVES

IBG has been applied successfully to both simple cavity defects such as those seen in protrusio acetabulae, as well as more extensive segmental or acetabular wall defects. The latter require augmentation to convert these to contained stable cavities, and the use of metal mesh as well as trabecular metal (TM) augments has been well documented to this end[5-8].

Acetabular fractures that have been stabilised may also be amenable to this technique. The presence of infection precludes IBG and requires a staged procedure, and as long as infection has been appropriately eradicated, the technique can be employed at second stage surgery. A previous or recent history of local radiotherapy will not provide the appropriate environment for healing and graft incorporation, and alternative techniques should be employed in these cases.

An alternative biological solution to the problem of acetabular bone loss is the use of structural allograft which may be used in combination with non-biological alternatives. The use of large diameter uncemented "jumbo" acetabular components with or without bone graft is one such option[5]; these have the disadvantage of not restoring any lost bone, and also tend to produce a higher hip center, with consequent biomechanical disadvantages. Metal augments, TM cup-cage constructs, and custom-made triflange components may be used individually or in combination to address massive bone loss or pelvic discontinuity[9]. Finally, the cement-only or "cementoplasty" technique may have a place in a small minority of patients with higher morbidity and lower mobility[10], although there is a high rate of loosening.

Patients for whom revision surgery poses an unacceptably high risk of morbidity or mortality should undergo non-operative management.

TECHNICAL ASPECTS OF IMPACTION BONE GRAFTING

Routine preoperative work-up of the patient should include a complete history and examination, in order to ascertain the reason for and to aid planning revision surgery. Any findings suggestive of infection would relatively contra-indicate IBG at that sitting.

Diagnostic studies may therefore include aspiration and microbiological analysis prior to surgery. Our imaging examination protocol consists of standard anteroposterior (AP) and lateral radiographs of the hip, occasionally augmented by computed tomography scan, with the understanding that the presence of orthopaedic implants may cause image degradation. We find that the posterolateral approach with the patient positioned laterally provides excellent circumferential exposure of the acetabulum, although any well performed extensile approach familiar to the surgeon may be used.

Inadvertent bone loss during implant removal should be avoided. Once the acetabulum is adequately exposed and debrided of cement and fibrous tissue, the extent of bone defect can be assessed, which is invariably worse than that predicted on preoperative imaging. Large or segmental defects require cages or TM augments in addition to mesh to provide a stable contained construct.

As soon as the decision to proceed with IBG has been confirmed, the frozen femoral head allograft can begin thawing in warm saline. In some cases the requirement of two or more femoral heads must be anticipated by the surgeon.

The graft should be prepared using large rongeurs or a bonemill, although the latter produces a smaller size bone chip. Our experience confirms previously published data[7,11,12] showing that larger bone chip sizes of around 8 mm produce increased stability for acetabular IBG; therefore–despite being time-consuming–we recommend hand-made bone chips using rongeurs (Fig. 1-3).

Washing the graft in saline is advisable, and some surgeons also bathe the graft in a small amount of the patient's blood prior to implantation. There is evidence that rinsing the graft aids in achieving stability, perhaps by removing extraneous soft tissue which would otherwise hinder 5 incorporation[13].

The bone bed is prepared by removing any fibrous tissue as much as possible; however, if this is the only barrier between the medial wall and the intra-pelvic contents, it is left *in-situ*. Bleeding points of subchondral bone are the ideal bed for graft, and some surgeons advocate the use of small drill holes to perforate sclerotic bone[14].

The bone graft is applied in layers and each layer is well-impacted with hemispherical impactors[15]. Reverse reaming the graft bed may disrupt stability of the impacted graft by shear forces and should therefore be avoided[16].

Trial cup insertion can be performed at appropriate intervals; we prefer a 3 mm cement mantle, which means that the impactor is 6 mm larger than the planned polyethylene cup. After further lavage (some surgeons advocate hydrogen-peroxide) a low-viscosity PMMA cement is pressurised into the graft bed and the acetabular component implanted and held in its correct position until the appropriate curing time has elapsed.

Fig. 1. Ideal bone chip sizes, hand produced by rongeur, range between 8 mm and 10 mm.

Postoperatively patients undergo mobilised toe-touch weight bearing for a period of six weeks, followed by six weeks of partial weight bearing (Fig. 4-7).

IMPACTION GRAFTING STABILISATION IN COMPLEX COMBINED BONE DEFECTS

With the advent of new technology and success of TM and uncemented systems, the use of impaction grafting as originally performed has decreased. The relative paucity of femoral head bone graft and high fresh frozen femoral head unit cost outside larger centers has resulted in the more frequent use of uncemented systems. No doubt some early failures were reported in large combined defects if IBG was used in isolation and this was primarily due to lack of stability within the construct.

This reflects our clinical experience of observing early migration of the acetabular component within five years after what initially appeared to be well impacted bone grafting of the socket in the initial postoperative radiographs and

Fig. 2. Range of bone chip sizes, cancellous bone in the left dish and larger cortico-cancellous in the right.

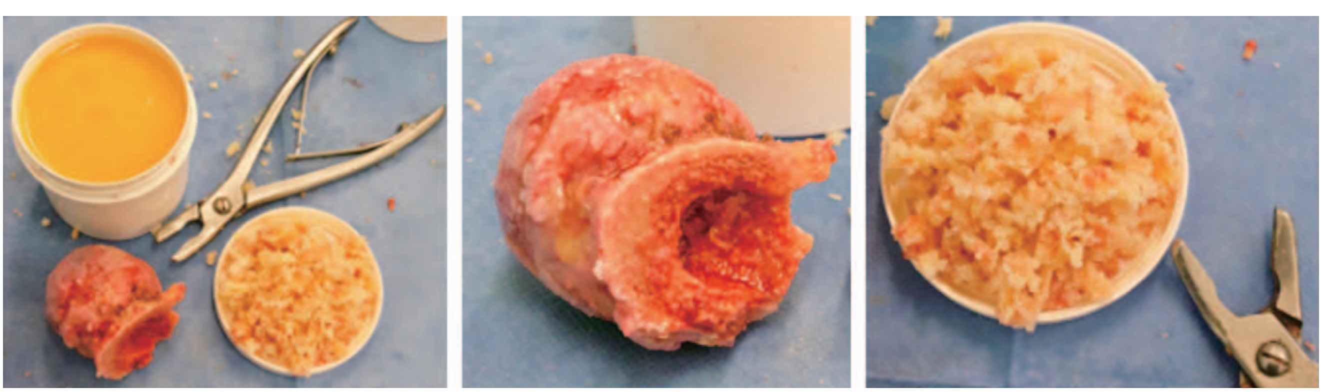

Fig. 3. In cases where the autograft bone quality is poor, cancellous bone is harvested, which may be augmented by cortico-cancellous allograft.

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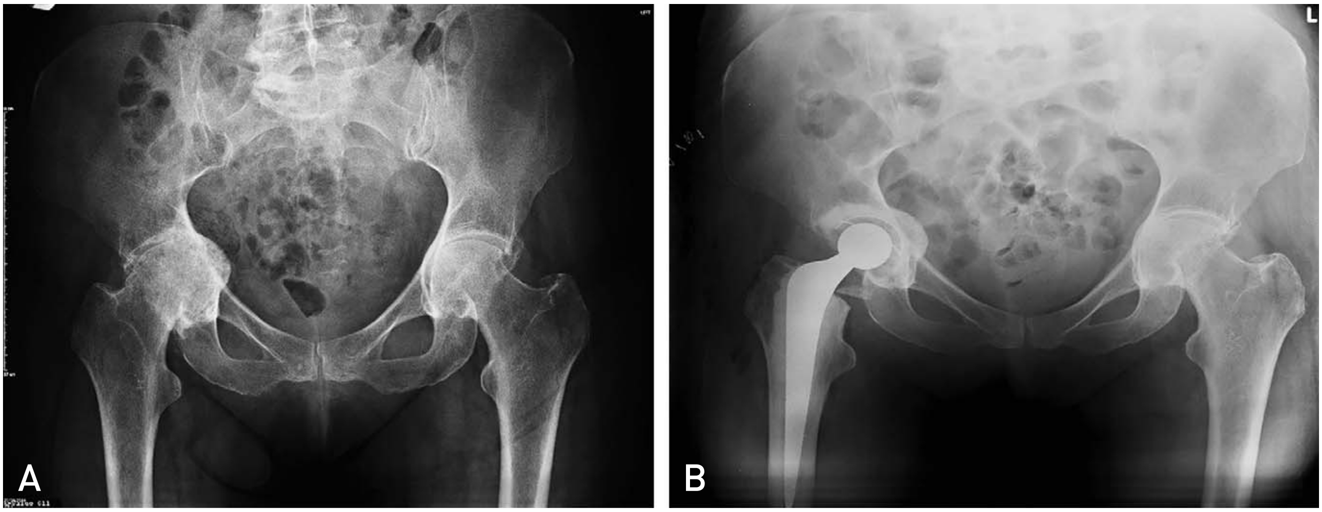

Fig. 4. (A, B) The use of impaction bone grafting in protrusio acetabulae, and the performance of a complex primary total hip replacement to restore hip biomechanics.

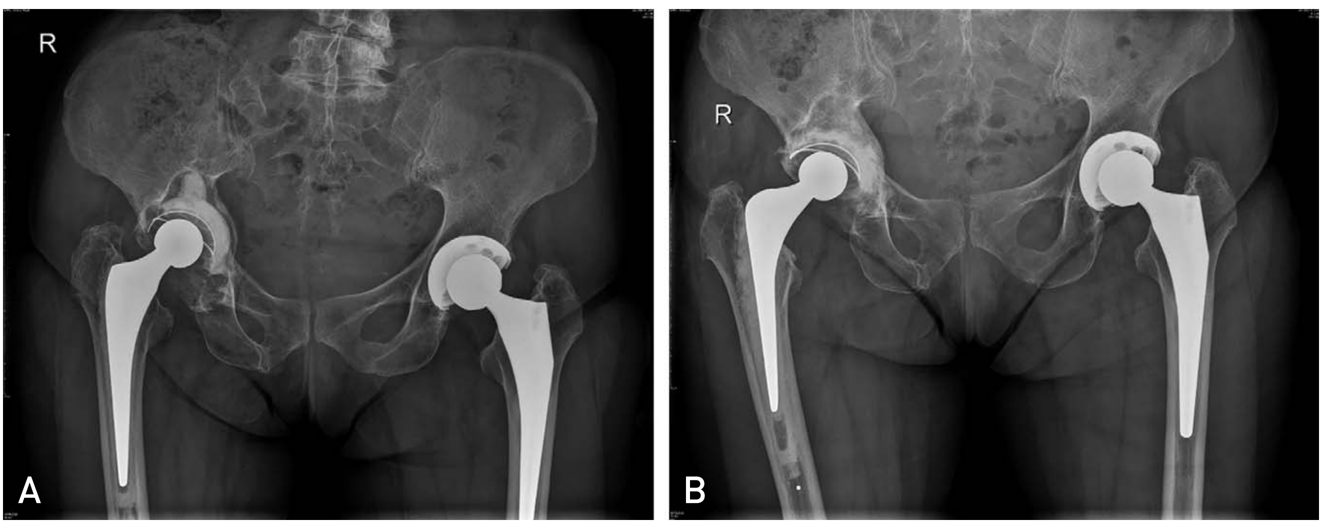

Fig. 5. Radiographs of a 77-year-old female undergoing revision of a loose cemented acetabular component. Preoperative radiograph (A) and 5-year follow-up radiograph (B) after impaction bone grafting and cemented cup on right. Restoration of bone stock, leg length, and femoral offset as well as incorporation of graft is shown.

at the first year post-surgery imaging.

The restoration of bone stock in younger people is nonetheless very attractive, and femoral head bone graft is still being used, both to fill defects and as structural allograft. Deviation from minute details of the traditional technique of impaction grafting outside major centers in the UK has not always produced good long-term results. Early failure of grafting in large central defects and superior defects will lead to failure of the impaction grafting technique. In our opinion, in these cases, the use of Gap Cup-Cage systems to add stability to the impacted graft is critical to avoiding failures.

The technique of impaction bone grafting can be combined with following options:

1) Impaction grafting with uncemented large cups

Where the traditional technique involved used of cemented cups along with impaction grafting, the current trend is to use this technique alongside modern uncemented shells.

2) Impaction grafting with stability shells such as the Gap Cup

In larger combined defects where it is felt that the cavitary defect is large and the posterior or anterior column are involved and become unstable, a metal shell augment is used both to confine the graft and provide initial stability for bone graft to incorporate. In our experience, the results

Fig. 6. Radiograph showing appearances after eight years. Note screw breakage, protrusio acetabulae deformity, and superior migration of acetabular component which demonstrates significant polyethylene wear.

Fig. 7. The same patient shown in Fig. 6, three years after acetabular impaction grafting. Note that the medial bone stock is restored and appears to have incorporated. Some features suggest that this implant may migrate as well.

of such cases at 5 years follow up are encouraging, as shown in Fig. 8-10.

DISCUSSION

Numerous well designed studies demonstrating good results of acetabular IBG in primary and revision total hip arthroplasty have been reported.

In 2013, Wilson et al.[8] reported excellent outcomes for purely cavitary defects of the acetabulum, with nine-year survival of 100% in 81 patients undergoing acetabular IBG during primary hip arthroplasty. Segmental and combined segmental-cavitary defects showed poorer results, perhaps owing to the more unstable nature of these patterns.

Gilbody et al.[17], who published a minimum 10-year follow-up series of 128 hips in 2014, reported that with aseptic loosening as the end-point, 85.9% survived for 13.5 years. The study included examination of multiple radiological markers as possible tools to predict or classify graft incorporation or loosening. There was no consistently useful radiological finding and the authors suggest that while persistent radiolucent lines may be a sign of aseptic loosening, this finding alone should be treated with care.

The excellent results published from the originating group have not always been reported in other studies. Kostensalo et al.[11] in 2015 reported relatively inferior results with a seven-year survival of only 73%; while they acknowledge that their results were comparable to those of van Haaren et al.[18] in 2007, a higher proportion of Paprosky III complex defects was common to both studies. Other confounding factors include duration of protected weight bearing postoperatively, and the use of smaller bone chip sizes.

Uncemented acetabular components are widely used in primary and revision hip arthroplasty and accepted as showing excellent results; however, the use of such implants with IBG is still gaining popularity compared with the traditional techniques described by Slooff et al.[2]. When performing IBG with uncemented cups, the principle of a cement-bone graft composite cannot exist, and initial stability would appear to be more tenuous. There remain significant proponents of this technique, citing excellent results for the management of type II defects.

In 2018, Stigbrand et al.[19] reported on their outcomes of 170 cases employing acetabular IBG with an uncemented titanium shell into which a polyethylene component was cemented. The overall 10-year survival was 92% and the

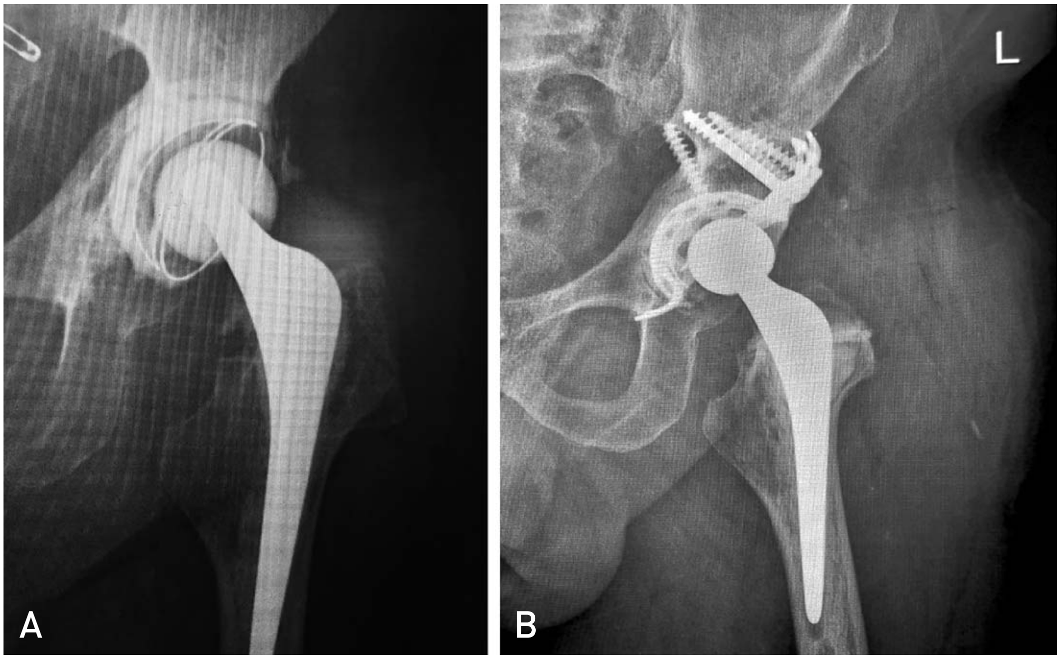

Fig. 8. (A) Radiograph of early failure of a cemented total hip replacement (THR) at four years postoperative in a 45-year-old amputee. Core biopsy result suggested low-grade infection. (B) Radiograph at 12 months post impaction bone grafting and good incorporation of graft with a Cup-Cage system.

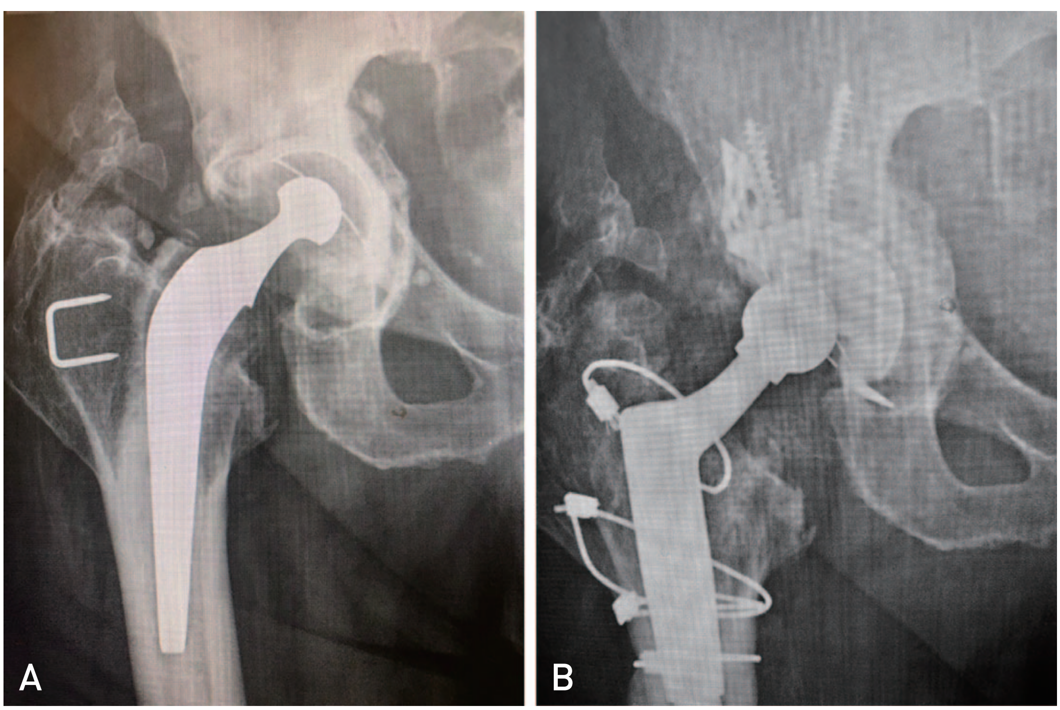

Fig. 9. Preoperative radiograph 2009 (A) and 10-year postoperative (B) radiographs 2019 of an 83-year-old patient undergoing revision of cemented total hip replacement.

authors report four factors contributing to a successful outcome, including meticulous graft preparation, containment of the bony defect, stability of the graft, and adequate loading of the graft, postulated to be at initial impaction and subsequently by the titanium shell.

In 2020, Perlbach et al.[20] reported excellent long term

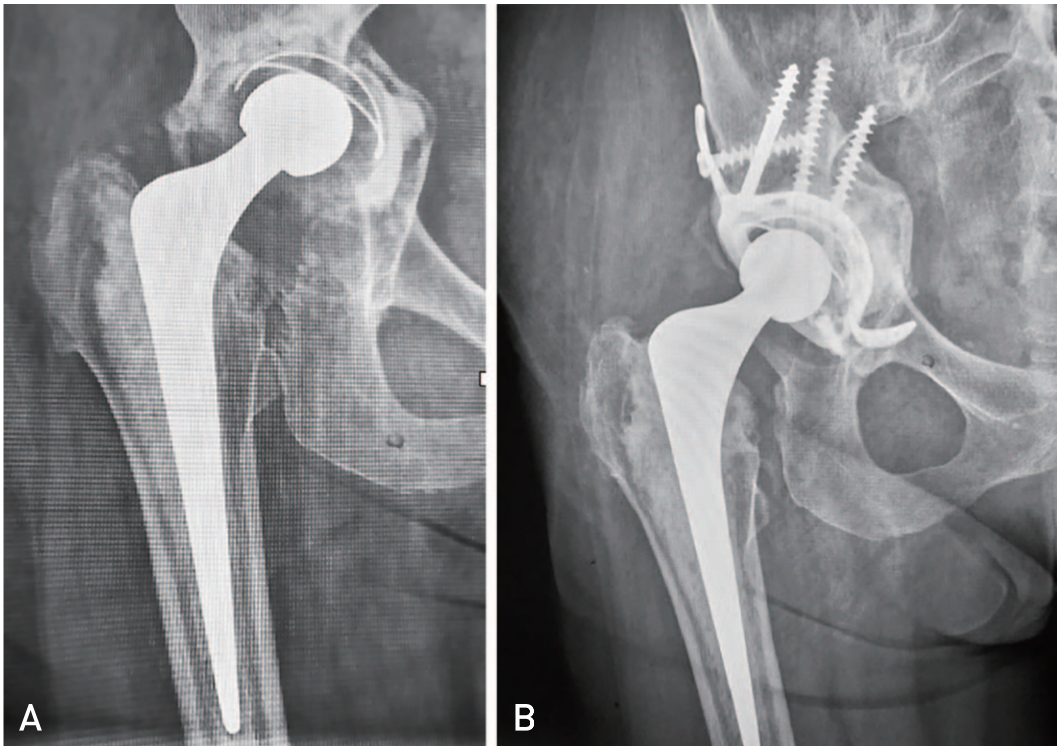

Fig. 10. Preoperative (A) and postoperative (B) radiographs showing central and superior migration of the cemented acetabular component. The cup-cage construct is useful to stabilise and prevent proximal migration, hence affording the construct increased stability.

outcomes, with 10- to 15-year follow-up of patients undergoing impaction grafting using uncemented implants. Their large cohort of patients, the majority of whom demonstrated type 3 combined defects, showed 10-year survival of 96.3% for aseptic loosening and 89.9% for re-operation for any reason.

The use of TM augments has shown reasonable early results in very large acetabular defects. Numerous studies have reported satisfactory outcomes of TM acetabular augments alone when used in primary or revision hip arthroplasty[5,17)], but few have reported their outcomes when TM and IBG are combined.

In 2012, Borland et al.[5)] used TM augments for segmental defects followed by standard IBG and a cemented cup. This prospective series of 24 patients had only one failure with follow-up of three to seven years. In their small series of 15 hips, Gill et al.[21)] postulated reduced component migration with the use of IBG with TM augments.

Areas of further investigation include variability of bone graft properties and the possible use of bone graft substitutes. Issues regarding the high cost, low availability, infection risk, and immunogenicity of femoral head allograft notwithstanding, the biological (osteoinductive) and mechanical (osteoconductive) properties of the bone graft alter by type (cancellous vs cortico-cancellous), as well as by the method of pre-treatment (fresh frozen vs freeze dried).

The use of synthetic bone substitutes has been proposed to address the aforementioned issues. Alternatives to allograft bone such as calcium phosphates and hydroxyapatite ceramics have been shown to demonstrate osseointegration and thus may have a place as bone graft extenders. In 2009, Blom et al.[4)] used a commercially available hydroxyapatite and calcium phosphate composite in a 50:50 mix with allograft with good results at 2-year follow-up.

CONCLUSION

The increasing burden of revision arthroplasty consequent to an ageing population, coupled with increased patient expectations and longevity will require well-proven and measured surgical solutions. It is likely to become commonplace for patients to undergo multiple revision surgeries and the costs associated with these will certainly become problematic for healthcare services. Although it is a time-consuming and technically demanding option, we believe that well-performed acetabular IBG is a cost effective option, which improves

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the viability of any future reconstruction in these patients.

CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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