Cancellous Impaction Bone Grafting of Acetabular Defects in Complex Primary and Revision Total Hip Arthroplasty

NILESH PATIL, MD; KATHERINE HWANG, MS; STUART B. GOODMAN, MD, PhD

abstract

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The reconstruction of major acetabular bone defects during revision, conversion, and primary total hip arthroplasties (THAs) is challenging. We reviewed a consecutive series of 168 THAs (108 revisions, 8 conversions, and 52 primary THAs) performed by 1 surgeon (S.B.G.) between 1997 and 2008 using impaction bone grafting for acetabular reconstruction. Autograft, cancellous allograft croutons, and demineralized bone matrix were used to fill bone defects as needed. The acetabular bone deficiency was classified according to the American Academy of Orthopaedic Surgeons: type I, segmental deficiency with significant rim defect; type II, cavitary defects medially or posteriorly; type III, combined cavitary and segmental deficiency; type IV, pelvic discontinuity; and type V, arthrodesis. According to this method, 56 hips had type I, 31 hips had type II, 48 hips had type III, and 27 hips had type IV deficiencies.

Of the 168 patients, 19 subsequently died of causes unrelated to the THA, and 11 were lost to follow-up. All patients had at least 2 years of follow-up. Average Harris Hip Score improved from 45.5 ± 17.9 preoperatively to 81.1 ± 16.5 postoperatively (P < .05) for revision THAs, from 40.0 ± 11.3 preoperatively to 85.0 ± 12.8 postoperatively (P < .05) for conversion THAs, and from 42.3 ± 14.9 preoperatively to 85.0 ± 12.0 postoperatively (P < .05) for primary THAs. All impaction grafted bone (allograft, autograft, or a combination) incorporated radiographically, thus restoring bone stock. Complications included 1 early infection, which was managed successfully with debridement and liner exchange, and 2 late infections that were managed successfully with staged revision. Two revisions required subsequent re-revision for late loosening. Two hip dislocations occurred, 1 of which required surgical treatment to place a constrained liner.

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Dr Patil is from Penn State Orthopedics, State College, Pennsylvania; and Ms Hwang and Dr Goodman are from the Department of Orthopaedic Surgery, Stanford University, Stanford, California.

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Correspondence should be addressed to: Stuart B. Goodman, MD, PhD, Department of Orthopaedic Surgery, Stanford University, R144, 300 Pasteur Dr, Stanford, CA 94305 (goodbone@stanford.edu).

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Figure: Preoperative anteroposterior pelvic radiograph of painful left hemiarthroplasty with acetabular bone loss and medial migration of the prosthetic head. The stem has migrated into varus (A). Anteroposterior pelvic radiograph 2 years after conversion total hip arthroplasty with impaction grafting of the acetabulum (B).
Acetabular bone deficiencies encountered during total hip arthroplasty (THA) vary from cavitary or segmental defects to complete discontinuity. These acetabular defects often present challenges in revision THA and result from periprosthetic osteolysis, implant migration, infection, congenital abnormalities, or iatrogenic bone loss during implant removal. Several techniques exist to manage these defects, including placement of a jumbo cup, use of a high hip center, specialized roof and reconstruction rings, modular porous metal augments, bone void fillers, or bulk or morselized bone grafts. The use of morselized cancellous bone graft and a cementless porous coated acetabular component is a well-established technique in acetabular revision surgery in the presence of bone deficiency. A high rate of graft incorporation has been reported when morselized bone graft is used in contained bone defects during acetabular reconstruction.

The current study analyzed the clinical and radiographic outcomes of a consecutive series of primary, conversion, and revision THAs in which acetabular defects were managed with impacted, morselized, cancellous bone graft.

Materials and Methods

This study was approved by our institution’s Internal Review Board, and all patients provided consent for the study. We retrospectively reviewed 168 consecutive THAs, including 108 revision THAs, 8 conversion THAs (ie, traumatic arthritis with internal fixation and unipolar, resurfacing, or resection THAs converted to THA), and 52 primary THAs performed by the senior author (S.B.G.) at our institution between 1997 and 2008 using cancellous bone grafting for acetabular reconstruction. Of the 168 patients, 19 patients subsequently died of causes unrelated to the THA, and 11 patients did not return for clinical follow-up and could not be contacted. Fourteen patients were contacted by mail for self-reported (questionnaire) clinical assessment. Overall, 93 patients with revision THAs, 7 patients with conversion THAs, and 38 patients with primary THAs were assessed. All patients had a minimum follow-up of 2 years.

In the entire cohort of 168 patients, the revision THA group comprised 41 men and 67 women (mean age, 65 years [range, 34-89 years]), the conversion THA group comprised 1 man and 7 women (mean age, 67.8 years [range, 54-87 years]), and the primary THA group comprised 12 men and 40 women (mean age, 55.6 years [range, 20-88 years]).

The diagnosis at revision was aseptic loosening in 40 patients, osteolysis with or without acetabular component loosening in 37 patients, instability in 24 patients, previous infection in 5 patients, liner dislodgement in 1 patient, and component malposition with iliopsoas impingement in 1 patient. The conversion THA group included 4 patients with posttraumatic arthritis and prior internal fixation, 2 patients with failed hemiarthroplasty, 1 patient with a failed hip resurfacing, and 1 patient with a resection THA. The presenting diagnosis in the primary THA group was hip dysplasia with secondary osteoarthritis in 25 patients, primary osteoarthritis in 12 patients, rheumatoid arthritis in 8 patients, avascular necrosis in 6 patients, and ankylosing spondylitis in 1 patient.

The mean duration from the index or primary procedure to revision surgery was 12.3 years (range, 1 month to 33 years). Fourteen patients had at least 1 revision procedure prior to revision THA, which included 6 patients with 3 previous revision procedures. Fifteen patients also underwent revision of the femoral component at acetabular revision.

The acetabular bone deficiency was classified according to the American Academy of Orthopaedic Surgeons: type I, segmental deficiency with significant rim defect; type II, cavitary defects medially or posteriorly; type III, combined cavitary and segmental deficiency; type IV, pelvic discontinuity; and type V, arthrodesis. This classification was based on the preoperative radiographs and intraoperative findings after removal of the cup. According to this method, 56 hips had type I, 31 hips had type II, 48 hips had type III, and 27 hips had type IV deficiencies. An additional 6 hips had bone grafting of extensive acetabular defects without removal of the stable cementless metal shell. A roof ring was used in 12 revision cases; a reconstruction cage construct was used in 17 revisions and 1 primary THA with severe hip dysplasia. Porous tantalum implants were used in 47 revision THAs and 3 primary THAs. Retention of the acetabular component, extensive cancellous bone grafting, and polyethylene liner exchange were performed in 6 cases. A constrained liner was used in 10 patients with hip instability; abductor reconstruction with Achilles tendon allograft was performed in 1 patient with hip instability.

All surgeries were performed under the direction of the senior author. A posterior approach was used in 45 revision THAs and 4 conversion THAs. A direct lateral approach was used in 49 primary THAs, 25 revision THAs, and 3 conversion THAs. A transtrochanteric approach was used in 28 revision THAs. A trochanteric slide was required in 10 revision THAs, 3 primary THAs, and 1 conversion THA.

Cancellous allograft croutons alone, obtained from the Musculoskeletal Transplant Foundation (Edison, New Jersey) were used in 38 revision THAs, 1 conversion THA, and 1 primary THA. Cancellous autograft obtained from acetalubar reamings, morselized femoral head, or both was used in 48 primary THAs, 4 conversion THAs, and 8 revision THAs. A combined mixture of allograft and autograft was used in 62 revision THAs, 3 conversion THAs, and 3 primary THAs. Demineralized bone matrix was mixed with allograft bone croutons for its osteoinductive potential in selected cases.
In cases with >50% loss of acetabular structural bone stock, in addition to the use of morselized autograft/allograft, a fresh-frozen structural allograft (femoral head or acetabulum) was used for acetabular reconstruction during 12 revision THAs and 1 primary THA.

The majority of patients were managed using a standardized surgical reconstructive technique and postoperative rehabilitation protocol from inception of our study. The only change was the introduction and subsequent use of a new technology that was not available when the study was initiated. We have been using trabecular metal implants since their introduction with excellent results, thus precluding the use of roof rings and cages. During the early part of our study, roof rings and cages were the only implants available for complex acetabular reconstruction.

In revision THA, the hip was carefully dislocated after adequate mobilization of the femur. The acetabular component was removed, preserving as much host bone as possible. The pseudomembrane at the bone–implant interface was thoroughly debrided. Gentle acetabular reaming was performed until adequate visualization of bleeding bone and optimum coverage was observed with the smallest possible reamer. Then, localized defects were filled with morselized allograft or combined bone graft (mixture of allograft and autograft obtained from the acetabular reamings) and firmly impacted. Reverse reaming was performed to impact the bone graft. Cavitary, segmental, or combined segmental and cavitary defects were managed with impaction bone grafting using morselized bone graft where good component stability could be obtained using the remaining posterior column and weight-bearing dome. The primary objective of acetabular preparation in type III or IV defects was to achieve a hemispherical acetabulum from an oval cavity with care being taken to avoid damage to the posterior column and dome. Then, a trial shell was placed in the acetabulum to assess stability of the component. In the case of inadequate stability using the trial component and significant bone deficiency, a structural allograft was used to support the acetabular component. A ring or cage construct with a cemented cup was used when <50% host bone contact existed earlier in the series.

For primary THAs with acetabular deficiency, the acetabular cavity was prepared in a similar fashion, except the bone defects were generally less extensive than revision procedures. Acetabular sockets were reamed line to line (earlier in the series) or underreamed by 1 mm depending on the bone quality. In primary and revision THAs, screws were used to augment the fixation with an average of 2 screws (range, 2-4 screws) in primary and conversion THA and 4 screws in revision THA (range, 4-7 screws).

Weight bearing was restricted to touch down for 6 weeks, followed by 50% weight bearing for 6 weeks in patients with compromised bone quality or poor host bone contact (<50%) as determined by intraoperative assessment. Full weight bearing was permitted at 12 weeks postoperatively. In patients with good bone stock and satisfactory initial mechanical stability, patients were permitted weight bearing as tolerated after 6 weeks.

Clinical evaluation was performed using the Harris Hip Score (HHS)\textsuperscript{19,20} preoperatively and at most recent follow-up, as well as the SF-12 or SF-36 and the Western Ontario and McMaster Universities Arthritis Index (WOMAC). Radiographic assessment was accomplished using the anteroposterior radiograph of the pelvis and cross-table lateral radiograph of the involved hip. Oblique Judet views and computed tomography scans of the pelvis were reviewed as available preoperatively. Serial radiographs were assessed for radiolucencies at the bone–implant interface, orientation and migration of the acetabular cup, breakage of the screws, and heterotopic ossification. Acetabular component inclination was measured on the anteroposterior pelvic radiograph, and radiolucent lines at the implant–bone interface were recorded according to the zones described by DeLee and Charnley.\textsuperscript{21} Radiographic cup loosening was based on the criteria of Schmalzried and Harris\textsuperscript{22} and included progressive cup migration using the acetabular teardrop and the femoral head size as landmarks and guides. Bone graft was considered incorporated when the amorphous radiodensity noted on the immediate postoperative radiographs was subsequently seen as a more uniform, less radiodense mass with the presence of continuous trabecular streaming, both within the host bone and adjacent cancellous allograft. Heterotopic ossification was graded according to the classification of Brooker et al.\textsuperscript{23}

RESULTS

For revision THA, mean follow-up was 43 months (range, 24-110 months). Average HHS improved from 45.5 ± 17.9 (range, 9-86) preoperatively to 81.1 ± 16.5 (range, 32-100) postoperatively (P < .05) (Table 1). Mean postoperative SF-12 and SF-36 Physical Health score was 41 and Mental Health score was 52 at a follow-up of 46.7 months (range, 22.8-140.8). Mean WOMAC pain, stiffness, and function scores were 82.6, 69.0, and 72.3, respectively (Table 2).

For conversion THA, mean follow-up was 41 months (range, 24-52 months). Average HHS improved from 40.0 ± 11.3 (range, 28-57) preoperatively to 85.0 ± 12.8 (range, 66-97) postoperatively (P < .05). Mean postoperative SF-12 and SF-36 score Physical Health score was 42 and Mental Health score was 59. Mean WOMAC pain, stiffness, and function scores were 83.8, 73.4, and 87, respectively.

For primary THA, mean follow-up was 45 months (range, 24-120 months). Average HHS improved from 42.3 ± 14.9 (range, 9-77) preoperatively to 85.0 ± 12.0 (range, 51-100) postoperatively (P < .05). Mean postoperative SF-12 and SF-36 Physical Health Score was 40 and Mental
Radiographic analysis revealed that the average acetabular inclination was 46° (range, 32°-62°) in the revision THA group, 44° (range, 36°-50°) in the conversion THA group, and 42° (range, 36°-55°) in the primary THA group. Characteristic trabecular bone streaming in the cancellous allograft and surrounding bone was evident in all primary THAs and in 70 of 83 revision THAs. The remaining 13 revision cases had an amorphous or sclerotic appearance to the bone graft (Figures 1-3). Twelve patients had grade I heterotopic ossification, 5 patients had grade II, 3 patients had grade III, and 1 patient had grade IV.

Seven patients in the revision THA group had radiolucency (<2 mm) in 1 zone and 6 had radiolucencies (<2 mm) in 2 zones. The 6 patients with radiolucencies in 2 zones included 2 patients with rheumatoid arthritis and 2 patients who underwent >2 revision procedures before the index revision. No patients undergoing revision THA had progressive radiolucency (>2 mm) in all 3 zones or component migration. Two patients in the primary THA group had radiolucency (<2 mm) restricted to 1 zone. One patient with severe hip dysplasia who had multiple procedures before the primary THA had radiolucencies in 2 zones. One patient with severe protrusio and soft bone due to juvenile idiopathic arthritis who underwent primary THA had radiographic evidence of component migration (change in angle of acetabular inclination >5°). However, the cup has subsequently integrated with the surrounding bone, which has consolidated. No further surgery was necessary.

Two patients developed deep periprosthetic infection at 24 and 40 months, respectively, after revision THA. Both patients were managed with 2-stage revision procedures and have good function and an HHS >85 at latest follow-up. Another patient developed a methicillin-resistant staphylococcal infection 1 month following revision, which was managed successfully by debridement, femoral head and acetabular liner exchange, and 6 weeks of intravenous antibiotics.

Two patients were revised for aseptic failure at 77 months and 24 months, respectively, following revision THA. One patient had a reconstruction cage and allograft construct and had been revised 3 times before the present revision procedure. One patient had juvenile idiopathic arthritis revised for aseptic loosening with a porous coated cementless acetabular component.

One patient fell, sustaining a periprosthetic fracture (Vancouver type C) of the femur 3 months after revision THA. The fracture was managed with open reduction and internal fixation with a locked compression plate. This patient had excellent function (HHS=92) at 48-month follow-up. One patient with grade IV heterotopic

#### Table 1

<table>
<thead>
<tr>
<th>Harris Hip Scores</th>
<th>Mean Harris Hip Score (Range)</th>
<th>Mean Follow-up (Range), mo</th>
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<tbody>
<tr>
<td>THA Group</td>
<td>Preoperative</td>
<td>Postoperative</td>
</tr>
<tr>
<td>Revision (n=79)</td>
<td>45.5±17.9 (9-86)</td>
<td>81.1±16.5 (28-57)</td>
</tr>
<tr>
<td>Conversion (n=7)</td>
<td>39.8±10.5 (28-57)</td>
<td>85.0±12.8 (66-97)</td>
</tr>
<tr>
<td>Primary (n=43)</td>
<td>42.3±14.9 (9-77)</td>
<td>85±12.1 (51-100)</td>
</tr>
</tbody>
</table>

Abbreviation: THA, total hip arthroplasty.

#### Table 2

<table>
<thead>
<tr>
<th>WOMAC Scores</th>
<th>Revision THA (n=65)</th>
<th>Conversion THA (n=7)</th>
<th>Primary THA (n=31)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
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</tr>
<tr>
<td>Pain</td>
<td>56.7</td>
<td>60</td>
<td>38.4</td>
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<tr>
<td>Stiffness</td>
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<td>44.6</td>
<td>39.2</td>
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<tr>
<td>Physical function</td>
<td>56.6</td>
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<tr>
<td></td>
<td>Postoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>82.6</td>
<td>83.8</td>
<td>86</td>
</tr>
<tr>
<td>Stiffness</td>
<td>69</td>
<td>73.4</td>
<td>73.8</td>
</tr>
<tr>
<td>Physical function</td>
<td>72.3</td>
<td>87</td>
<td>73.8</td>
</tr>
</tbody>
</table>

Abbreviations: THA, total hip arthroplasty; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

aMean postoperative follow-up, 46.8 months (range, 18.5-140.8 months).
bMean postoperative follow-up, 35.3 months (range, 22.3-50.1 months).
cMean postoperative follow-up, 45.7 months (range, 21.7-98.1 months).
ossification underwent excision of the heterotopic ossification with postoperative single-dose radiation therapy (700 rads) 1 year following revision THA. This patient had persistent stiffness and an HHS of 68 at 36-month follow-up. Subsequent excision of more bone with soft tissue releases has improved the patient’s function and range of motion.

Two patients had dislocation following revision THA. One patient was managed with closed reduction under anesthesia, and the other patient required cementing of a constrained liner for persistent instability.

**Discussion**

Impaction bone grafting allows the surgeon to obtain a stable construct while offering the potential to restore bone stock for future reconstructions, should they be necessary. Particulate cancellous autograft is expected to achieve reliable incorporation due to its characteristic osteogenic properties. Morselized cancellous allograft bone is primarily osteoconductive and functions as a scaffold to enhance bone formation on its surface. Histological retrieval studies have demonstrated consistent incorporation of particulate cancellous allograft used in the treatment of acetabular bone deficiencies.10,17,24-27

Several studies report impaction bone grafting with cemented sockets in revision THA when significant bone loss exists.4,7,11,12,28,29 Recently, cementless implants have gained increasing popularity for acetabular reconstruction in primary and revision THAs because of technical simplicity, potential for long-term biologic fixation, and good reported clinical results. Recent reports on the use of impaction bone grafting and cementless acetabular components in revision THA have demonstrated encouraging clinical results.9,26,30,31 A minimum of 50% host bone contact is considered necessary to enable stable fixation with a cementless porous coated acetabular component.5,8,32 Garcia-Cimbrelo et al5 reported a high failure rate with cementless acetabular components implanted in hips with bone defects >50% during revision surgery. Thus, the use of reconstruction rings or cages has been recommended where the remaining host bone stock is not sufficient to support the cementless acetabular component. We previously used a reconstruction ring or cage construct with or without structural allograft along with...
impaction bone grafting when significant host bone deficiency existed in the posterior column or weight-bearing dome.\textsuperscript{5,33-36} Three of these patients required revision procedures, which included 2 revisions for septic failure and 1 revision for aseptic failure. The patient with aseptic loosening of a cage and structural allograft construct had 2 revision procedures prior to the index revision, which may have contributed to poor host bone quality and subsequent loosening. More recently, we and others have used cementless implants with a highly porous surface of tantalum or similar material, multiple screw fixation, impaction grafting, and metallic augments (instead of structural allografts) in situations in which a ring or cage would otherwise be used.\textsuperscript{13,14,37} This is particularly useful in cases of failed acetabular cages\textsuperscript{38} and in cases with <50\% apposition of the prosthesis to host bone.\textsuperscript{39}

Few reports exist on the use of impaction bone grafting in primary THA. Pereira et al\textsuperscript{40} reported excellent results with 100\% survivorship of impaction bone grafting in a retrospective review of 23 primary THAs at a mean 7.9-year follow-up. Similarly, Mullaji and Marawar\textsuperscript{40} noted a good clinical outcome and satisfactory consolidation of autografts used for the treatment of protrusio in 30 primary THAs at a mean 4.2-year follow-up. Similarly, no revisions were performed in the primary THA group in our study. One patient with protrusio due to severe juvenile idiopathic arthritis and extremely poor bone stock had radiographic evidence of component migration that subsequently stabilized. The bone graft incorporated into the remaining bone bed. Another patient in the revision THA group with a history of juvenile idiopathic arthritis required revision surgery with cage and structural allograft for aseptic loosening of a porous coated component. Similarly, Mont et al\textsuperscript{41} reported a high failure rate with 44\% survivorship at 108 months in 30 revision THAs managed with morselized bone grafting and cementless acetabular components in patients with rheumatoid arthritis.

Radiographs revealed reliable incorporation and remodeling of allograft and autograft with trabecular formation in primary and revision THAs. The majority of the grafts demonstrated streaming trabecular formation by 6 months. Two patients with rheumatoid arthritis who underwent revision and 2 patients who underwent surgical procedures prior to index surgery had radiolucencies (<2 mm) in 2 zones. However, the clinical importance of these radiolucencies is controversial. These radiolucencies probably represent areas of bone remodeling, resorption, or fibrous ingrowth. In addition, acetabular components with nonprogressive radioluencies have not been associated with a higher incidence of loosening or migration.\textsuperscript{42,43}

In the current study, the type of acetabular component (porous coated or trabecular metal) had no influence on the ultimate clinical outcome or failure rate with this technique in primary or revision THA. We observed several failures in patients with juvenile idiopathic arthritis (1 aseptic loosening and 1 migration that subsequently stabilized) or those who had multiple revision procedures (1 aseptic and 1 septic loosening). This number is small, but caution is recommended in patients with juvenile idiopathic arthritis secondary to compromised host bone stock.

This study had some limitations. The study analyzed the clinical and radiographic outcome of a consecutive series of patients who underwent acetabular reconstruction for various bone deficiencies during revision, conversion, and primary THAs. Although some may debate the merits of such a nonhomogeneous series of cases, it represents the cases and methods of management of acetabular bone defects by 1 THA surgeon in a busy adult reconstructive referral practice over a 12-year period. We also recognize that cancellous bone grafting was combined with other techniques in some patients, including the use of demineralized bone matrix and structural allografts. This is also a retrospective study of prospectively gathered data, with short- to intermediate-term follow-up. Longer-term follow-up is necessary to confirm continued success of the techniques used.

Despite these shortcomings, this study confirms the usefulness of cancellous impaction bone grafting with several types of acetabular implants in primary and revision THA performed by a single surgeon using standardized techniques at a single institution. Given the above clinical and radiographic follow-up, acetabular cancellous impaction grafting for bone defects continues to be a safe and reliable technique in the management of bone defects in primary and revision THA.

\textbf{REFERENCES}


