Extended Ischiopubic Fixation Using Porous Metal Augments In Cementless Acetabular Reconstruction During Revision Total Hip Arthroplasty

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Abstract

Background: As opposed to rim fixation, 3-point fixation provides sufficient primary stability for cementless cups in the presence of massive bony deficiency. While several methods, including doming augments or flying buttress augments, have been introduced to reconstruct superior supportive points, good methods to establish supportive ischiopubic points are currently lacking. The aims of this study were to introduce the definition, indication and surgical technique of extended ischiopubic fixation (EIF) and to investigate the early clinical and radiographic results and complications of hips revised with EIF.

Methods: Patients who underwent revision THA utilizing the technique of EIF with porous metal augments secured in the ischium and/or pubis in a single institution from February 2015 to February 2020 were retrospectively reviewed. 25 patients were included based on the criteria of minimum 2-year follow-up. The median duration of follow-up was 48.06 months (interquartile range: 41.37-62.20 months). The patients' clinical results were assessed using of the Harris Hip Score and Western Ontario and McMaster Universities Osteoarthritis index and any complications including infection, intraoperative fracture, dislocation, postoperative nerve palsy, hematoma, wound complication and/or any subsequent reoperation(s) were documented. The radiographic results were assessed with the construct stability, the position of the center of rotation and cup orientation.

Results: At the most recent follow-up, 20 (80%) patients rated their satisfaction level as "very satisfied", 5 (20%) were "satisfied". The median HHS score improved from 36.00 preoperatively to 81.00 ($p=0.001$) while the median WOMAC index score decreased from 74.50 preoperatively to 16.50 at the latest follow-up ($p=0.001$). No intraoperative or postoperative complications were identified. All constructs were considered to have obtained stable fixation. The median vertical and horizontal distance between the latest postoperative center of rotation to the anatomic center of rotation improved from 13.62 mm and 8.68 mm preoperatively to 4.42 mm and 4.19 mm, at final follow-up ($p<0.001$), respectively.

Conclusions: Early follow-up of patients reconstructed with porous metal augments using the EIF technique demonstrated satisfactory clinical results with no particular complications, stable fixation and restoration of the center of rotation.

Introduction

In the presence of a massive acetabular bone defect in the setting of revision total hip arthroplasty (THA), the primary stability of a hemispheric cementless cup is typically achieved via 3-point fixation given that the continuity of the acetabular rim no longer exists and rim fixation is thus not feasible [1–3]. A jumbo cup is often used to span the enlarged cavity and to reach 3 bony points located at the iliac and ischiopubic segments of a hemipelvis, thereby maintaining initial stability of the acetabular component [2]. However, it is not uncommon for a bone defect to be so extensive that the bony points are not supportive or do not exist at all. While options exist to reconstruct the iliac supportive point, including the

use of “doming” or “flying buttress” techniques[4] with metal augments or structural allografting, no good methods currently exist to reconstruct supportive ischiopubic points and facilitate “3-point fixation”.

Jenkins et al [4] and Solomon et al [1] strongly recommended routinely driving multiple zone 3 screws into the inferior hemipelvis to improve the ischial and/or pubic fixation of the component in cases where major bone loss was identified. Unfortunately, in the presence of bone loss, inferior screws do not always achieve good bony purchase. Moreover, it is not always possible to achieve adequate contact between the inferior surface of the metal shell and host bone. Cup cages have been utilized to extend fixation to the ilium and ischium to protect the hemispheric cementless shell until it achieves adequate bone ingrowth [5]. However, current cages require the inferior flange to be inserted into, or fixed onto, the ischium; this is technically demanding, requires extensive dissection and exposure which increases the risk of sciatic nerve injury and is predicated upon the ischium itself having strong and adequate bone stock.

As a result of facing severe ischiopubic bone loss and being unsatisfied with inferior screw or cup cage techniques, we invented a technique of extended ischiopubic fixation (EIF) to establish a means by which to establish ischiopubic supportive points. We defined the EIF technique as securing the porous metal augment more than 5 mm deep into the ischium and/or pubic ramus to gain adequate mechanical support and fresh host bone for bony ingrowth, while we define using a disc shaped TM (TM) restrictor augment (Zimmer, Inc, Warsaw, IN) which is thinner than 5 mm to reconstruct minimal ischial and/or pubic bone defect as inferior acetabular rim restoration. The rationale for these definitions is based on whether the porous metal augment is used for restoring the inferior acetabular rim or reconstructing mechanically supportive points in the ischium and/or pubic ramus. If the bone loss was less than 5 mm deep, a disc shaped TM restrictor augment was used to “tighten” the acetabular rim. When a press fit hemispherical cup was inserted, the acetabular rim recoils to hold the implant as a rim fit device. However, when the bone defect in the ischium and/or pubic ramus was more than 5 mm deep, it is technically difficult to use a press-fit shell as a rim fit device. Therefore, ischial and/or pubic supportive point/points had to be constructed to achieve “3-point fixation” of the hemispherical cup.

There remains a paucity of literature reporting other techniques than multiple screws and an ischial flange or hook of cages to reinforce the ischiopubic fixation of the cup. The aims of this study were to introduce the definition, indication and surgical technique of EIF and to investigate the early clinical and radiographic results and complications of hips revised with EIF.

Patients And Methods

This retrospective case series study of prospectively collected data was approved by our institutional review board. Patients who underwent revision THA utilizing the technique of EIF in a single institution from February 2015 to February 2020 were retrospectively reviewed. Initially, a total of 43 patients were identified, which represents only 7.6% of the 568 patients who underwent revision THA at the same time period. Inclusion criteria was patients whose surgical dates allowed possible 2-year follow-up. Exclusion

criteria was patients revised due to neoplastic disease. After applying the inclusion and exclusion criteria, a total of 26 hips (25 patients) were eligible for the study and were enrolled. No patients were lost to follow-up or deceased postoperatively.

EIF was indicated when a lack of supportive points existed inferiorly. We evaluated preoperative radiographs and a CT scan to estimate the size and shape of the bone defect and would consider using porous metal augments inferiorly if a bone defect(s) exceeded a depth of 5 mm in the ischium or pubic ramus. Intraoperatively, the acetabulum was reamed to fresh bleeding bone at the anatomic level to the extent that this was possible. The final reamer was positioned at an anatomic level as a cup trial, after which the gap between the bone bed and the cup trial was gauged. Iliac bone loss was managed with a wedge or buttress augment depending on the size and shape of the defect to reconstruct a firm superior, anterosuperior or posterosuperior supportive point. A cup trial 1–2 mm larger than the final reamer was used to ensure a press fit and initial stability. Unsatisfactory primary cup stability as a result of lacking an inferior supportive point(s) triggered the use of extended ischiopubic fixation.

The implant selection or preparation was carried out according to the shape and size of the bone defect. Between February 2015 and May 2017, we used TM wedge or shim augments (Zimmer, Inc, Warsaw, IN) to reconstruct a firm inferior supportive point(s) before the lotus augment was available. If the shape or size did not fit, an osteotome or high speed carbide blade was utilized to cut a wedge augment or shim augment to fit the defect. To improve the fit and shape of the ischium and pubis, a new type lotus augment (AK Medical Co., Ltd, Beijing, China) was designed, which consisted of a piece of porous titanium metal with a concave disc and a curved or straight stalk manufactured with electron beam melting technology (EBM Q10 System, Acram AB, Sweden) after April 2017 [6] (Fig. 1a). The lotus augment was an approved medical device and was designed based on a dodecahedron unit cell with a porosity of 80%, pore size of 600 μm –800 μm , modulus of elasticity of 0.5–1.3 Gpa on average and coefficient of friction on cancellous bone of 1.00–1.08. We broached the ischium or pubic ramus with a finger shaped, curved rasp (Fig. 1b, 1c, 1d, 1e) and press-fitted the TM augment or lotus augment stem into the “canal” with an impactor. If the ischial and/or pubic bone defect was deep and extensive, a wedge augment with proper size was secured to the ischiopubic segment of the hemipelvis with screws to achieve the EIF. Bone cement was placed at the augment-cup interface, and then a hemispherical cementless cup was impacted and fixed with multiple screws. The patients were encouraged to ambulate using a partial weight bearing protocol with 10–15 kg in the immediate postoperative period, and thereafter to gradually increase the weight bearing at 6–8 weeks postoperatively until full weight bearing was tolerated.

The median age of these 25 patients was 62.00 (interquartile: 54.25–68.25 years) years, with a median body mass index (BMI) of 22.60 kg/m² (interquartile: 21.49–25.12 kg/m²). A total of 12 (48%) patients were female. 3 hips had evidence of pelvic discontinuity and was managed with the distraction technique as described by Sporer et al[22]. The median duration of follow-up for the enrolled population was 48.06 months (interquartile range: 41.37–62.20 months).

In addition to the EIF, 23 of the 26 hips were simultaneously reconstructed by securing buttress or wedge augments in the superior, anterosuperior and/or posterosuperior ilium to reconstruct mechanically supportive points superiorly. Twenty-two TM augments (15 trimmed augments and 7 untrimmed wedge augment) were used in 20 hips (two hips with trimmed augments secured in the ischium and pubic ramus simultaneously) (Fig. 2) and 7 lotus augments were used in 6 hips (1 hip with 2 lotus augments secured in the ischium and pubic ramus simultaneously) (Fig. 3) to obtain EIF, respectively. Nineteen hips were reconstructed with augments secured solely in the ischium and 4 hips were reconstructed with augments secured solely in the pubis.

All inpatient and outpatient records were examined for complications, including infection, intraoperative fracture, dislocation, postoperative nerve palsy, hematoma, wound complication and/or any subsequent reoperation(s). The patients' clinical results were assessed using of the Harris Hip Score (HHS) [7] and Western Ontario and McMaster Universities Osteoarthritis (WOMAC)) index [8] at each office visit 3, 6, 12 months and every other year thereafter postoperatively. Patients who failed to visit the hospital postoperatively were contacted via telephone and mailed standard surveys. Patients were also asked to rate their satisfaction level regarding their clinical result based on an arbitrary scale with five levels of satisfaction: very satisfied, satisfied, neutral, dissatisfied, or very dissatisfied [9].

Two surgeons assessed the severity of the acetabular bone deficiency using the immediate preoperative plain radiograph according to Paprosky classification for acetabular bone defects [10, 11]. 1 (3.1%) hips were classified as Paprosky type IIA acetabular bone defects, 4 (15.4%) as type IIB, 1 (3.8%) as type IIC, 8 (30.8%) as type IIIA and the rest 12 (46.2%) were classified as type IIIB. The vertical and horizontal distances of the postoperative center of rotation to the anatomic center of rotation were measured on the preoperative and postoperative radiographs [12]. All plain radiographs were calibrated with knowledge of the known head size. All the postoperative serial plain radiographs were strictly reviewed to assess whether a radiolucent line(s) existed in the bone-cup or bone-augment interfaces, especially in the zone 3. The inclination angle of the acetabular shell was measured with reference to the inter-teardrop line on the anteroposterior plain radiograph. Anteversion of the acetabular shell was measured according to the method devised by Lewinnek et al [13]. The implant construct loosening was defined as presence of 1 mm or larger radiolucent line in all the three acetabular zones [14, 15] or if inclination angle of the acetabular shell changes more than 10° or if the horizontal or vertical position of the acetabular shell change more than 6 mm [16].

Normality of the parameters were examined using the Shapiro-Wilk test. Continuous data were compared using Wilcoxon signed rank tests and summarized as the median with interquartile in parentheses. Categorical data were summarized as numbers and percentages. The significance level was set at $p < 0.05$. All statistical analyses were 2-sided and were performed with SPSS 24.0 (IBM; Armonk, NY, USA).

Results

At the most recent follow-up, 20 (80%) patients rated their satisfaction level as “very satisfied”, 5 (20%) were “satisfied”. The median HHS improved from 36.00 (interquartile range: 31.25–49.75) preoperatively to 81.00 (interquartile range: 74.75–88.25) at the most recent follow-up ($p < 0.001$) while the median WOMAC index score decreased from 74.50 (interquartile range: 67.00–79.50) preoperatively to 16.50 (interquartile range: 12.75–22.25) at the latest follow-up ($p < 0.001$). No intraoperative or postoperative complications were identified. No radiolucent lines were detected between the bone-cup and bone-augment interfaces on the serial postoperative radiograph. No implant construct migration or screw breaks were detected, and all constructs were considered to have obtained bony ingrowth fixation.

The median vertical distance between the latest postoperative center of rotation to the anatomic center of the femoral head improved from 13.62 mm (interquartile range: 5.81 mm–22.65 mm) preoperatively to 4.42 mm (interquartile range: 2.81 mm–9.15 mm) at final follow-up ($p < 0.001$). The median horizontal distance between the latest postoperative center of rotation to the anatomic center of femoral head improved from 8.68 mm (interquartile range: 3.18 mm–15.41 mm) preoperatively to 4.19 mm (interquartile range: 1.89 mm–6.95 mm) at the most recent follow-up postoperatively ($p = 0.008$). The median acetabular cup abduction angle improved from 52.55° (interquartile range: 43.25°–61.83°) preoperatively to 43.98° (interquartile range: 40.99°–48.91°) at the most recent follow-up postoperatively ($p = 0.001$). However, there was no difference in the median cup anteversion angles preoperatively (median: 8.99°, interquartile range: 5.32°–15.35°) to postoperatively (median: 12.77°, interquartile range: 9.73°–15.87°) ($P = 0.382$).

Discussion

A retrieval study [17] revealed that the majority of the cages had failed due to the ischial flange breaking or pulling out, to which end the authors pointed out that ischial fixation remained a persistent problem to address in revision THA. Poor ischial fixation may contribute to the failure of bony ingrowth at the inferior hemipelvis and progressive or non-progressive radiolucent lines in zone 3 have been demonstrated in several studies, especially in the setting of severe acetabular bone defects and pelvic discontinuity [4, 5, 18, 19]. To address the problem of insufficient fixation and bone ingrowth in the inferior hemipelvis, the current study introduced a technique of EIF to reinforce ischiopubic fixation of the acetabular cup and demonstrated that patients obtained satisfactory clinical results in an early timeframe with no particular complications, stable fixation and restoration of the center of rotation.

The cranial part of the acetabulum has been demonstrated as the main region of through which load transfer of the cup occurs and the ilioischial diagonal axis provides the highest press fit for a cup [3]. Therefore, a reliable method of support in the cranial ilium and the dorsal column is conceivably essential for good long-term results of acetabular components. However, fixation in the inferior hemipelvis is also important and should receive attention given that it counteracts the superior and lateral deforming hip stress during walking [20]. Biomechanical studies have demonstrated distractive or separative stresses acting at the ischial region during physiologic loading of the acetabulum [21, 22]. Won et al [21, 22] indicated that there are compressive forces in the superior iliac rim and distractive forces at the inferior

ischial rim around a non-press fit acetabular shell, which would cause cephalad rotation. Moreover, Solomon et al[1] demonstrated inferior ischial and/or pubic screw fixation reduced the proximal translation and sagittal rotation of the components in a radiostereometric analysis with revision THA. Jones et al [23] found that insufficient ischial fixation influenced the survival of custom flange acetabular components and a lack of inferior ischial fixation predisposed the components to fail. Consequently, in addition to emphasizing solid cranial ilium and posterior column fixation, importance should be conferred to the ischiopubic fixation; namely, zone 3 fixation.

The substantial improvement in Harris Hip Score and decrease in WOMAC index in the present study were comparable to what has been reported of the patients with similar complex bone defects [16, 24], indicating that EIF combined with cranial iliac fixation with porous metal augments facilitates satisfactory short-term functional outcomes. The acetabular component in the current study was extended and fixed to the relatively strongest and healthiest bone available through EIF by spanning the worst quality and quantity of bone. We speculate that EIF assists with reconstructing a firm inferior ischial and/or pubic supportive point(s) to obtain 3-point fixation of the cup, thereby enhancing the primary stability of the acetabular cup, which has been demonstrated in a previous biomechanical study by Tang et al[25]. No complications such as intraoperative bone fracture or nerve palsy were reported, which demonstrated that EIF technique was safe during the early follow-up.

The EIF with porous metal augments is advantageous over common techniques (screws, flanges or hooks of cages, impaction bone graft) by providing a instant ischial and/or pubic supportive point to obtain immediate stability of the acetabular cup and the potential of biological bone-ingrowth fixation in the long-term. Presumably a benefit of the EIF over the cup-cage construct is the ability to use a modular rather than cemented liner. In addition, forceful insertion of the ischial flange of cages introduces the risk of iatrogenic pelvic dissociation. Impaction bone grafting to restore the ischial and/or pubic bone defect(s) are technically demanding and are associated with risk of bone resorption, poor graft incorporation, acetabular fracture and disease transmission [26, 27].

The use of bone cement is also strongly recommended to optimize bonding of the ischial and/or pubic augment and acetabular cup. Beckmann et al previously demonstrated that this can minimize the relative movement and geometry of the combined construct may resist migration [28]. Another advantage of cementing the augment to the shell is to prevent the potential for micromotion and particle shedding at the augment-shell interface, which has been reported without the use of cement between augments and acetabular cups [29]. However, potential problems with porous metal augment for EIF of the acetabular shell includes unknown long-term durability, the potential for debris generation if there is loosening of the augment or cup, the potential for fatigue failure, and the inability to restore bone stock for future revisions.

The postoperative vertical and horizontal positions of the center of rotation in the present study were restored to 4.42 mm and 4.19 mm in relation to the anatomic femoral head center, which is similar the results of previous literature [4]. This indicates that extended ischiopubic fixation allows cup

reconstruction of near normal centers of rotation and hip biomechanics. Restoration of the center of rotation also helps avoid leg length discrepancy. No radiolucent lines were detected in this study between the bone-cup and bone-augment interfaces in any of the three acetabular zones and all constructs were considered to have obtained bony ingrowth fixation, which demonstrated that the extended ischiopubic fixation facilitates the shell to obtain sufficient initial stability and subsequent biologic fixation.

The present case series has several limitations. First, the patient cohort is relatively small with a short-term follow-up time period; however, this is a sub-specialized area of revision hip arthroplasty focusing on ischial and/or pubic bone defects and EIF, which is uncommon in clinical practice. A small case series at a relatively short follow-up time period is therefore compelling. Furthermore, 20 (76.9%) of the cases were Paprosky type III acetabular bone defects, which represents a relatively complex case cohort amongst any clinical practice setting. Second, the present study lacks a comparison group, which is difficult to undertake in studies of complex revision THA; we were therefore limited in assessing whether this EIF technique was advantageous over other techniques. Third, a comparison of the porous titanium lotus augments and TM augments was not performed due to the different follow-up durations and the small number of patients with the lotus augments. Fourth, we did not calculate a Kaplan-Meier survivorship of these cases given that the duration of follow-up was short and no cases failed.

Conclusion

In summary, early follow-up of patients reconstructed with porous metal augments using the EIF technique demonstrated satisfactory clinical results with no particular complications, stable fixation and restoration of the center of rotation. Mid-term and long-term follow-up results with larger number of patients are warranted to demonstrate the survivorship, clinical and radiographic outcomes of the porous metal augment for EIF in revision THA.

Abbreviations

EIF: extended ischiopubic fixation;

WOMAC: Western Ontario and McMaster Universities Osteoarthritis;

HHS: Harris Hip Score.

Declarations

Ethics approval and consent to participate:

This work was approved by the Institutional Review Board at Beijing Jishuitan Hospital and obtained informed consents by every patient.

Consent for publication:

All authors have participated in conducting the research study, and have consented to submit this paper.

Availability of data and materials:

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests:

Each author certifies that he has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

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Authors' contributions:

Y H contributed to follow-up of the patients, data curation, formal analysis and writing original draft. Y Z contributed to the conception of the study, performing the surgery and revising the manuscript; H S contributed to performing the surgery, formal analysis, reviewing and editing the draft; H T contributed significantly to follow-up of the patients and formal analysis; D Y helped perform the surgery, formal analysis with constructive discussions; B Z measured the X-rays and participated the data curation.

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Figures

Figure 1

Pictures of the 3D printed porous titanium lotus augments and finger shaped curved rasp. (a) lotus augments of various sizes demonstrating a superior concave disc (black arrow) and a curved or straight stalk (white arrow); the holistic view (b), lateral view (c), lateral oblique view (d) and axial view (e) of the curved rasp for broaching the ischium or pubic ramus intraoperatively.

Figure 2

A representative case of extended ischiopubic fixation using a TM wedge augment. (a) preoperative anteroposterior radiograph of the bilateral hips of a 60-year-old male demonstrating loosening of the left cup and substantial left ischial osteolysis; (b) immediate postoperative anteroposterior radiograph of the

bilateral hip demonstrating a wedge augment secured into the ischium to reconstruct an ischial supportive point and a TM buttress augment secured in the ilium to simultaneously reconstruct a firm superior supportive point; (c) postoperative anteroposterior radiograph of the bilateral hips with 4.2-year follow-up demonstrating a stable construct on the left side with no radiolucent lines around the cup and augments.

Figure 3

A representative case of extended ischiopubic fixation using porous metal lotus augments. (a) preoperative anteroposterior radiograph of the pelvis of a 70-year-old female with Parkinson's disease demonstrating substantial ischial and pubic osteolysis in the left hip; (b) immediate postoperative anteroposterior radiograph of the pelvis demonstrating two lotus augments secured into the ischium and pubic ramus to reconstruct two firm inferior supportive points (note the two TM augments secured in the ilium simultaneously to reconstruct one superior supportive point); (c) postoperative anteroposterior radiograph of the bilateral hips with 3.6-year follow-up demonstrating a stable cup with bony fixation and no radiolucent lines around the construct.