

Research Article

Outcomes of a Novel Modular Porous Acetabular Shell in Revision Total Hip Arthroplasty

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Abstract

Background: Modular porous acetabular shells were developed for use in revision Total Hip Arthroplasty (rTHA) where severe bone loss may impede implant fixation and osteointegration. This study reports one- and two-year outcomes of a novel modular porous acetabular shell in rTHA.

Aim: To report short-term outcomes of a novel modular porous acetabular shell for the treatment of acetabular bone loss in rTHA.

Methods: A retrospective study of 100 patients who received a novel modular porous acetabular shell in rTHA with minimum one year of follow-up was conducted at a large academic medical center between December 2018 and June 2022. Data was collected on patient demographics, surgical information, clinical outcomes and Patient Reported Outcome Measures (PROMs). The primary outcome was rate of shell re-revision.

Results: The main indication for revision was aseptic loosening. A Paprosky acetabular defect of 2A or greater was found in all patients. Revision-free survivorships of the modular porous acetabular shell were 97% at one year and 96% at two years of follow-up. Among patients who retained their shell at one year, osteointegration was 100% and shell migration was 0%. Three shells (3.0%) were re-revised by one year due to dislocation (1.0%), acetabular fracture nonunion (1.0%) and infection (1.0%). One shell (1.9%) required re-revision by two years of follow-up due to infection. All four re-revised shells failed to osteointegrate prior to re-revision - two due to infection, one due to periprosthetic fracture nonunion and one was revised too early to achieve osteointegration.

Conclusion: This novel modular porous acetabular shell in rTHA demonstrates excellent osteointegration and survivorship at both one and two years of follow-up.

Keywords: Total Hip Arthroplasty; Revision Total Hip Arthroplasty; Modular Porous Shell; Survivorship; Outcomes

Core Tip

This study reports one- and two-year outcomes of a novel modular porous acetabular shell used in the treatment of acetabular bone loss in the setting of revision total hip arthroplasty. Revision-free survivorships of the modular porous acetabular shell were 97% at one year and 96% at two years of follow-up. Three shells were re-revised by one year due to dislocation, acetabular fracture nonunion and infection. One additional shell was re-revised by two years of follow-up due to infection. Overall, this novel modular porous acetabular shell demonstrated excellent short-term osteointegration and survivorship.

Introduction

The incidence of hip osteoarthritis and associated disability has continued to rise, with an incidence of 18.7 per 100,000 people and disability-associated life-years of 12.57 per 100,000 people in 2019 [1]. As the number of primary THA (pTHA) increases, so too has the need for revision THA (rTHA). In their recent articles, Shichman, et al., projected that over 719,000 pTHA will be

performed annually by 2040 and 43,000 rTHA will be performed annually by 2040 [2,3].

Historically, one of the most common indications for rTHA was osteolysis, a macrophage-mediated reaction in patients who received conventional Ultra-High Molecular Weight Polyethylene (UHMWPE) components [4-6]. Although the incidence has decreased with the advent of Highly Cross-Linked Polyethylene Components (HXPPE), many patients whose procedures were performed prior to the advent of HXPPE still have conventional UHMWPE polyethylene components implanted [7]. In the hip, osteolysis is often associated with major acetabular bone loss and aseptic loosening, often necessitating rTHA. Other causes of major acetabular bone loss in the setting of pTHA include Periprosthetic Joint Infection (PJI), periprosthetic fracture, pseudotumor/metallosis and implant failure for other reasons [8].

Numerous strategies have been developed to treat acetabular bone loss, including bone grafting, cages, augments, jumbo hemispherical shells, shell-cage constructs and customized triflange components [8]. Hemispherical revision shells have been an important workhorse implant for treating acetabular defects. These implants are commonly composed from porous material that facilitates bony ingrowth. Different shell-liner interface mechanisms have been developed to allow for a stable construct, including cemented polyethylene liners for fully porous acetabular shells and liners for modular acetabular shells with a locking mechanism ("snap-in"). An advantage of the locking mechanism is its modularity: if future revisions are required, the liner can be easily removed and exchanged, which is much more difficult with a cemented liner. The locking mechanism also takes the onus of stability off the cement-implant interface, which is susceptible to cementation error and subsequent failure of the cement-implant interface.

Although multiple short-term studies have been conducted to examine outcomes of fully porous implants with cemented polyethylene liners, we were unable to identify any studies that have investigated the outcomes following implantation of a modular porous acetabular shell [9,10]. The purpose of this study is to report the short-term outcomes of a novel modular porous acetabular shell for the treatment of acetabular bone loss in the setting of rTHA.

Materials and Methods

Study Population

A retrospective cohort of 134 patients was identified who underwent rTHA with a novel modular porous acetabular shell (REDAPT Revision Acetabular System; Smith & Nephew, Memphis, Tennessee) at a large academic medical center between December 2018 and June 2022. Revision THA was defined as a return to the operating room in which the implants were exchanged from a prior THA. Patient and implant data were extracted from the electronic medical record system (Epic Systems Corporation, Verona, Wisconsin). Patients were included in the study if they had a rTHA with the use of this novel modular porous acetabular shell confirmed upon review of the operative note and implant log. There were 118 patients that had the potential for one year of follow-up. Cases were excluded if they did not occur before June 13, 2022, which allowed for at least one year of follow-up at the time this study was conducted. One hundred patients were found to have a recorded one-year follow-up visit and 53 of those patients had a documented two-year follow-up visit. Ethical approval for the study design was provided by our institutional review board.

In the final study population, the mean age of the patients included was 65.6 years (range 37.0-90.0) and mean BMI was 29.6 kg/m² (range 19.1-54.4). Women comprised 61.0% of the total patients. Ninety-six percent of the patients had an ASA classification score of 2 or greater (Table 1).

Data Collection

Chart review was conducted to collect patient demographics as well as surgical characteristics and outcomes. Patient demographics collected included age, Body Mass Index (BMI), sex, race, smoking status, insurance type, marital status, American Society of Anesthesiology (ASA) score and Charlson Comorbidity Index (CCI) score [11]. All time-dependent demographics were collected based on data at the time of the rTHA. Surgical characteristics collected included indication for rTHA, Paprosky classification, surgical approach, utilization of computer navigation, allograft, cage, augments, number of screws, bearing type, whether the femoral stem was revised, surgery duration and lengths of stay in the hospital. Additionally, the outcomes collected included the follow-up duration following the procedure, shell migration or osteointegration, in-hospital complications,

Emergency Department (ED) visits within 90 days following surgery, return to the operating room and readmissions.

Importantly, data on re-revisions was collected, including the implants that were re-revised, the indication for the re-revision and the time to re-revision. HOOS, JR scores were also collected pre-operatively as well as at one and two years postoperatively. Preoperative HOOS, JR was completed by 63% of patients, one-year postoperative HOOS, JR was completed by 59% of patients and two-year postoperative HOOS, JR was completed by 11% of patients.

Data Analyses

The primary outcome was rate of re-revision. Secondary outcomes were shell migration and osteointegration, in-hospital complications, ED visits within the first 90 days following surgery, readmissions and HOOS, JR scores. Demographics, surgical characteristics and outcomes were reported as either a mean or median with an accompanying range or as the number of cases with the percentage of total cases. The differences in HOOS, JR scores from the preoperative score to one- and two-year postoperative score were also reported. Analyses were performed with the use of SPSS v25 (International Business Machines Corporation, Armonk, New York). This study was performed in accordance with the ethical standards of the Institutional Review Board (study number i17-01223_CR5) and the Helsinki Declaration.

Results

The most common indication for revision was aseptic loosening (40.0%), followed by infection (22.0%), instability (15.0%), osteolysis (10.0%), other indications (6.0%), fracture (5.0%) and metallosis (2.0%). All of the cases had an acetabular defect of 2A or greater (Table 1).

The posterior approach was the most common approach (75.0%). Computer navigation was utilized in 56 (56.0%) cases. Allograft was required for 29 cases (29.0%) and only one case required a cage (1.0%). Three cases (3.0%) required the use of metal augments. The median number of screws used was 4 (range 2.0-8.0). A fixed bearing was used for 47.0% of cases, while a dual mobility implant was used for 53.0% of cases. Forty-three (43.0%) cases required a femoral stem revision. The mean surgery duration was 160.0 minutes (range 84.0-398.0) and the mean lengths of stay in the hospital following surgery was 3.3 days (range 1.0-15.0) (Table 1).

The most common immediate postoperative complication following revision surgery was postoperative anemia requiring red blood cell transfusion (14.0%). Other postoperative complications included Venous Thromboembolism (VTE), nerve palsy, Urinary Tract Infection (UTI) and Acute Kidney Injury (AKI). There were four ED visits for dislocation within the first 90 days following surgery and three of those dislocations required readmission. There was one ED visit for periprosthetic fracture and one for infection, both of which required readmission. There was also one ED visit for uncontrolled pain and one for hematoma and the hematoma required readmission. Among patients who retained their modular porous acetabular shell at one year, osteointegration was 100% (97 out of 97 cases) and shell migration was 0%.

Revision-free survivorships of the modular porous acetabular shell were 97% (97 cases) at one year of follow-up and 96% (51 cases) at two years of follow-up (Fig. 1). Survival from aseptic failure was 98% (Fig. 2). Of the three shells that were re-revised by one year, one was re-revised for dislocation, one for nonunion due to periprosthetic fracture and one for infection. One additional patient required re-revision by two years of follow-up due to infection. None of the four re-revised shells had osteointegrated prior to re-revision. Two failed to osteointegrate due to infection and one due to nonunion from an acetabular periprosthetic fracture. The fourth shell was re-revised too early (9 days following shell placement) to achieve osteointegration. By one year of follow-up, six patients required re-operation during which the shell was retained and other components were re-revised. Indications for these re-operations included dislocation (3 cases), infection (2 cases) and hematoma (1 case). One additional patient required re-reoperation by two years that did not include shell re-revision. The indication for this re-operation was a loose lateral trochanteric plate and broken cables. The average time to re-revision was 131 days (range 9.0-328.0) (Table 3). HOOS, JR scores were collected pre-operatively and at one and two years postoperatively. The mean preoperative HOOS, JR score was 47.6 (range 0.0-85.0). The mean one-year post-operative HOOS, JR score was 71.4 (range 33.0-100.0) and the mean two-year post-operative HOOS, JR score was 71.2 (range 36.0-100.0). The difference between preoperative and one-year postoperative HOOS, JR scores was 25.5 (range -17.0-79.2) and between preoperative and two-year postoperative HOOS, JR scores was 31.0

(range -13.9-50.1) (Fig. 3,4, Table 4).

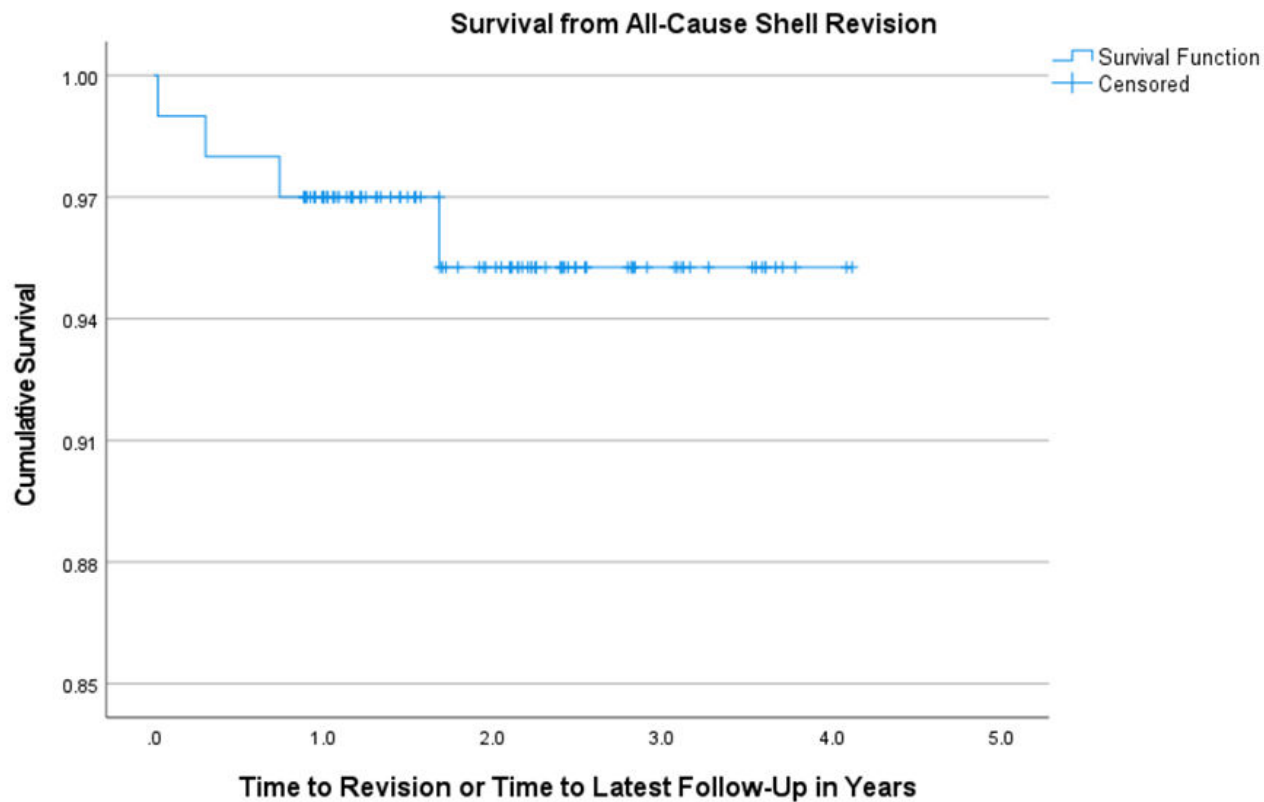


Figure 1: Survival from all-cause shell re-revision.

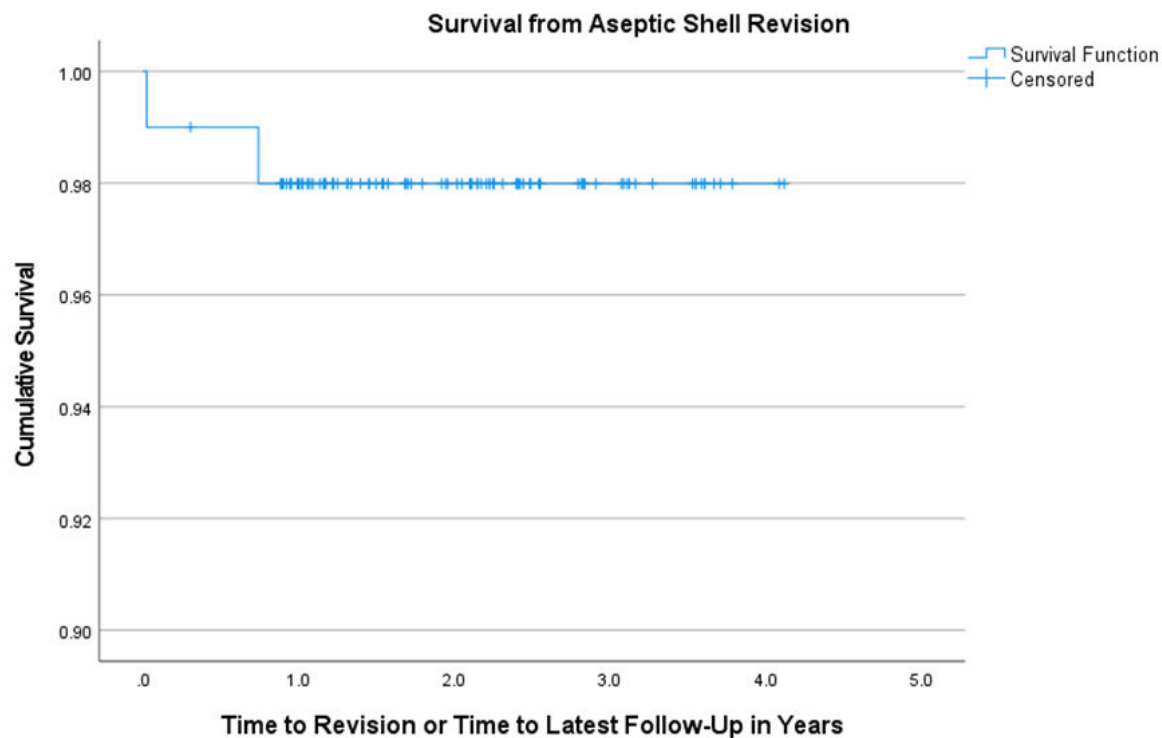


Figure 2: Survival from aseptic shell re-revision.

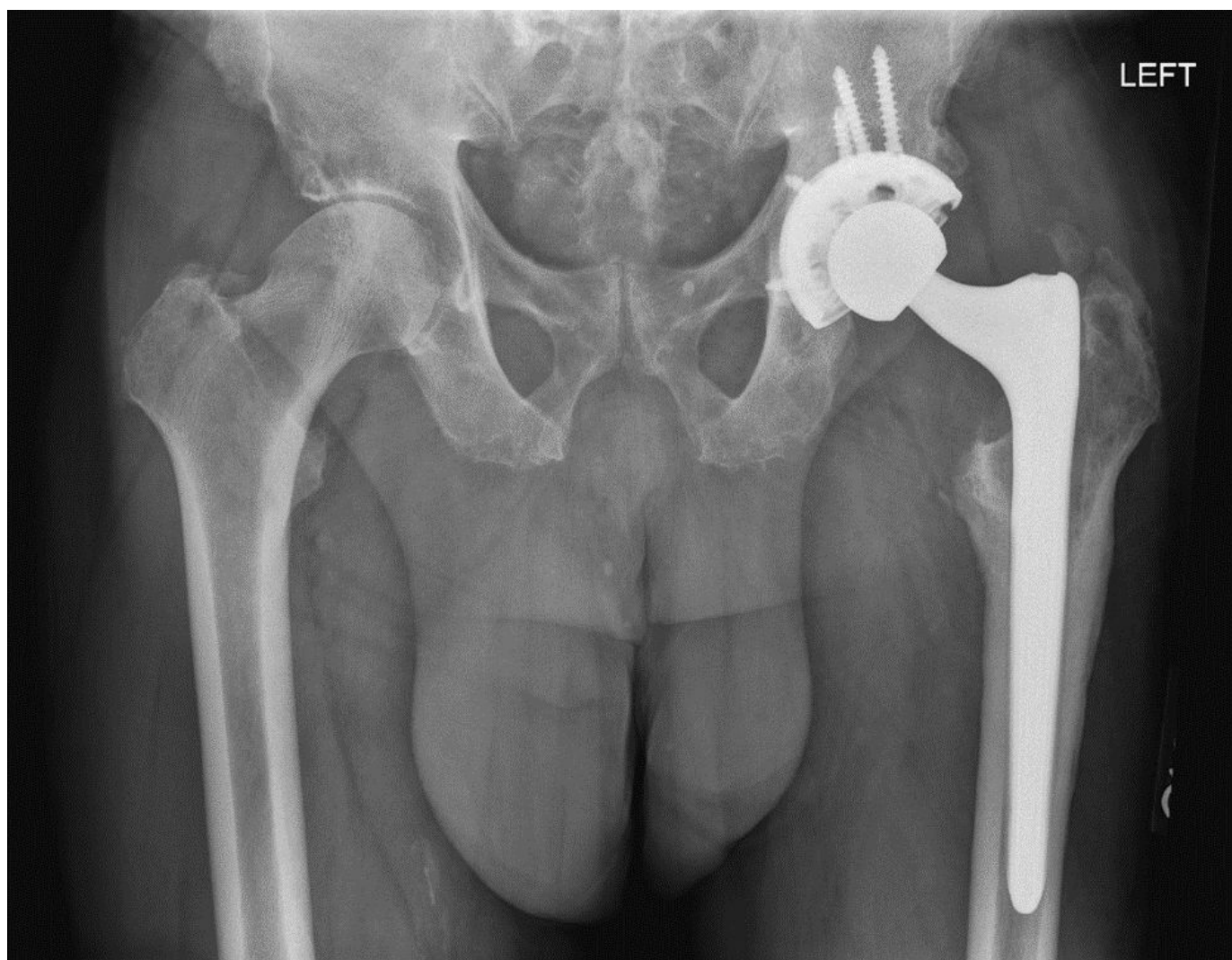


Figure 3: Example X-ray: AP pelvis X-ray showing placement of the novel modular porous acetabular shell.



Figure 4: Novel modular porous acetabular shell.

	N (%) unless otherwise specified (n=100)
Mean Age, years [range]	65.6 [37.0-90.0]
Mean BMI ^a , kg/m ² [range]	29.6 [19.1-54.4]
Women, n (%)	61 (61.0)
Race, n (%)	
White	68 (68.0)
Black	14 (14.0)
Asian	1 (1.0)
Other/Unknown	17 (17.0)
Smoking Status, n (%)	
Never	55 (55.0)
Former	38 (38.0)
Current	7 (7.0)
Insurance Type, n (%)	
Medicare	55 (55.0)
Medicaid	7 (7.0)
Commercial	33 (33.0)
Other	5 (9.4)
Marital Status, n (%)	
Married	47 (47.0)
Divorced	14 (14.0)
Single/Widow	37 (37.0)
Unknown	2 (2.0)
ASA ^b Classification, n (%)	
1	4 (4.0)
2	55 (55.0)
3	41 (41.0)
Mean CCI ^c [range]	3.4 [0.0-17.0]
Indication for Revision, n (%)	
Aseptic Loosening	40 (40.0)
Fracture	5 (5.0)
Infection	22 (22.0)
Instability	15 (15.0)
Metallosis	2 (2.0)
Osteolysis	10 (10.0)
Other	6 (6.0)
Paprosky Classification, n (%)	
2A	34 (34.0)
2B	32 (32.0)
2C	22 (22.0)
3A	5 (5.0)
3B	6 (6.0)
4	1 (1.0)
Surgical Approach, n (%)	

Anterior	4 (4.0)
Posterior	75 (75.0)
Lateral	21 (21.0)
Navigation Utilization, n (%)	56 (56.0)
Implant Used, n (%)	
Allograft	29 (29.0)
Cage	1 (1.0)
Augment	3 (3.0)
Median Number of Screws [range]	4 [2.0-8.0]
Bearing, n (%)	
Fixed	47 (47.0)
Dual Mobility	53 (53.0)
Femoral Stem Revisions, n (%)	43 (43.0)
Mean Surgery Duration, minutes [range]	160.0 [84.0-398.0]
Mean LOS ^d , days [range]	3.3 [1.0-15.0]
^a BMI, Body Mass Index; ^b ASA, American Society of Anesthesiologists; ^c CCI, Charlson Comorbidity Index, ^d LOS, Length of Hospital Stay	

Table 1: Patient demographics, preoperative assessment and surgical data.

	N (%) unless otherwise specified (n=100)
Follow-Up Duration, years [range]	2.0 [0.9-4.1]
Shell Migration ^e , n (%)	0 (0)
Osteointegration ^e , n (%)	96 (100)
In-Hospital Complications, n (%)	
RBC ^f Transfusion	14 (14.0)
VTE ^g	2 (2.0)
Nerve palsy	2 (2.0)
UTI ^h	1 (1.0)
AKI ⁱ	2 (2.0)
90-Day ED ^j Visit, n (%)	8 (8.0)
Hematoma	1 (1.0)
Dislocation	4 (4.0)
Uncontrolled Pain	1 (1.0)
Periprosthetic Fracture	1 (1.0)
Infection	1 (1.0)
Readmissions, n (%)	6 (6.0)
Hematoma	1 (1.0)
Dislocation	3 (3.0)
Fracture	1 (1.0)
Infection	1 (1.0)
^e Among patients who had a retained shell from their index revision (>1-year Follow-up (n=97) and >2-year Follow-up (n=51))	
^f RBC, Red Blood Cell; ^g VTE, Venous Thromboembolism; ^h UTI, Urinary Tract Infection; ⁱ AKI, Acute Kidney Injury; ^j ED, Emergency Department	

Table 2: Clinical outcomes.

	1 Year Minimum Follow-Up (n=100)	2 Years Minimum Follow-Up (n=53)
Total Re-revisions, n (%)	9 (9.0)	9 (17.0)
Modular Components	6(6.0)	7 (13.2)
Acetabular Component Only	2 (2.0)	2 (3.8)
Acetabular and Femoral Components	1 (1.0)	0 (0.0)
Indication for Re-Revision, n (%)		
Infection	3 (3.0)	3 (5.7)
Dislocation	4 (4.0)	3 (5.7)
Hematoma	1 (1.0)	1 (1.9)
Nonunion	1 (1.0)	1 (1.9)
Mechanical failure	0 (0.0)	1 (1.9)
Time to Re-Revision, days [range]	131 [9.0-328.0]	310 [13.0-1113.0]

Table 3: Re-revisions.

	N (%) unless otherwise specified (n=100)
Mean Pre-Operative HOOS, JR. ^k [range]	47.6 [0.0-85.0] n=63
Mean HOOS, JR. ^k at One Year [range]	71.4 [33.0-100.0] n=59
Mean HOOS, JR. ^k at Two Years [range]	71.2 [36.0-100.0] n=11
Δ HOOS, JR. ^k Between Pre-Operative and One-Year Scores [range]	25.5 [-17.0-79.2]
Δ HOOS, JR. ^k Between Pre-Operative and Two-Year Scores [range]	31.0 [-13.9-50.1]
^k HOOS, JR. Hip dysfunction and Osteoarthritis Outcome Score Joint Replacement	

Table 4: Patient reported outcomes.

Discussion

To our knowledge, this is the first study examining one- and two-year outcomes of this novel modular porous acetabular shell for rTHA. The principal finding was a 97% 1-year acetabular shell survival rate and a 96% 2-year acetabular shell survival rate with 100% osteointegration and no cases of shell migration at most recent follow-up. The majority of patients in this study had moderate to severe acetabular bone loss, as evidenced by the 100% of patients with Paprosky scores of 2A or higher. Given the complexity of these cases, the low rates of acetabular component re-revision in this short-term follow-up is excellent.

The overall 5-year survival rate of rTHA is estimated to be roughly 81%, indicating that nearly 1 out of 5 rTHA will require a subsequent revision [12]. The survival rates of the acetabular component in the present study was 97% and 96% at one- and two-year follow-up, respectively. Longer follow-up is required to see if the survivorship in our series will fall to match previously mid and long term published reports. Given the moderate overall 5-year survival rate of rTHA, modular acetabular shells with a liner locking mechanism offer an advantage over cemented liners as they allow for greater flexibility if future rTHA are required, as a modular component exchange can be performed. Modular component exchanges are shorter procedures that can reduce the required anesthetic time and blood loss from surgery, offering a safer option for patients. Modularity may offer future ease in acetabular liner revision. This becomes relevant in cases where the femoral component may need to be revised but the acetabular component is in good position or in the case of a modular component exchange for an acute periprosthetic infection or instability.

In addition to allowing for modular component exchange, modular acetabular shells also allow for a wider range of modular liners to be inserted with varying levels of constraint, including larger heads, dual mobility constructs and fully constrained liners [8]. Having a wider range of implants in the armamentarium is essential in these complex rTHA cases, as the final implant stability may be at risk due to a compromised soft tissue envelope.

Other aspects of the implant's design that may contribute to the reported survivorship results is the porous titanium material and variable-angle locking screws. The function of porous titanium coating is to provide a high coefficient of friction to allow for initial stability and facilitate bony ingrowth [13]. Supplemental screw fixation improves the initial stability of the acetabular implant to allow for bony ingrowth [14]. The efficacy of these qualities is demonstrated in the excellent osteointegration and lack of shell migration in the present study.

The short-term complication rate following implantation of this novel modular porous acetabular component are comparable to other studies investigating outcomes following rTHA [15,16]. The most common complication was postoperative anemia requiring a blood transfusion, which is often required either during or after these complex and typically long procedures. Sershon, et al., examined 175 rTHA and found a transfusion rate of 16%, with lower preoperative hemoglobin, higher preoperative International Normalized Ratio (INR) and longer operative time all contributing as important risk factors for transfusion [17]. This is consistent with the rate of blood transfusion in the present study (Table 2).

Finally, the present study demonstrated notable increases in Hip dysfunction and Osteoarthritis Outcome Score Joint Replacement (HOOS JR) scores by over 25 points from preoperative to one-year postoperative and 31 points from preoperative to two years postoperative. This exceeds the Minimum Clinically Important Difference (MCID) for HOOS JR scores, which has been reported to be 18.0 in a recent study [18]. This notable improvement in HOOS JR scores from preoperative to one- and two-year postoperative further demonstrates the achievable functional level after rTHA in patients with marked acetabular bone loss.

Limitations

This retrospective observational study is not without its limitations. Given the retrospective nature, it is subject to collection error. Additionally, the relatively limited sample size and short-term follow-up limit the amount of information that can be gleaned about the performance of this implant over the longer-term. To address this, larger prospective multi-center studies are warranted with greater follow-up to fully understand the long-term performance of this implant. Direct comparison of this implant with other rTHA acetabular implants is also necessary. Despite these limitations, our findings indicate that this implant has excellent short-term survivorship that certainly has a role to play in the treatment of acetabular bone loss in the setting of rTHA.

Conclusion

In conclusion, the use of this novel modular acetabular component in the setting of rTHA showed excellent short-term survivorship and osteointegration with no cases of shell migration. The modularity of the construct allows for a wider variety of articulation configurations and allows for modular component revision to be performed more easily than with a fully porous shell and cemented liner if future rTHA are indicated. Further studies with longer follow-up are necessary to understand how this shell will perform over the longer-term when compared to other available acetabular implants.

Conflict of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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No benefits in any form have been received or will be received related directly or indirectly to the subject of this article. No funding was received in order to perform this study.

STROBE Statement

The authors have read the STROBE Statement checklist of items and the manuscript was prepared and revised according to the STROBE Statement checklist of items.

Ethics Approval / Institutional Review Board Statement

Not applicable

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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