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ORIGINAL STUDY

Porous titanium revision shells permit early weight-bearing and rapid rehabilitation in revision hip surgery

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An aging population and younger primary arthroplasty candidates have led to increased demand for acetabular bone deficient revision hip surgery. Seventy consecutive revision arthroplasty porous titanium shells prior to December 2011 were reviewed. We sought to determine evidence of implant instability in a cohort of patients that are mobilised early. Radiological data were analysed for stability. Primary endpoint was revision of implant. Mean age at surgery was 69.9 (±10) years. Median time since primary surgery was 13 years (range: 0.3-37). Forty-nine per cent had Paprosky Type IIb or greater acetabular deficiency. Bone graft and augments were not used. One shell was revised for ingrowth failure. Mean acetabular inclination was 35.4° (±7.3) post-operatively and 36.9° (±7.28) at latest follow up. There were no screw fractures. Porous titanium shells in revision arthroplasty are stable and permit rapid rehabilitation.

Keywords : Porous titanium ; uncemented ; cementless ; revision arthroplasty ; Paprosky.

INTRODUCTION

Acetabular component revision surgery is challenging. By 2030, the number of revision hip arthroplasties is predicted to increase by 137% *(7)*. Traditional methods to reconstruct acetabular defects such as allograft impaction bone grafting and cemented components are arduous for both patient and surgeon *(4)*. Moreover, there is limited availability to banked allograft. A long-term review of comparable cohorts who received either cementless or cemented acetabular fixation during primary total hip arthroplasty shows a significant lower need for revision surgery in the group with cementless acetabular fixation *(19)*. Cemented components are even associated with increased mortality compared to cementless arthroplasty *(8)*. Cementless acetabular shells have evolved considerably *(16)*. Consequently, outcomes with cementless components have improved over time *(10)*. A significant design improvement has been the introduction of porous metal. In a comparison

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between patients with ≤ 50% acetabular bleeding host bone contact with the porous metal acetabular revision shells and patients with > 50% to 85% bleeding host bone contact, no significant difference in failure were seen *(21)*. By using porous metals with Young's modulus similar to bone, good osseous integration with low stress shielding can be achieved *(9)*. Originally, bulk or support allograft was used for surgical reconstruction of acetabular defects *(15)*. Recently, surgeons are reporting good results with cementless shells with and without metal augments and allograft *(17,20)*. We use porous titanium cluster shells without allograft or augments for acetabulum revision and permit immediate full weight-bearing. This study presents early outcome for 70 shells. We sought to determine evidence of implant instability in this cohort.

MATERIALS AND METHODS

This is a single surgeon retrospective consecutive case series. All patients that underwent revision of acetabular component using porous titanium cementless press fit shell (Tritanuim® Acetabular Shell, Stryker®, NJ, U.S.A.) (Fig 1) from February 2009 to December 2011 were reviewed. Patient operative records, clinical notes and radiology were examined. Pre-operative demographic data, operative details and post-operative course were recorded (MEDITECH, MA, U.S.A.). Indications for surgery were aseptic loosening, sepsis, instability or peri-prosthetic fracture of primary or revision hip arthroplasty. Primary endpoint was revision of implant or implant failure. Secondary endpoint was implant movement.

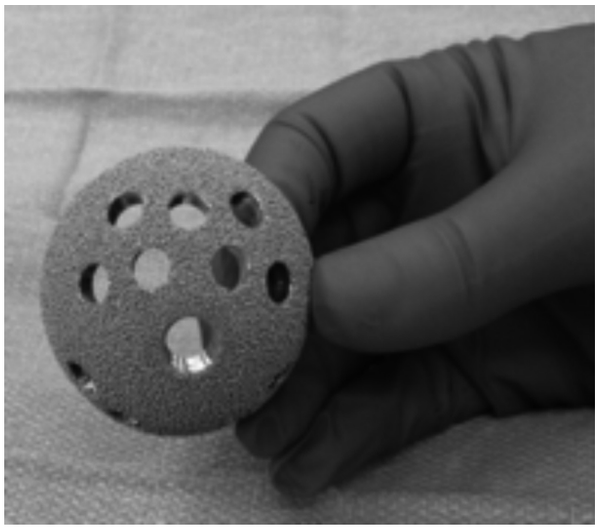

Fig. 1. — Photograph of Tritanium® shell demonstrating porous titanium surface with multiple screw hole options

Patients were positioned laterally with anterior and posterior pelvic support. Spinal anaesthesia was used routinely with a target mean arterial pressure of 70-80 mm Hg to minimise blood loss. General anaesthesia was used for failed spinal anaesthesia or in the event of prolonged surgical time. Cefuroxime chemoprophylaxis was standard except for those patients sensitive to penicillin or following transfer from another institution whereby erythromycin or vancomycin was the antibiotic of choice respectively. Scrub-side staff used Charnley gown and exhaust system. The surgical technique employed is similar to previously described *(18)*. An extensile posterolateral approach was used when concomitant femoral revision was indicated (62 cases). Direct lateral approach was used if acetabular only revision was performed (8 cases). Haemostasis was achieved with monopolar diathermy and radiofrequency coagulation (AquaMantys®, Salient Surgical Technologies, NH, U.S.A.). Cell-salvage was not employed. Existing hip arthroplasty was dislocated and when required, stem was removed. Arthroplasty stems were explanted with sequential osteotomes and high speed bur (Elite Bur, Stryker) or extended trochanteric osteotomy. Acetabular exposure was achieved with two Charnley pins and Hohmann retractors placed inferiorly in the obturator foramen and anterior to the acetabulum. Soft tissue clearance surrounding acetabular component was achieved with diathermy. Existing acetabular component was explanted. In the case of cementless shells, removal was performed using an extraction tool. For cemented cups, curved osteotome was used. Fibrous tissue and other products of osteolysis were carefully debrided once shell was removed and remaining acetabulum was inspected for defects. The inferior and superior hemipelvis was tested for discontinuity. Superior pubic ramus and ischium were assessed for screw placement suitability. Final

grading of acetabular deficiency was determined at this stage. Hemispherical cancellous bony floor was achieved where possible in lesser defects with sequential reaming to accommodate press-fit trial shell stable to longitudinal traction. Trident® Tritanium™ Acetabular System (Stryker®, NJ, U.S.A) revision shell with multiple screw holes was used in all cases. In contained defects, two-point, typically anteroposterior, interference fit was achieved and assessed for stability with trial shells. In uncontained defects or cases of dissociation, "Jumbo" shells were used taking advantage of recoil of the hemipelvis'. Shells ≥ 62mm in women and ≥ 66mm in men were considered "Jumbo" size. Shell screws (6.5mm cancellous bone screws) placed posterosuperiorly and inferiorly in the pubis and ischium were used to bridge the discontinuities or defects. Final cup position with an abduction angle of 40° and anteversion of 15° was sought using pelvis landmarks and the horizontal. Defects were filled with synthetic bone substitute (Actifuse™, Apatech®, Baxter, UK) on occasion according to surgeon discretion. Polyethylene 36mm internal diameter liners (X3 Bearing, Stryker®, NJ, U.S.A) were used in all cases and 10° liners were used for posterolateral approaches.

Femurs were revised using either cementless, press fit stems (Tri-Lock® Bone Preservation Stem, DePuy Orthopaedics, Inc., IN, U.S.A.), cement-in-cement short or standard length double taper, polished stems (Exeter® Total Hip System, Stryker®) or modular, reamed press-fit systems (Restoration Modular System, Stryker®). Choice of implant was based on proximal femoral bone stock. Metal (Orthinox®, Stryker) or ceramic (Alumina, Stryker; BIOLOX®, DePuy) 36 mm heads with appropriate off-set to achieve stability were used.

Closed system re-infusion drains were used routinely. Closure was layered (PDS II®, 2/0 Vicryl®, 3/0 Monocryl®, ETHICON Inc., OH, U.S.A.) and completed with Steri-strips® (3M, MN, U.S.A.), Mepore® dressing (Mölnlycke Healthcare, Göteburg, Sweden) and wound pad.

Pre-operatively, patients were given 2g paracetamol, 200 mg celecoxib, 25 mg pregabalin and a 400 ml carbohydrate drink (Pre-op) at 0700 hrs regardless of planned operative time.

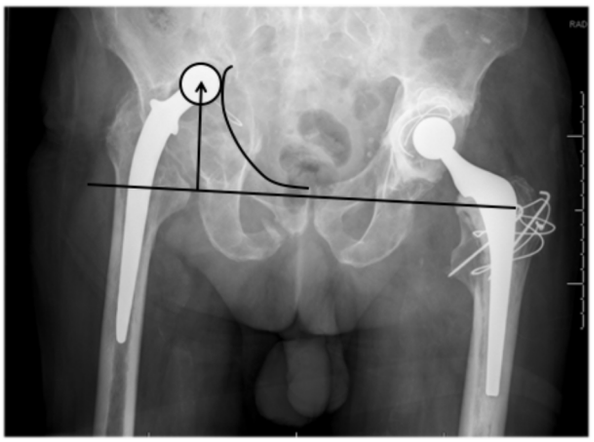

Fig. 2. — Radiograph demonstrating pre-operative acetabular deficiency and migration of femoral head (A) relative to Kohler's line (B) and inter-teardrop line (C).

Uncontaminated drained blood was re-infused within three hours of surgery. A target of physiotherapist-supervised full weight bearing within three hours of surgery was set. Ward and gym based physiotherapy was continued twice daily until stair climbing was achieved and patients were discharged home or to convalescence. Physiotherapy focused on active hip abduction, flexion and extension exercises and balance and proprioception training. Patient controlled opiate infusion pumps were not used. Paracetamol, celecoxib, pregabalin was continued postoperatively and 50 mg (Palexia FCT) four-hourly was used for breakthrough pain control. Subcutaneous low molecular weight heparin, tinzaparin (Innohep®, LEO Pharmaceutical Products, Ballerup, Denmark) thromboprophylaxis was changed to oral rivaroxaban (Xarelto®, Bayer Healthcare Pharmaceuticals, Germany) upon discharge for a total of six weeks. Above knee thromboembolic deterrent stockings were routinely used. Pneumatic compression pumps were used when in bed during in-patient stay. Discharge analgesia was Arcoxia 120 mg daily, Pregabalin and solpadol. Fifteen Palexia FCT tablets were given for breakthrough pain. Patients were reviewed at 6 weeks, 3 months, 6 months, 1 year and 2 years following surgery. Evaluation included radiology and clinical assessment.

Digitised radiographs of both hips and femora were assessed for pre-operative acetabular

deficiency according to Paprosky *(15)* using Adobe Photoshop CS5.1 (Adobe®, San Jose, CA., U.S.A.). Latest follow-up radiographs were compared with immediate post-operative radiographs and assessed for screw fracture and acetabular shell migration according to Nunn *(12)* (Fig 2). Radiographs were evaluated independently by the first (FR) and senior (DB) author and consensus was obtained for final measurements. Correction for radiographic magnification was based on known femoral head diameter and acetabular shell diameter. Preoperative evaluation included location of hip centre in relation to interteardrop line and teardrop to determine both vertical and horizontal position. Malrotation of the pelvis was corrected using largest interteardrop distance. Postoperative evaluation included initial and latest post-operative radiographs for cup inclination and centre of rotation migration horizontal to the teardrop. Post-operative vertical migration could not be calculated since malrotation could not be excluded without a definable vertical line *(12)*. Inclination change of > 5° or horizontal migration of > 4mm was defined as movement *(3)*. Recovery room radiographs were not used for analysis owing to substandard quality as previously described *(11)*. WOMAC *(1)* scores and visual analogue scales (VAS) for general health and patient satisfaction with surgery were recorded at clinical review or via postal questionnaire.

The degree of (linear) relationship between the change variables and continuous patient characteristics was assessed graphically using Lowess smoothers and numerically using either the Pearson or Spearman's Correlation coefficient as appropriate. The association between categorical variables was assessed using the Chi Square test. Linear regression was used to model the relationship between the change variables and patient characteristics collectively in order to identify those variables, if any that were significant predictors of inclination change for example: variables that may correlate with shell movement were analysed. All analyses were performed using Minitab 16 and SPSS 20 and the significance level for each analysis was set at the 0.05 significance level.

RESULTS

Seventy consecutive porous titanium cementless press fit shells were implanted in 65 patients with a mean age of 69.9 (±10) years (Table I). There were forty (61%) male patients. One male patient had bilateral surgery. Another male patient required revision of his shell to another shell. There were 25 (39%) females of which three underwent bilateral surgery. The most common indication for acetabular revision was osteolysis. Cemented (acetabular and femoral components) arthroplasty was the most frequent primary implant with median 13 years (0.30-37) since index surgery. None of the primary arthroplasties revised in this series were hybrid replacements. Forty-nine per cent of patients had Paprosky Type IIb or greater acetabular deficiency. Mean pre-operative haemoglobin was 12.9(±1.56)g/dL. Mean pre-operative albumin and total lymphocyte count was 42.1(±3.9) mm ol/L and 1.39 x 109 respectively.

The mean shell size implanted was 60mm (Table II). There were five "Jumbo" cups in females and

Table I. — Patients

	Demographics
Male	40 (61%)
Female	25 (39%)
Age at surgery years (mean ±SD)	69.9 (±10)
Years since last arthroplasty median (range)	13 (0.3 – 37)
	Primary Acetabular Implant
Cemented	50 (71%)
Resurfacing	12 (17%)
Uncemented	8 (11%)
	Indication for revision
Fracture	3 (4%)
Instability	6 (9%)
Osteolysis	56 (80%)
Sepsis	5 (7%)
	Paprosky
I	26 (37%)
IIa	10 (14%)
IIb	13 (19%)
IIc	13 (19%)
IIIa	7 (10%)
IIIb	1 (1%)

Table II. — Operative detail

	Mean (SD) [Median]	Min-Max	Q1-Q3
Shell size (mm)	60 (4.5)	54 - 72	58-64
Number of screws used (n)	3 (1.8)	0 - 8	2-4
Intra-op Transfusion	0.77 (1.2) [0]	0 - 4	0.0-2.0
Post-op Transfusion	1.28 (1.8) [0]	0 - 9	0.0-2.0
No graft	56 (80%)		
Synthetic graft	14 (20%)		
Femoral revision Modular cementless stem	16 (23%)		
Tapered cemented stem	36 (51%)		
Cementless stem	10 (14%)		
None	8 (11%)		

Table III. — Clinical (64 shells) and radiological (67 shells) follow-up

	Mean (SD)	Median	Q1-Q3
Radiology follow-up (months)	9.85 (8.5)	6.9	3.2-13.3
Total follow-up (months)	12.89 (10.3)	9.28	-4.5-20.1
First inclination (degrees)	35.4 (7.32)		30-39
Latest inclination (degrees)	36.9 (7.28)		31.8-41.4
First horizontal (mm)	30.77 (5.11)	30	26.9-34.4
Latest horizontal (mm)	30.78 (6.01)	30	26.0-35.1
WOMAC (0-96)	59.8 (25.4)	60	50-80
VAS Health (0-100)	76.2 (25.7)	88	60-95
VAS Satisfaction (0-100)	32.3 (23.6)	28	0-100

12 “Jumbo” cups in male patients. An average of three screws was used to augment press-fit fixation. Screws were not required in six cases of acetabular revision. No bone allograft or metal augments were used. Synthetic bone graft was used in fourteen cases. Chi Square test suggested no significant association ($p = 0.57$) between synthetic graft use and Paprosky classification type. Concomitant femoral stem revision was performed in 88% of cases with 23% of these requiring extended trochanteric osteotomy. Median units of blood transfused intra-operatively and post-operatively were 0 (0-4) and 0 (0-9) respectively. An analysis of variance used to compare the difference in mean intra-operative blood transfusion suggest no evidence of difference across the four femoral revision groups (no femoral revision, cementless stem, cemented stem and extended trochanteric osteotomy with modular cementless stem), $p = 0.17$. Kruskal Wallis test and Mann Whitney multiple comparisons of median post-operative blood units transfused identified higher median for extended trochanteric osteotomy and modular cementless stem compared with both cemented stem and cementless stem ($p = 0.002$ and $p = 0.036$ respectively).

Median clinical follow up was 9 (0.43-36) months (Table III). Three patients had died of unrelated causes at latest review and three patients were lost to follow up after initial six-week post-operative review. These patients had undergone unilateral surgery and were excluded from analysis of patient reported outcome scores. This corresponds with a 90.7% complete dataset. Mean WOMAC score was 59.8 (±25).

Mean VAS for overall health was 76.2 (±25.7) and mean VAS for satisfaction with acetabular revision surgery using cementless porous titanium shell was 28 (13-46). A positive relationship between increasing overall health VAS and better WOMAC score was identified ($p = 0.001$). Two shells were revised. One shell was revised for sepsis and the other shell was revised for mechanical failure due to spin out. There was one episode of sciatic nerve palsy that failed to resolve at latest evaluation. There was no hip joint instability. There were no clinical thromboembolic events.

Complete radiological data (pre-operative, day one post-operative and latest follow-up) were available for 95.7% of the cohort. Median radiological follow up since revision surgery was 6.9 (0.43-36.3) months (Table III). Mean initial and latest post-operative acetabular inclination was 35.4˚ (±7.3) and 36.9˚ (±7.28) respectively. Mean difference in horizontal migration of centre of femoral head was 0.011mm.

Only five of sixty-four shells demonstrated inclination change ±5˚ (Fig 3). This includes the

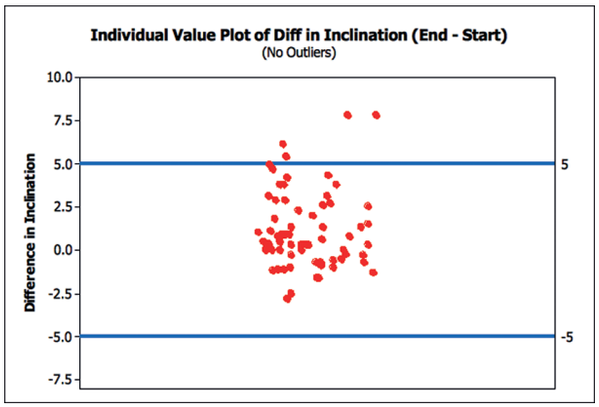

Fig. 3. — Scatterplot showing difference in acetabular shell inclination for each individual.

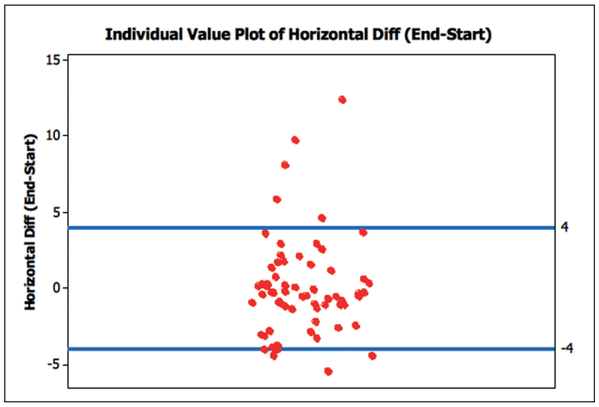

Fig. 4. — Scatterplot showing difference in horizontal migration for each individual.

shell that was revised for spin-out from initial inclination of 33.2˚ to final inclination of 141.4˚. Overall, last acetabular inclination values tended to be higher than initial values ($p < 0.0001$). The corresponding 95% confidence interval of 0.628 to 1.76 suggests that inclination tends to be higher at the end compared to the start where the typical change is likely to be between 0.63 to 1.76 degrees. Ten individuals (15.2%) demonstrated horizontal movement of centre of femoral head of ±4mm from initial measurement to last measurement (Fig 4). Overall, paired t-test identified no significant horizontal migration ($p = 0.98$). Horizontal movement of any magnitude did not demonstrate significant coronal predilection since 41% of shells migrated positively and 59% migrated negatively. Only two of the seventy shells exhibited relevant concomitant horizontal position and inclination change thus movement is not associated between planes.

Variables that may correlate with shell movement were analysed: Patient age, Paprosky acetabular deficiency subtype, shell size, number of screws used and concomitant femoral component revision. There is a positive relationship between difference in acetabular inclination and age at surgery. A similar positive relationship was observed for difference in horizontal position and age however this did not achieve statistical significance ($p = 0.246$). Difference in acetabular inclination demonstrated variability across Paprosky subtypes but with no obvious difference in medians. Results were similar for horizontal movement. There was no significant association between shell size and either horizontal movement ($p = 0.958$) or acetabular inclination change (0.814). Similarly, there was no association with the numbers of screws used to augment shell fixation ($p = 0.335$, $p = 0.985$). Finally, concomitant femoral revision was not associated with change in acetabular inclination or horizontal migration.

DISCUSSION

This series of seventy consecutive cementless porous titanium shells implanted without structural augments for revision arthroplasty and rapidly mobilised has good early outcome. Revision due to mechanical failure is low, peri-operative transfusion rate is low, defined shell movement is uncommon and patient reported outcomes are comparable to similar surgeries *(17)*.

We acknowledge limitations of our experience using cementless shells for all acetabular deficiencies. Firstly, the relative short follow-up does not allow us report osteolysis surrounding shells. Osteolysis was not a variable we sought to investigate. Primary cementless implants have already demonstrated lower revision rates and less radiographic loosening compared to cemented acetabular components *(19)*. Our aim was to evaluate immediate stability of an acetabular implant that permits weight bearing and a rapid rehabilitation protocol in the revision setting. Primary concern to the operating surgeon is stability of a cementless implant that facilitates early mobilisation. Cementless component com-

paction with early weight bearing has shown good biological and mechanical results in canine models *(5)*. We allow our patients fully weight bear from the first post-operative day under the supervision of physiotherapists. Rehabilitation is progressed from ward to gym and patients are deemed suitable for discharge once they can safely climb stairs. This rapid rehabilitation protocol creates a high bed turn-over rate at our institution with inherent cost-benefit.

Secondly, the numbers of IIIa and IIIb Paprosky subtypes are small. Contrary to this, almost half of the series were Paprosky IIb acetabular deficiency subtype or greater. Furthermore, a large proportion (17%) of the revisions we report are for recalled resurfacing devices that although are lower grades of acetabular deficiency in this series, have demonstrated higher revision failure rates *(20)*.

Thirdly, there is heterogeneity within the series regarding primary implant and concomitant femoral revision but type of primary implant or subsequent reconstructive strategy used did not correlate with cup movement. Similarly, there were no dislocations in this heterogeneous group despite 88% femoral revision rate. We use 36mm femoral heads in line with previous reports of good stability following revision *(6)*.

Despite the aforementioned limitations, we present good early results without augments or allograft. With limited access to banked allograft, we have evolved our reconstructive strategy. This is deviant from Paprosky's original or current management algorithm *(9,14)*. Synthetic bone graft was used in fourteen cases early in the series. Chi Square test did not suggest a significant association between Paprosky severity and synthetic bone graft use ($p = 0.57$). We have since discontinued synthetic bone use.

Perceived advantage to cementless components is reduced operative time. Skin-to-skin operative time is not recorded at our institution. Time between entering and leaving the operating theatre does not accurately reflect surgical time. Our intra-operative (median zero (0-4) units) and post-operative median zero (0-9) transfusion rate is low for a cohort with 88% concomitant femoral revision. Our single deep infection is a similarly low rate. Transfusion and sepsis have been shown to correlate with operative times in arthroplasty surgery *(23-24)*.

Our single mechanical failure was early in the series. No screws were used to augment the fixation. We feel that not employing screws contributed to failure despite an initially stable press-fit. As a result, we recommend using screws with this construct and do not see a draw-back to their use when safe trajectories are employed. Despite this, there was no evidence that screw use correlated with shell movement in this cohort. Screws were typically inserted in a posterosuperior trajectory. The overall inclination change from immediate post-operative radiograph to latest radiograph tended to be positive rather than negative ($p < 0.0001$). We propose that ischial screws may reduce inclination change however we acknowledge that any change likely to be between 0.63° and 1.76°, is not manifestation of movement or clinically relevant *(3)*.

Bone density declines with age *(2)*. Low total lymphocyte count and serum albumin are markers of protein energy malnutrition *(13)*. There was no correlation between total lymphocyte count and albumin and outcome in this series. Conversely, increasing age was found to correlate with inclination change. We extrapolate that inherent bone density is important for implant stability.

Our experience is similar to recent publications that have demonstrated good results with shell-only revision *(20)*. Our study results suggest acetabular component stability and early weight bearing regardless of simultaneous femoral revision is possible. In conclusion, porous titanium shells provide good early results and stability in all acetabular deficiencies without bone graft or augments and allow rapid rehabilitation.

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