Successes and Failures of a Freedom™ Constrained Cup Used in a Major Salvage Procedure

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Abstract

Background: This is a case report of a 36mm constrained cup (Freedom™, Biomet IN) that performed successfully for 7-years in a salvage case involving a total-femur implanted in a leg already short by 3-4 inches. The goal was to enhance hip motion and stability using a 36mm head instead of the usual 32mm size. Templating indications were for a 50mm cup (Freedom™; Arcom™ liner). The proximal femur inserted in 2008 incorporated the 36mm constrained THA and was anchored distally to bone using the Compress™ fixator. By 2012 the fixator loosened and was replaced by hinged total-knee arthroplasty (TKA). The THA was retained at revision and patient's clinical follow-up was satisfactory for 4 years. As indicated by Martel radiographic method, the Arcom™ liner showed minimal wear over this period. Radiographs in Feb-2016 showed the cup's constraint ring had rotated slightly but the patient had no symptoms. By Dec-2016, the patient had experienced three falls and also had heard a popping sound in her hip. At Dec-2016 office visit, radiographs indicated additional rotation of the constraint ring and CT scans showed an eccentric head position contacting the metal shell. At revision, 50% of the Arcom rim was ablated and the remainder present as a loose fragment. Following insertion of new Freedom liner and 36mm head, her follow-up appears satisfactory 10-months later. Her leg shortening remains but she walks to office visits using a cane and doesn't need the cane at home.

Methods: Retrieved Arcom liner and detached rim fragment were reconstructed, photographed, and then bi-

valved for comparison to similarly prepared exemplar liners, one identical to our revision and one with a thicker wall. Details of liner sections were taken from photographs and reconstructed by computer graphics (Canvas Draw-3™). Wear performance over the first 7 years was assessed using the Martel x-ray method.

Results: Inspection of retrieved liner showed a large oval depression in the ablated rim. The contra-rim featured the large Arcom fragment and the underlying liner wall was less than 1mm thick. Comparison to exemplar liners showed that the large fragment had separated along the lower edge of the constraint groove. Exemplars demonstrated a substantial rim buttress spanning 13mm, which had been ablated in our retrieval.

Discussion and Conclusion: Although this was not a high-demand patient, the considerable hip-impingement forces in a flail limb likely levered the head repeatedly against the liner's constrained rim. Neck impingement was clearly evident in the damaged liner. A subluxing femoral head would also thin the contra-wall, as would backside wear. We do not know if the eccentric ring image in Feb-2016 radiographs depicted failure. The liner may have escaped from the shell's locking-ring and with activity, ablated the Arcom contours and led to rim fracture. It is also possible that the liner constraint was damaged when the patient fell, thereby allowing the liner to mobilize.

Keywords: Constrained Cup, mechanical impingement, salvage, complex revision

Level of Evidence: AAOS Therapeutic Level III

Educational Value & Significance: JISRF Level C

Background

Failed total hip arthroplasty (THA) may necessitate novel designs of revision implants that present unique risks as well as special salvage benefits. Use of constrained cups to enhance joint stability is offset by a reduction in the range of motion with concomitantly higher risk of impingement. [1-3] The patient in this case report had a total hip arthroplasty (THA, left leg) in her early thirties that subsequently became infected. This was revised to a Girdlestone hip and she had to walk with crutches for 19 years (1989-2008). Now in her early 50's, she had an attempted THA re-implantation but that immediately became infected. Following multiple debridements, an antibiotic bone-cement spacer and two nails were inserted (Fig. 1A). Now in her early fifties (2008) she desired a more functional result and talked her surgeon into implanting a revision THA. With 3-4 inches of leg shortening, and lacking hip musculature, this patient was clearly at risk for dislocation. Therefore, a constrained-cup design with as large a femoral head as possible was essential.

In 2008, the patient's left femur was salvaged with a proximal femoral replacement (Fig. 1B). The choice of cup provided for a 36mm head with enhanced stability and improved range-of-motion (Freedom™, Biomet, Warsaw, IN). The polyethylene insert (Arcom™) did not appear as motion restrictive as other designs and the external clamping ring came pre-installed from the factory. In addition, this design incorporated a unique method for inserting the 36mm femoral head into the cup. Three bone screws were added for additional security. The shaft of the femoral-implant was anchored distally using the Compress™ fixator system (Biomet, Warsaw, IN). With a leg 3-4 inches short and with limited hip muscles, this patient's activity was considered low demand. Nevertheless, this reconstruction of her left femur represented a major salvage operation with success depending on fixation in the small segment of distal cortex and cancellous bone of the condyles.

At the 2011 office visit (2.5 years follow-up), the distal fixation was satisfactory with no signs of loosening (Fig. 2A). However, she presented at the 2012 office visit with distal-fixation failure at the level of connecting pin (Fig. 2B). This was revised to a hinge-knee arthroplasty while the original Freedom cup was retained. Her post-op results were satisfactory and follow-up continued satisfactorily from 2012 into 2014 (Fig. 3B).

Radiographs taken during office visit of February 2016 indicated that the external clamping ring had a rotational migration of 8° in the AP view (Fig. 4A) and 2.6° in the lateral view (Fig. 4B). This suggested that the cup's locking-mechanism may have failed but the patient offered no

Figure 1. Patient radiographs illustrating (A) Girdlestone hip that the patient walked on for 19 years, and (B) her 2008 revision with the THA incorporating a Freedom constrained cup, a large femoral replacement, and distal Compress knee fixator.

Figure 2. Patient radiographs illustrating success of Compress distal fixation at 2.5 years (2011) but loose and disassociating at 3.5 years.

Figure 3. Radiographs illustrating, (A) hinge total knee replacement in 2012, and (B) retention of original Freedom cup, noting the clamp ring aligned with the acetabular cup.

Figure 4. Imaging showing clamp-ring eccentric to Freedom cup, (A) 8° rotation in AP view, and (B) 2.6° rotation in lateral view.

Figure 5. Martell x-ray method indicating very low wear.

complaints. Multiple radiographic assessments using the Martell software provided 0.4mm and 323mm³ estimates for linear and volumetric wear averages, respectively (Fig. 5). Over her 7-year follow-up (8/6/08 to 6/20/15) this would indicate linear wear was as low as 0.06mm/year. Thus, cup wear did not appear to be a problem. Repeat of radiographic wear assessments over the following 8-month period (6/20/15 - 2/16/16) revealed linear-wear measurement had increased from 0.4 to 1.1mm.

Unfortunately, this patient had a fall in December 2016 and presented in the office two days later. She also claimed two prior falls and had heard a “popping” sound from her hip. Radiographs revealed that the external clamping ring now had a rotational shift of 14.3° (Fig. 6A). This indicated that the cup’s locking-mechanism had failed. CT scans showed the femoral head was in contact with the metal acetabular shell (Fig. 6B). Small cystic areas were also visible behind the acetabular shell (arrowed).

At revision operation, fully 50% of the liner’s polyethylene rim had been abraded and a large loose fragment represented the other 50% (Fig. 7A). The rim-clamping ring and the cup-locking ring were also recovered. While the femoral head had been making some contact with the metal acetabular shell, there was no tissue-staining. A new Freedom liner and femoral head were installed following the recommended procedure. The patient’s left leg remains 3-4 inches short but she walks in for office visits using a cane and doesn’t use the cane at home. Her follow-up appears satisfactory to date.

Methods

Damage on the retrieved 36mm femoral head was analyzed by scanning electron microscopy (Zeiss, SEM), energy dispersive x-rays (Bruker, EDS) and interferometry for roughness assessment (ZYGO, NewView600). The retrieved liner was photographed and sectioned through the thin wall section located under the detached rim fragment (Fig. 7B). The components and sections were photographed for dimensional comparison with exemplar liners using computer graphics (Canvas Draw-3, ACDsee, Inc.)

Results of Failure Analysis

There were four striking aspects to this retrieved liner. These were, (i) 50% of the liner’s rim missing, (ii) a large rim fragment loose, (iii) liner thickness under the loose fragment reduced to less than 1mm thick, and (iv) large oval depression on contra liner-rim. The average dome

Figure 6. Images showing, (a) clamp ring rotated 14.3°, and (b) femoral head contacting metal shell and cystic changes indicated by arrows.

Figure 7. Retrieved Freedom liner with its detached rim fragment, (A) opposite side of liner to the fragment showed large indent typical of impaction by the femoral neck, (B) liner was cut into two sections in the plane through the thinnest region that lay under the fragment.

Figure 8. Comparison of liner contours, (A) rim fragment superimposed on sectioned retrieval showed thinned wall, and (B) section of exemplar Freedom liner.

Figure 9. Matching sections retrieved and exemplar liners, comparing details of (1) cup rim, (2) groove for clamp ring, (3) sub-rim, (4) anti-rotation scalloping, and (5) groove for liner locking-ring to metal shell.

thickness of the retrieved liner approximated 7.5-7.7mm (Fig. 7). Two exemplar liners were compared, one similar to our patient's and one with a thicker wall. This design has a substantial rim buttress and scalloped contours measured 13.4mm high (Fig. 8B). Comparison of the sections confirmed a major loss of circumferential contours (Fig. 7A, 8A, 9).

Two exemplar liners were compared, one similar to our patient's and one of a thicker wall design. The average dome thickness of the retrieved liner approximated 7.5-7.7mm (Fig. 7). Comparison of the sectioned retrieval to the new liners confirmed there was a major loss of circumferential polyethylene (Fig. 7A, 8A, 9). This liner design has a substantial buttressed rim and scalloped contours averaging 13.4mm high (Fig. 8B).

The groove for the locking ring had approximately a 3mm polyethylene thickness in this design (Fig. 8B: detail 'B'). However, this (Fig. 9A: contour '5') was not where rim fracture occurred. Rim separation occurred at the level of the clamping-ring groove (Fig. 9A: contours '2' and '3'). Equally remarkable was that the intermediate rim contour ('3') and scalloping detail ('4') had also been ablated (Fig. 9). In addition, the liner wall was paper thin under the loose fragment, (Fig. 8A).

Discussion

This is the first detailed report of a Freedom constrained cup performing over 8-years in a complex salvage case. Prior to this reconstruction, our patient had coped with a Girdlestone hip on the left side for 19 years before demanding a more functional outcome. Her subsequent Freedom cup and femoral construct did well for four years until the distal fixator failed. Revision to a hinged TKA gave her another four years before the Freedom cup failed.

As in other revisions of this nature, our planning was more focused giving our patient adequate mobility and stability by using a large head in a constrained liner, thereby reducing risk of multiple dislocations. It appeared very unlikely that this Arcom liner would show minimal wear for 8-years and then suddenly produce high wear in the last 8 months of follow-up. It was a retrospective

analysis of the radiographs that showed an 80 rotation of the liner's clamp ring, suggesting the liner was loose as of February of 2016. At revision, gross abrasion of the liner's external surface confirmed that the liner had been loose and free to piston inside the shell. We had not anticipated the degree of polyethylene destruction that could result from a flail limb habitually impinging on a polyethylene liner. At revision, the typical deformation pattern of the femoral neck was still visible on the ablated polyethylene rim (Fig. 7A). In addition, the polyethylene wall under the fractured rim was paper thin (Fig. 8A). We surmised that the resulting contact with the repeatedly subluxing femoral-head produced cold-flow and back-side wear in the polyethylene, thereby facilitating rim fracture. The patient confirmed she had 3 falls in the 9-months prior to revision, one accompanied by a "popping" sound. It was therefore likely that the patient's falls were contributory to the final fracture of the liner with release of the clamp ring. We noted that rim fracture had occurred around the lower edge of the clamp groove (Fig. 8B: 'A') and not at the site of the cup-locking ring (Fig. 8B: groove 'B')

Our learning experience in this educational case was six fold, (i) monitoring rotation of the clamping ring relative to the cup face may be a key indicator of liner failure, (ii) habitual impingement can be anticipated even when using a large head, (iii) we were impressed by the severity of polyethylene damage created over 9-months, (iv) wear of the Arcom liner was anticipated but did not materialize, and (v) Freedom liners with thicker polyethylene are available for the 36mm head. This may be a consideration in the future for patients with suitably large hip joints.

Conclusion

In conclusion, it was notable that this constrained liner functioned very well for 7 years in our complex case and was easily revised at 8 years to another Freedom liner. The unique method for inserting the 36mm femoral head into the Freedom cup greatly facilitated the revision operation.

References

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AUTHOR DISCLOSURES

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