Early Failure Mechanisms of Constrained Tripolar Acetabular Sockets Used in Revision Total Hip Arthroplasty

Christopher C. Cooke, MD,* William Hozack, MD,† Carlos Lavernia, MD,‡ Peter Sharkey, MD,† Shani Shastri, MD, MPH,† and Richard H. Rothman, MD, PhD†

Abstract: Fifty-eight patients received an Osteonics constrained acetabular implant for recurrent instability (46), girdlestone reimplant (8), correction of leg lengthening (3), and periprosthetic fracture (1). The constrained liner was inserted into a cementless shell (49), cemented into a pre-existing cementless shell (6), cemented into a cage (2), and cemented directly into the acetabular bone (1). Eight patients (13.8%) required reoperation for failure of the constrained implant. Type I failure (bone-prosthesis interface) occurred in 3 cases. Two cementless shells became loose, and in 1 patient, the constrained liner was cemented into an acetabular cage, which then failed by pivoting laterally about the superior fixation screws. Type II failure (liner locking mechanism) occurred in 2 cases. Type III failure (femoral head locking mechanism) occurred in 3 patients. Seven of the 8 failures occurred in patients with recurrent instability. Constrained liners are an effective method for treatment during revision total hip arthroplasty but should be used in select cases only. **Key words:** constrained sockets, complications, dislocation.

Dislocation of a total hip arthroplasty (THA) is a traumatic event for both the patient and the surgeon. In primary hip arthroplasty, its incidence has been reported to be between 0.6% and 9.9% [1,2]. With revision surgery, it can be as high as 20% [1,3]. Patient-related conditions such as compliance [4], substance abuse [3,5], neuromuscular disorders that affect hip mechanics [3,6], and primary reconstruction for hip fracture [2,7,8] have been associated with higher dislocation rates than normal. Iatrogenic issues also play a role. These include improper component position [9,10], sources of secondary impingement [11], operative approach [11,12], and poor soft-tissue tension at the time of implantation [13,14].

Revision surgery for recurrent dislocation includes changing component position [10,11], larger femoral head component [15], use of an elevated liner [16], trochanteric advancement [17], conversion to a bipolar or tripolar device [18,19], or to a constrained socket [20,21]. Bipolar devices have been shown to be an effective salvage, yet they are known to carry a risk for groin pain and erosion of the remaining acetabular bone with subsequent failure [22–24].

Constrained acetabular liners have proven themselves to be an effective operative treatment for the recurrent dislocating hip, especially when more conventional means of revision surgery fail [20,21].
Albeit in few reports with relatively short-term follow-up, constrained liners have shown a failure rate as low as 4%, depending on the study and brand of constrained liner (Table 1). To date, there are no studies examining specifically the failure mechanisms of constrained sockets. Our objective was to review our constrained acetabular sockets and to describe the different mechanisms of failure observed.

**Materials and Methods**

Fifty-eight total hip revisions using constrained acetabular liners were performed by one surgeon between February 1998 and November 1999. During the same period, 430 total hip revisions were performed. All patient records were reviewed. This study included a total of 28 males and 30 females. The average male age, height, and weight was 64.3 years (range, 35.7–90.7 years), 68 inches (range, 61–74 inches), and 207 pounds (range, 130–285 pounds), whereas females averaged 65.4 years (range, 39.3–86 years), 63.6 inches (range, 51–70 inches), and 160.6 pounds (range, 110–260 pounds), respectively.

Osteonics tripolar constrained acetabular liners were used in all 58 patients (Fig. 1). Forty-nine of these liners were inserted directly into a cementless shell affixed directly to bone. Of the remaining 9, 6 were cemented into a pre-existing cementless shell, 2 were cemented into a reconstruction cage, and 1 was cemented directly into the acetabular bone.

Indications for use of a constrained acetabular component and the number of patients with each indication were as follows: preoperative recurrent instability (46), girdlestone reimplant (8), correction of leg lengthening (3), and periprosthetic fracture (1). The minimum follow-up after surgery was 2 years (range, 2–3.6 years). In 9 cases operated on for recurrent instability and in the 3 cases operated on for leg-length discrepancy, the use of a constrained socket was dictated because of intraoperative instability of the hip. A femoral head size of 22 mm was used in 11 hips, 28 mm in 46 hips, and 32 mm in 1 hip. Skirted necks were used in 10 hips and nonskirted necks in 48 hips.

Three different failure mechanisms were identified (Fig. 2). Type I failures occurred at the acetabular bone-prosthesis interface. Type II failures occurred at the locking mechanism holding the constrained liner to the acetabular shell (liner locking mechanism failure). Type III failures occurred when the femoral head dislodged from its capturing mechanism (femoral head locking mechanism failure).

**Results**

Fifty patients (50 hips) continue to function well at follow-up, with no dislocations and no failure of the constrained liner mechanism.

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**Table 1. Failure Rates Reported in the Literature**

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Socket Brand</th>
<th>No. of Components</th>
<th>F/U</th>
<th>Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lombardi, 1991</td>
<td>S-ROM</td>
<td>57</td>
<td>30 mo</td>
<td>12%</td>
</tr>
<tr>
<td>Anderson, 1994</td>
<td>S-ROM</td>
<td>21</td>
<td>31 mo</td>
<td>29%</td>
</tr>
<tr>
<td>Goetz, 1998</td>
<td>Osteonics</td>
<td>101</td>
<td>61 mo</td>
<td>4%</td>
</tr>
</tbody>
</table>

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**Fig. 1.** A diagrammatic representation of the Osteonics constrained tripolar prosthesis.

**Fig. 2.** The 3 modes of failure of a constrained acetabular socket.
Eight patients (13.8%) required reoperation specifically for failure of the constrained implant (Table 2). The time to failure ranged from 3 days to 2.4 years.

In the 49 cementless cups with a snap-in constrained liner, there were 6 failures (12.2%). One of 6 constrained liners cemented into a well-fixed cementless shell failed (16.6%). Two constrained liners were cemented into a cage; 1 failed. Seven of the 8 failures were in patients being treated for instability. There was no correlation between femoral head size and the rate of early failure ($P = .966$). Among the patients who had a 22-mm head, there was no significant difference in early failure rate between the skirted neck and nonskirted neck ($P = .478$). The same pattern was observed in patients with the 28-mm head ($P = .599$).

Three type I failures were identified. In 1 patient, the constrained liner had been cemented into an acetabular reconstruction cage, which subsequently failed by pivoting laterally about the superior fixation screws. Upon failure, the inferior flange pulled out laterally, destroying the lateral ischial cortex (Fig. 3). In the other 2, the recently implanted cementless shell became loose at the bone-prosthesis interface. Fixation screws for the cementless cup or the cage had been placed only superiorly, with no fixation inferiorly. All cages and cups failed in a similar manner—they cantilevered about their superiorly placed fixation (Fig. 4).

Two type II failures were found (Fig. 5). In 1 case, the constrained liner had been placed in standard fashion into a freshly inserted cementless shell. Failure in this case was related to bony impingement, which was removed at revision surgery, with reinsertion of a new constrained liner without shell revision. In the other patient, the constrained liner

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Table 2. Failures in this Series

<table>
<thead>
<tr>
<th>Patient</th>
<th>Failure Type</th>
<th>Time to Failure</th>
<th>Acetabular Component</th>
<th>Failure Analysis</th>
<th>Revision Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL</td>
<td>Type I</td>
<td>401 d</td>
<td>Liner cemented into reconstruction cage</td>
<td>Superior flange blade-plated into ischium pulled out</td>
<td>Cementless constrained cup—developed type I failure</td>
</tr>
<tr>
<td>EL</td>
<td>Type I</td>
<td>54 d</td>
<td>Cementless shell with snap-fit liner</td>
<td>2 Screws in superior quadrant fractured</td>
<td>Cementless cup</td>
</tr>
<tr>
<td>BZ</td>
<td>Type I</td>
<td>790 d</td>
<td>Cementless shell with snap-fit liner</td>
<td>3 Screws in superior quadrant fractured</td>
<td>Cage reconstruction with cemented constrained liner—developed type I failure</td>
</tr>
<tr>
<td>WA</td>
<td>Type II</td>
<td>455 d</td>
<td>Liner cemented into cementless shell</td>
<td>Liner dislodged from shell</td>
<td>Re-cement liner after burring outer liner surface, seat liner deeper into shell</td>
</tr>
<tr>
<td>WS</td>
<td>Type II</td>
<td>3 d</td>
<td>Cementless shell with snap-fit liner</td>
<td>Bone impingement</td>
<td>Excision of bone impingement, reinsertion of liner</td>
</tr>
<tr>
<td>WJ</td>
<td>Type III</td>
<td>889 d</td>
<td>Cementless shell with snap-fit liner</td>
<td>Fracture locking ring</td>
<td>Constrained socket of different company</td>
</tr>
<tr>
<td>AM</td>
<td>Type III</td>
<td>742 d</td>
<td>Cementless shell with snap-fit liner</td>
<td>Unknown. No locking ring fracture seen</td>
<td>New constrained liner placed</td>
</tr>
<tr>
<td>JS</td>
<td>Type III</td>
<td>91 d</td>
<td>Cementless shell with snap-fit liner</td>
<td>Bone impingement</td>
<td>New constrained liner placed</td>
</tr>
</tbody>
</table>

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Fig. 3. Type I failure of an acetabular reconstruction cage that was blade-plated into the ischium.
was cemented into a pre-existing cementless acetabular component that was well fixed by bone ingrowth and well positioned. The failure occurred at the thinnest portion of the mantle—the introitus of the metal-backed cup where the polyethylene socket pinched the cement mantle against the cup during the seating process. In this case, the failure occurred as a result of incomplete seating of the liner within the metal shell. This was treated with light backside burring and recementation of the socket, with more complete seating of the liner within the metal shell.

Type III failure occurred in 3 cases. In 1 case, the constrained liner femoral head locking ring overly broke (Fig. 6). This patient was converted to a modified tri-polar hip. The other 2 patients suffered a type III failure with no obvious damage to the femoral head locking mechanism and were treated with a new constrained liner (see Table 2).

Discussion

Initial concern about constrained sockets focused on the potentially deleterious effect of this device upon the prosthesis: bone interface (type I failure). However, 2 separate reports have shown no accelerated loosening on the acetabular side [21,27]. We described 3 type I failures. One occurred in an acetabular reconstruction cage. In this case, the inferior flange was not fixed with screws to bone, but molded to seat within the ischium to prevent collapse of a structural allograft seated in the roof of the acetabular defect. In each case, the socket pulled away from the medial wall, pivoting on their superiorly placed fixation screws. There are 2 other reports of failure at this interface. Fisher and Kiley described a patient who fell down some stairs 5
months after surgery, dislodging the acetabular component after 2 screws had broken. Goetz et al. described placing a constrained liner into a metal-backed cup that had been seated into a structural allograft 7 months before. Fifty-three months later, the structural allograft failed and the cup dislodged. Keeping in mind the risks of screw placement in the anterior-superior and posterior-inferior quadrants [32], it may be reasonable to place multiple screws in more than 1 quadrant [26]. Additional screws may not be necessary if secure press fit of the acetabular shell is achieved. Ultimately, if bone ingrowth is achieved, type I failure is unlikely. Those patients who require constrained sockets as part of an acetabular cage reconstruction are likely to be at highest risk of this failure mechanism. There are 9 reports of failure at the liner locking mechanism interface (type II failure) [21,26,27]. Goetz et al. experienced 2 type II failures. In 1, excessive cup abduction was to blame. The second dissociation occurred when the polyethylene liner delaminated from the cement mantle. Hein et al. also described 2 disassemblies of an SROM liner at the cement-liner interface, as well as 1 at the metal cup-liner junction. They stated that they had 7 other patients who were functioning well with a cemented constrained liner assembly and advocated its usage. In our series, 1 failure occurred after the socket was cemented into a well-fixed cup. Subsequent to this series, the authors have seen an additional such failure. In each of these 2 cases, the liner was not fully seated into the socket shell. This technical error led to relatively rapid failure. In a further effort to minimize cement-polyethylene debonding, the authors now lightly score the outer polyethylene surface with a burr to enhance the interdigitation of cement. Specific failure of the liner locking mechanism occurred in 1 case in our series. Upon reoperation, it was found that bony impingement of the femoral component was responsible for the failure. Removal of the source of bone impingement solved the problem.

Overt mechanical failure of the femoral head locking mechanism (type III failure) is the most common mode of failure reported in the literature. In 1986, Bryan and Reeve reported the first failure of a constrained socket that incidentally met this description. The SRN prosthesis (a predecessor to the S-ROM, which bears much resemblance) was placed into a vertically oriented acetabular cup. The cup failed when the femoral neck impinged on the locking ring, eroding one half of the femoral neck and fracturing the ring—the event that led to failure. Lombardi et al. had 2 such failures [20]. One had an excessive acetabular cup abduction angle that caused posterior-superior wear and dislocation. The other socket failed secondary to incompletely engaging the constraining ring to the artificial labrum. Anderson et al. experienced 2 events in which the ring became dislodged. Goetz reported on the only such failure in a triporal device. In this case, the elevated rim of the socket impinged on the femoral neck, allowing the outer constraining ring to displace. Kaper and Bernini reported 2 failures that met this same description. We have reported 3 type III failures.

A reiterating scenario with type III failure is poor acetabular cup orientation—usually excessive abduction or version [20,21,25,27]. If the metal-backed cup version or abduction is miscalculated upon implantation, then primary impingement of the femoral neck upon the constrained liner and femoral head locking mechanism will occur. This will occur sooner when using a skirted head. Because the constrained device is treating a hip with poor soft-tissue tension, there is no reason to use a skirted head, and we discourage its use with constrained devices. It is also important to realize that low abduction angles for the socket also can lead to early neck-liner impingement, especially when there is a low head-neck ratio. Another cause of primary impingement is improper placement of the elevated liner. Furthermore, the femoral implant position is important because it is possible that a revision femoral implant can be retroverted, thus leading to impingement.

There are several reports of failure of the femoral head locking mechanism without obvious mechanical injury to the locking mechanism [20,27,29]. All of these have been reported in SROM prosthesis. We described 1 such failure, but in an Osteonics prosthesis. Lombardi et al. described 5 events that fit this pattern [20]. One was treated with increasing the femoral neck length and thus was ostensibly caused by impingement. Two events occurred in the same Parkinson’s patient with chronic positional dislocations who was eventually successfully treated with exchange of the liner and cast bracing. Their final case was noted to have the elevated liner in an anterior-inferior position causing cam-out of the femoral head with excessive adduction. Excessive acetabular cup abduction was the only predictive factor Anderson et al. were able to identify in all failures they described.

**Conclusions**

Constrained acetabular components have a high success rate in dealing with the significant problem
of recurrent instability. In patients with a high risk of dislocation (leg-lengthening correction, girdlestone reimplantation), judicious use of these implants appears appropriate. Three modes of failure have been identified that can be avoided with careful attention to surgical technique. Type I failures may be minimized by using supplemental screw fixation for the cementless shell before inserting the constrained liner, especially if bone quality reduces press-fit fixation of the shell achieved through underreaming. Cementing constrained liners into cementless shells can lead to type II failures if the liner is not properly seated fully into the shell. In an effort to avoid cement-polyethylene debonding, scoring the polyethylene lightly with a burr to enhance the grouting bond of the cement is advisable. The type III failures are likely related to the reduced range of motion associated with the constrained liners. Great care should be taken to evaluate any potential impingement (component-component or component-bone), because this will increase the chance any of the 3 failure mechanisms. Constrained liners are an important tool for the revision THA surgeon, but should be used only if absolutely necessary.

References

32. Reference not provided.