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Original Research

Cemented Constrained Liners Used as an Articulating Hip Spacer for the Treatment of Chronic Prosthetic Joint Infection

Nathanael D. Heckmann, MD*, Jennifer C. Wang, MD, Mary K. Richardson, MD, Brett M. Biedermann, MS, Ryan M. DiGiovanni, MD, Alexander B. Christ, MD, Donald B. Longjohn, MD, Daniel A. Oakes, MD

Department of Orthopaedic Surgery, Keck School of Medicine of USC, Los Angeles, CA, USA

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A B S T R A C T

Background: Two-stage exchange arthroplasty remains the gold standard for treating chronic hip periprosthetic joint infections. However, controversy remains regarding the optimal spacer type, particularly among patients with increased dislocation risk. This study reports on the outcomes of articulating hip spacers utilizing a single constrained-liner design.
Methods: All patients who underwent treatment for hip periprosthetic joint infection at a single institution were screened. Patients were included if they received an articulating spacer utilizing a constrained liner of a single manufacturer design. Indications for constrained liner, demographic variables, and surgical variables were recorded. Patients were assessed for dislocation and component loosening prior to the second stage or at the final follow-up if the second stage was not undertaken. Comparative analysis was performed.
Results: Overall, 26 constrained liners were utilized in 25 patients. Indications for constrained liner included history of dislocation (n = 14), massive proximal femoral bone loss (n = 14), greater trochanteric deficiency (n = 12), and absent abductors (n = 7). Many patients had more than one indication. In total, 9 hips (34.6%) underwent a second stage at an average of 7.4 months, while 17 hips never underwent a second stage with an average follow-up of 27.6 months. One patient experienced failure of their constrained liner prior to the second stage due to pelvic discontinuity and massive acetabular bone loss.
Conclusions: Utilization of a constrained liner as an articulating spacer is a viable option for patients at high risk of instability. Meticulous cement technique, appropriate component position, and implant selection are crucial in achieving successful outcomes.

Introduction

Periprosthetic joint infection (PJI) is a devastating complication following total hip arthroplasty (THA) [1-3]. The management of PJI is associated with increased patient morbidity and mortality, as well as increased costs to the healthcare system [4,5]. Although substantial efforts have been made to identify risk factors, prevent occurrence, and optimize treatment, PJI continues to complicate 1%-3% of all primary THAs [1]. As the THA volume in the United States continues to increase, the volume of PJI following THA is projected to increase, making the optimization of the management of this orthopaedic complication of utmost importance [6].

The gold standard treatment in the United States for a PJI includes a 2-stage surgical strategy including debridement, removal of retained implants, and placement of an antibiotic spacer, followed by a definitive reconstruction performed after the host has cleared the infection [7-10]. The second stage may be delayed for several reasons including patient requests, medical comorbidities, persistent infection, or patient mortality [11]. Surgical planning is further complicated by controversy regarding the optimal selection

* Corresponding author. Department of Orthopaedic Surgery, Keck Medical Center of USC, 1520 San Pablo Street, Ste 2000, Los Angeles, CA 90333, USA. Tel.: +1 323 704 6363.
E-mail address: nate.heckmann@gmail.com

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of spacer construct, particularly for patients at increased risk of dislocation [12,13].

Constrained liners represent a powerful tool to reduce the occurrence of hip dislocation in vulnerable patients such as those with abductor deficiency, extensive proximal femoral bone loss, or limited soft tissue constraint [14,15]. The use of constrained liners as part of a spacer construct has not been well described in the literature, in part because of concerns regarding implant loosening. Here we present data that evaluates the long-term stability of a single manufacturer constrained-liner design used as part of an articulating hip spacer construct for the treatment of PJI.

Material and methods

Study design

All articulating hip spacers utilizing a single constrained liner design (Freedom Constrained Liner, Zimmer Biomet, Warsaw, IN) performed by 4 fellowship-trained orthopaedic surgeons (N.D.H., A.B.C., D.B.L., and D.A.O.) from January 2013 to June 2022 were screened to identify a preliminary study cohort. Cases were excluded if the constrained liner was not utilized as a spacer in the setting of a PJI and if the constrained liner used was of a different design or manufacturer. Cases were also excluded if no radiographs were available for analysis.

All cases were performed utilizing meticulous acetabular preparation and cement technique. After component removal, the acetabulum was debrided of all fibrous tissue and sclerotic bone. The backside of the cement liner was coated with bone cement, and after antiseptic irrigation, the acetabulum was carefully dried before cement was pressurized into the bony acetabular bone stock. The liner was then placed, and a compressive force was maintained until the cement mantle had thoroughly cured.

A retrospective chart review was performed to collect patient demographic information (ie, age, sex, body mass index, comorbidities, number of prior surgeries on the joint of interest), operative details (ie, date of surgery, laterality, indication for constrained liner use), and clinical course (ie, if definitive reimplantation was achieved, date to final follow-up or definitive reimplantation, if a dislocation event occurred). The comorbidities collected included those utilized in the Elixhauser Comorbidity Index [16].

Plain radiographs from the time of liner implantation and at explantation, or at final follow-up if definitive reconstruction had not happened, were compared to evaluate for component loosening, anteversion, and inclination. The presence of loosening was evaluated by a fellowship-trained arthroplasty surgeon (N.D.H.). Component anteversion and inclination were measured independently by 2 trained reviewers (M.K.R. and B.B.) using TraumaCad (TraumaCad, Brainlab, Munich, Germany, 2022).

The primary outcome of interest was the rate of dislocation, with definitive reimplantation and final follow-up as endpoints. Secondary outcomes included the duration of component survivorship, rates of radiographic loosening and radiolucent lines, as well as radiographic measurements such as anteversion and inclination.

The present study was conducted as approved by the institutional review board (IRB HS-22-00214).

Statistical analysis

Statistical analyses were performed using SPSS version 27 (IBM, Armonk, NY). Patient demographics, descriptive variables, and radiographic measurements are presented as means or percentages with standard deviations or ranges where appropriate. The Elixhauser Comorbidity Index was calculated for each patient using the weighting system described by van Walraven et al [17]. Normally distributed continuous variables were compared using 2-sample *t*-tests, and categorical variables were compared using *chi*-square analysis with statistical significance at $P < .05$.

Patient characteristics

In total, 26 constrained liners were utilized in 25 patients for the purpose of an articulating spacer. Of these, 16 patients (61.5%) were women with an average age of 67.8 (range: 37-91) (Table 1). The cohort had an average body mass index of 27.4 kg/m^2 with a standard deviation of 7.8 (range: 16.7-45.9). The surgical intervention laterality was balanced with 57.7% left-sided (15/26). Patients received an average of 2.7 surgeries on the hip of interest (exclusive of arthroscopic procedures) prior to constrained liner implantation (range: 1-7).

The most common comorbidities included hypertension (65.4%), uncomplicated diabetes mellitus (30.8%), hypothyroidism (26.9%), depression (23.1%), obesity (19.2%), chronic deficiency anemia (19.2%), blood loss anemia (15.4%), congestive heart failure (15.4%), cardiac arrhythmias (15.4%), and arthritis/vascular collagen disorders (15.4%). The average Elixhauser Comorbidity Index by patient was 4.7 with a standard deviation of 5.6 (range: −7 to 15).

Results

Constrained liner

Indications for constrained liner included history of dislocation (n = 14), massive proximal femoral bone loss (n = 14), greater trochanteric deficiency (n = 12), and absent abductors (n = 7). Many patients had more than one indication of constraint. (Figure 1; Fig. 2) Regarding femoral components, a Prostalac (DePuy, Warsaw, IN) implant was utilized in 20 cases, a Biomet (Zimmer Biomet, Warsaw, IN) cemented implant in 5 cases, and a TJO (Total Joint Orthopedics, Salt Lake City, UT) implant in one case.

In total, 26 (100%) spacers contained vancomycin, 25 (96.2%) contained tobramycin, and 1 (3.8%) contained amphotericin. Of the spacers that contained vancomycin, the average dose was 3.69 g per bag. The average dose of tobramycin was 3.61 g per bag. The single spacer with amphotericin contained 50 mg per bag. The most prevalent organism in the 26 PJIs was methicillin-susceptible Staphylococcus aureus (Table 2).

In total, 9 hips (34.6%) underwent a second stage at an average of 7.4 months (range: 1.2-14.4), while 17 hips never underwent a second stage with an average follow-up of 28.3 months (range: 0.7-106.0). (Fig. 3; Table 1) Reasons for not undergoing second-stage surgery included patient choice to forego second stage given pain relief and adequate function (n = 13 hips), inability to undergo second stage for medical reasons (n = 2 hips), death (n = 1 hip), and spacer exchange for infection recurrence (n = 1 hip). One patient experienced multiple revisions related to a periprosthetic trochanteric fracture, which were addressed via

Table 1
Mean descriptive analysis among the entire cohort.

Patient characteristics	Mean descriptives			
	Minimum	Maximum	Average	STD
Age	37.0	91.0	67.8	13.0
BMI	16.7	45.9	27.4	7.8
Time for follow-up or definitive reconstruction	0.7	106.0	20.6	24.8
Number of prior surgeries	1.0	7.0	2.7	1.5

BMI, body mass index; STD, standard deviation.

Figure 1. (a) AP radiograph of the left hip taken prior to first-stage revision total hip arthroplasty, showing proximal femoral bone loss and greater trochanteric deficiency. (b) AP radiograph of the left hip taken following first-stage revision showing a constrained liner cemented in place. AP, anterior to posterior.

replacement of the femoral Prostalac only while the constrained liner remained intact without loosening for more than 55 months. (Fig. 4) One patient experienced implant failure prior to the second stage as they had a documented large pelvic discontinuity as a result of revision removal of a trabecular metal acetabular component, a posterior pelvic plate, a cage, and a constrained liner. There were no discrete events, falls, or accidents that contributed to the event (Fig. 5).

With respect to radiographic measurements of the implanted construct, the average anteversion was 22.6° (range: 7.5°-34.5°) and the average inclination was 38.7° (range: 19.5°-53°).

When evaluated by those who subsequently underwent a definitive second stage vs those who retained their constrained liner, the average anteversion was 23.8° and 22.0°, respectively, and the average inclination was 36.5° and 40.0°, respectively, which were not statistically significant (P = .636; P = .462). The single failure initially measured 7.5° of anteversion and 39° of inclination.

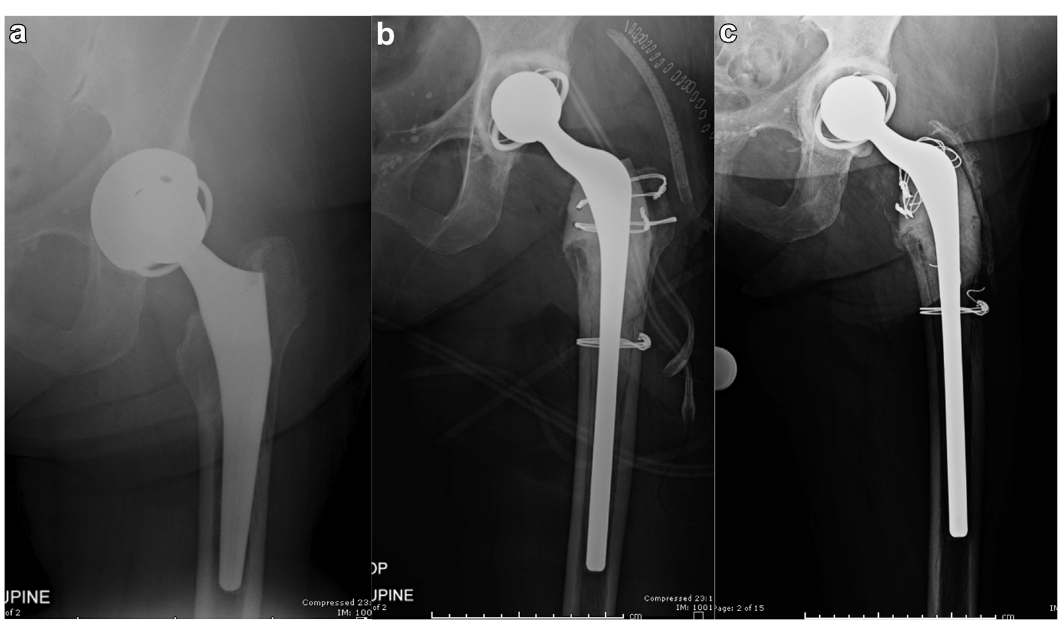

Figure 2. (a) AP radiograph of the left hip taken prior to first-stage revision total hip arthroplasty showing a constrained liner. (b) AP radiograph of the left hip taken immediately following first-stage revision, showing a constrained liner cemented in place. (c) AP radiograph of the left hip taken at 6-month follow-up. AP, anterior to posterior.

Table 2
Organisms involved in PJIs and number of cases per organism.

Organism	Number of cases
MSSA	5
No growth	5
MRSA	3
Staphylococcus epidermidis	3
Candida albicans	2
Enterococcus faecalis	1
Escherichia coli	1
Candida albicans, Corynebacterium	1
Enterococcus faecalis, Finegoldia magna	1
Staphylococcus epidermidis, Enterococcus faecalis	1
Pseudomonas aeruginosa	1
Proteus mirabilis	1
Nonspore forming Gram-positive rod, microbacterium, beta-lactamase negative Moraxella	1

MSSA, methicillin-susceptible Staphylococcus aureus; MRSA, methicillin-resistant Staphylococcus aureus.

Of the 17 patients who did not undergo a second stage, radiolucent lines were present in 2 cases (11.8%); however, there was no evidence of gross loosening in either of these cases.

Discussion

This study reported on the outcomes of a single constrained liner design used as an articulating spacer in the setting of abductor insufficiency, massive proximal femoral bone loss, or increased risk of instability. The findings presented herein report satisfactory outcomes and provide surgeons with an option when treating these challenging, high-risk patients. While the results of the present study demonstrated acceptable outcomes, it is important to note that appropriate technique is required to achieve satisfactory clinical results. The surgeons utilizing this technique were all experienced fellowship-trained surgeons who have performed a large number of hip spacers and have treated a high volume of PJIs. When considering a constrained liner as part of an articulating hip spacer construct, good results are contingent on appropriate implant selection, accurate component position, and meticulous cement technique. When these conditions are satisfied in the appropriately selected patients, durable outcomes can be achieved when using a constrained device as part of an articulating hip spacer construct.

Articulating hip spacers used to treat PJI have the benefits of preserving mobility and function when used as part of a 2-stage surgical strategy [13,18]. However, articulating spacers have a high rate of mechanical complications, the most common of which is dislocation [19]. A recent systematic review assessed 1659 articulating hip spacers in 40 studies and found an aggregate dislocation rate of 10.8% (range: 0%-42.3%). To address instability, other authors have reported on the use of constrained liners for articulating hip spacers [20,21]. Pizzo et al. reported a series of 15 patients who received an articulating hip spacer using a constrained liner [20]. No patient in this series experienced a dislocation with an average follow-up of 100 days. These results are similar to those reported in the present study, as we did not observe any hips with a dislocation. This is particularly reassuring, as several of the patients in our study had complete abductor deficiency or massive proximal femoral bone loss, placing them at increased risk of instability and implant failure.

Historically, constrained liners have had poor long-term outcomes when used during primary and revision THA [22,23]. Della Valle et al. reported the results of 55 consecutive patients who received a constrained liner of a single design (Duraloc Constrained Liner, DePuy, Warsaw, IN) during revision THA [23]. At a minimum of 2-year follow-up, 9 of 55 (16.4%) patients experienced a dislocation. Berend et al. assessed 755 consecutive primary and revision THA patients who received a constrained liner and reported a survivorship of 68.5% at 5 years and 51.7% at 10 years [22]. However, the vast majority of patients (736 of 755) in this study received a single device (S-ROM Poly-Dial constrained acetabular insert, Johnson & Johnson Co., Warsaw, IN) with a restricted arc of motion compared to more modern constrained liner designs. While the performance of constrained liners in these previous studies was suboptimal, it is important to note that these older constrained designs differ markedly from many of the constrained liner designs commonly used today.

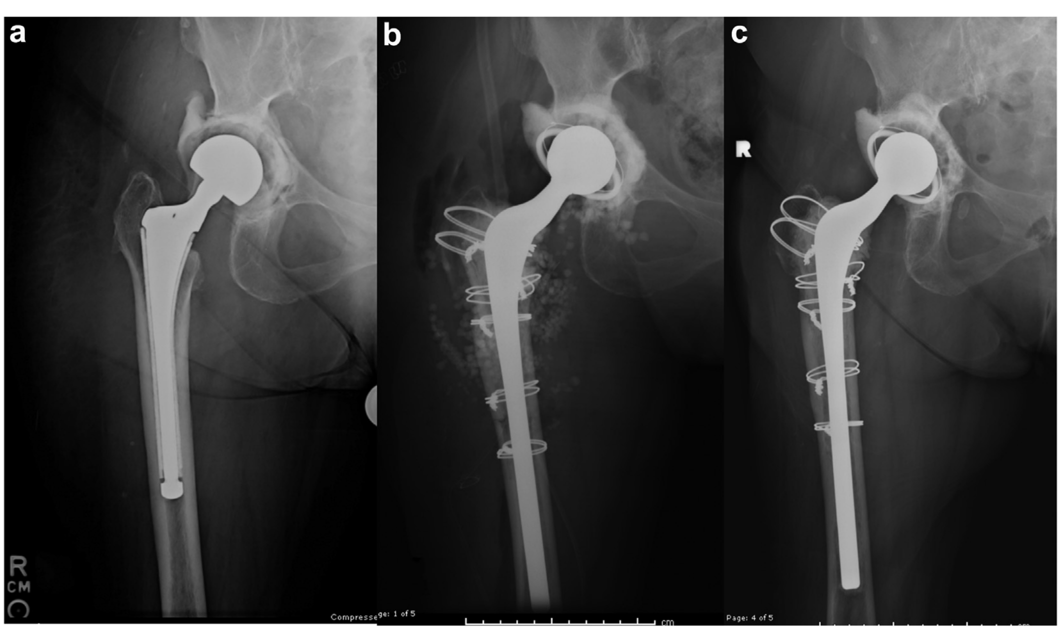

Figure 3. (a) AP radiograph of the right hip taken prior to first-stage revision total hip arthroplasty showing constrained liner. (b) AP radiograph of the right hip taken immediately following first-stage revision, showing a constrained liner cemented in place. (c) AP radiograph of the right hip taken at a 3-year follow-up. AP, anterior to posterior.

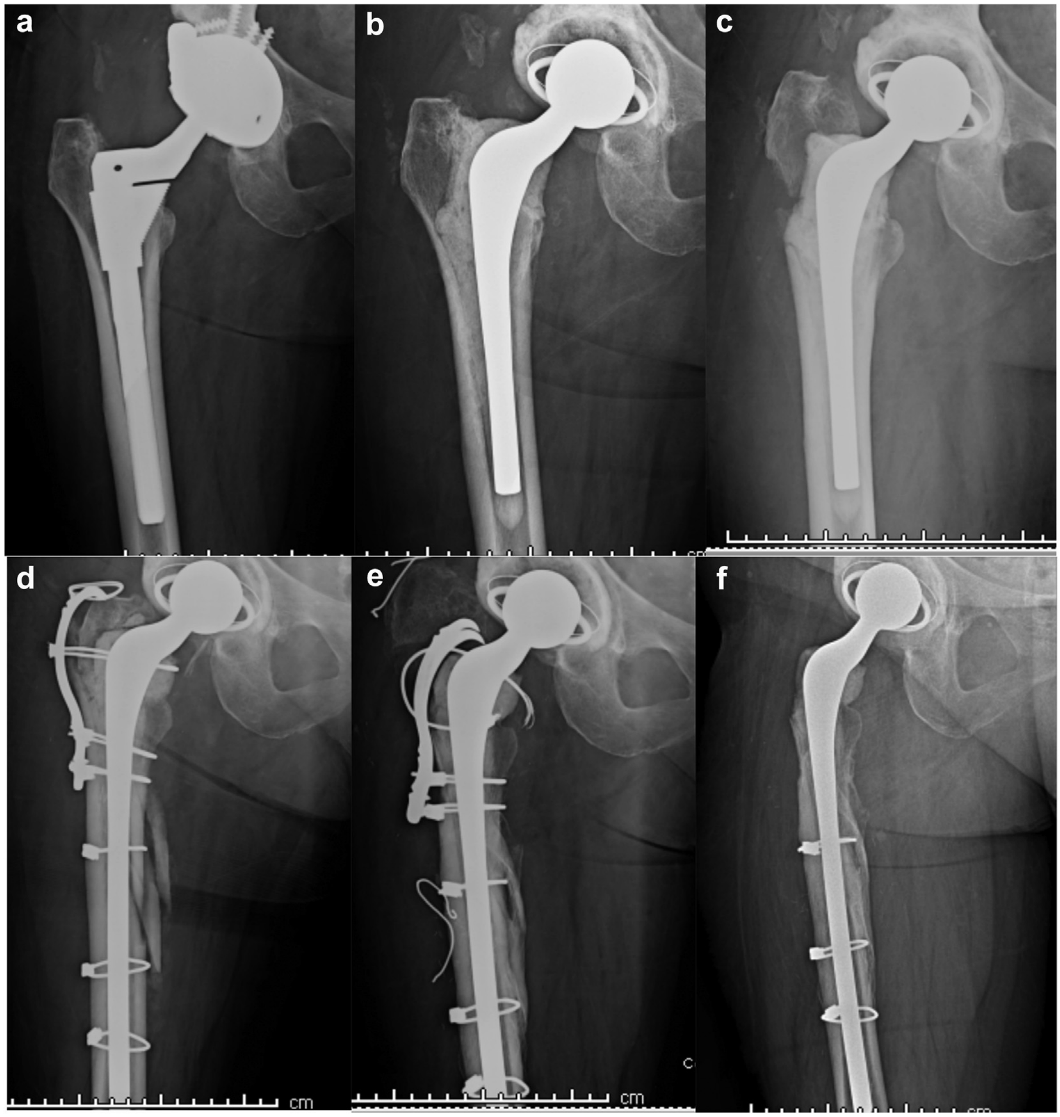

Figure 4. (a) AP radiograph of the right hip taken following a previous revision total hip arthroplasty. (b) AP radiograph of the right hip taken immediately following an additional first-stage revision showing a constrained liner cemented in place. (c) AP radiograph of the right hip taken showing a periprosthetic greater trochanteric fracture. AP radiograph of the right hip taken following open reduction and internal fixation of the periprosthetic fracture. (d) The femoral component was revised, while the femoral head and acetabular components remained intact. (e) AP radiograph of the right hip taken 1 year postoperatively from image d. (f) AP radiograph of the right hip taken at 55 months following initial constrained liner placement. AP, anterior to posterior.

Several commercially available constrained liners utilized today in contemporary arthroplasty practices allow for an increased impingement-free arc of motion relative to many of the older designs reported in the aforementioned studies [24]. The constrained liner in the present study has a 110°-114° arc of motion [25]. This is reassuring as most patients have a hip range of motion of 82° ± 15° throughout a functional arc of motion from standing to deep forward flexion, [26] suggesting contemporary constrained liners such as the one used in this study, when placed in an optimal orientation, may provide an impingement-free arc of motion that accommodates normal physiological hip motion. Berend et al. assessed 81 consecutive patients undergoing both primary and revision THA who received a constrained liner [24]. In their series, only one constrained liner failed for a survival rate of 98.8%. In a follow-up study from the same group, 177 primary and revision THA patients were followed for a minimum of 2 years and received the same constrained liner [27]. The 7-year survival with dislocation as the endpoint was 91.8%. These findings are consistent with the present study, as the constrained liner used in our series is the same device used in the 2 aforementioned case series.

The results of our study are in contrast with other studies that have reported poor outcomes for retained hip spacers used in the setting of PJI [28,29]. Petis et al. assessed 17 retained hip spacers implanted as part of a planned 2-stage surgical strategy and reported a 28% revision rate at 4-year follow-up [28]. The vast majority of patients in this cohort did not undergo a second stage for medical reasons. Vargas-Vila et al. assessed 15 retained spacers and reported a 39% failure rate at 3-year follow-up [29]. In contrast, in the present study, only 1 of 26 (3.8%) spacers experienced failure of the constrained liner. Of the 17 patients who did not undergo a second stage, radiolucent lines were present in 2 cases; however, there was no evidence of gross loosening in either of these cases. Our findings are similar to those of other authors who have also reported favorable outcomes in patients with retained hip spacers [30,31].

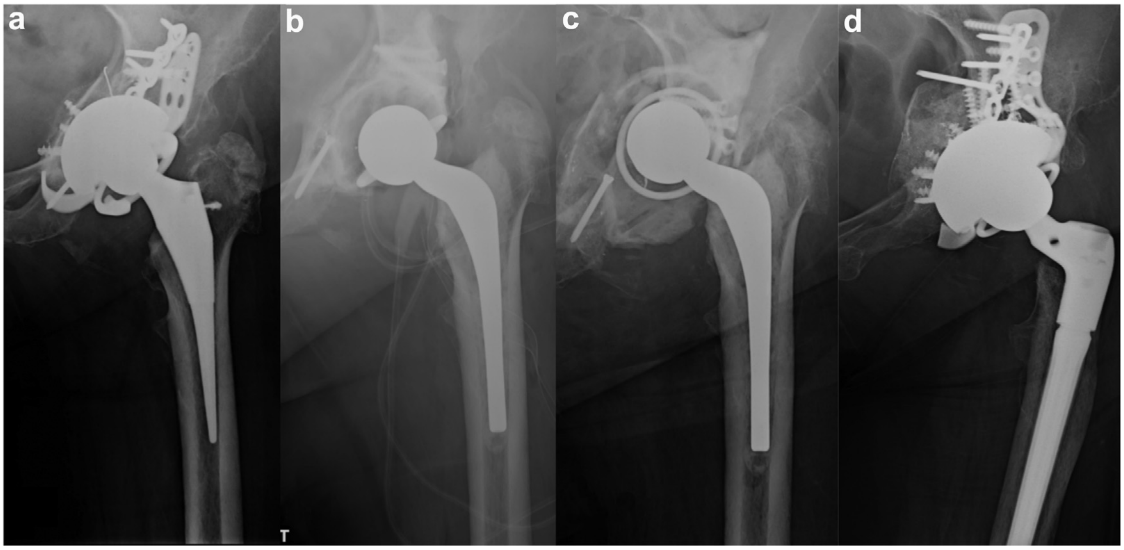

Figure 5. (a) AP radiograph of the left hip taken prior to first-stage revision total hip arthroplasty, showing a complex total hip arthroplasty. (b) AP radiograph of the left hip taken immediately following first-stage revision, showing a constrained liner cemented in place. (c) AP radiograph of the left hip taken at 1 month postoperatively, showing loosening of the constrained liner. (d) AP radiograph of the left hip following definitive reconstruction. AP, anterior to posterior.

There are several limitations to our study. First, our study did not capture patient-reported outcomes, and as such, we are unable to comment on the functional status of the patients included in our cohort. However, the present cohort includes patients with massive proximal femoral bone loss and abductor deficiency, leading to expected impairment in these patients' function. As such, the present study was not designed to capture and quantify functional status but rather to report on implant-related complications for these salvage surgeries. Second, our study only reported on the outcomes of a single device and did not provide comparative data as we did not have a control group. However, given the rare and complex pathology of PJI patients with abductor loss and massive proximal femoral loss, a comparative arm was not feasible. Third, the short-term duration of follow-up of 28.3 months is a limitation of our study. Longer-term follow-up is needed before this technique can be broadly recommended, particularly if a long-term durable spacer construct is desired.

Conclusions

This study reported satisfactory outcomes for a single constrained liner design used as an articulating spacer. When PJI of the hip is treated in the setting of abductor deficiency, proximal femoral bone loss, or greater trochanteric deficiency, using a cemented constrained liner may be a reasonable option.

Conflicts of interest

A. B. Christ is a paid consultant for Intellijoint Surgical and Smith & Nephew and is a board/committee member of AAOS, the Musculoskeletal Tumor Society, and the Orthopaedic Research Society. D. A. Oakes is a paid consultant for LimaCorporate and receives royalties from them. D. B. Longjohn receives financial/material support from 3M. N. D. Heckmann receives royalties from Corin USA; is a paid consultant for Intellijoint Surgical, MicroPort Orthopedics, Corin USA, and Zimmer; has stock options in Intellijoint Surgical; and is a board/committee member of AAOS, AJRR, and AAHKS. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101422.

CRediT authorship contribution statement

Nathanael D. Heckmann: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jennifer C. Wang:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Mary K. Richardson:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Brett Biedermann:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Ryan M. DiGiovanni:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis. **Alexander B. Christ:** Writing – review & editing, Supervision, Investigation, Formal analysis, Conceptualization. **Donald B. Longjohn:** Writing – review & editing, Supervision, Investigation, Formal analysis, Conceptualization. **Daniel A. Oakes:** Writing – review & editing, Supervision, Investigation, Formal analysis, Conceptualization.

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