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Dual-Mobility Implants and Constrained Liners in Revision Total Hip Arthroplasty

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A B S T R A C T

Background: Instability remains the most common complication after revision total hip arthroplasty (THA). The purpose of this study was to determine whether there was a difference in aseptic revision rates and survivorship between dual-mobility (DM) and constrained liners (CL) in revision THA.
Methods: We reviewed a consecutive series of 2432 revision THA patients from 2008 to 2019 at our institution and identified all patients who received either a CL or DM bearing. We compared demographics, comorbidities, indications, dislocations, and aseptic failure rates between the two groups. Bivariate and multivariate regression analyses were used to determine risk factors for failure, and a Kaplan-Meier survivorship analysis was performed with an aseptic re-revision as the endpoint.
Results: Of the 191 patients, 139 (72%) received a DM bearing, and 52 (28%) had a CL. At a mean follow-up of 14.3 months, there was no statistically significant difference in rates of dislocation (10.4% vs 14.0%, $P =$ .667), aseptic revision (30.9% vs 46.2%, $P = .073$), or time to revision (3.78 vs 6 months, $P = .565$) between the two groups. The multivariate analysis revealed CL had no difference in aseptic re-revision rates when compared with DM (odds ratio 1.47, 95% confidence interval 0.84-2.52, $P = .177$). The survivorship analysis found no difference in aseptic failure between the groups at 12 months ($P = .059$).
Conclusion: Both CL and DM bearings have high aseptic failure rates at intermediate term follow-up after revision THA. CL did show a higher risk of failure than DM bearings, but it was not statistically significant with the numbers available for this study. Further prospective studies are needed to determine the optimal treatment for recurrent instability.

Introduction

Instability remains a leading cause of failure and need for re-revision after revision total hip arthroplasty (THA) [1,2]. With an aging population, and a concomitant increase in primary THA, the performance of revision THA is expected to increase dramatically in coming years; as a corollary, the burden of recurrent instability will also likely rise over time [3-6]. The etiologies of instability after revision THA are multifactorial and include patient, technical, and implant-related factors. Previous studies have demonstrated that patient factors such as a history of instability and abductor deficiency can lead to additional risk of failure due to recurrent instability after revision THA [7-10]. In regard to technical factors, ensuring adequate component positioning and soft-tissue tension are critical to the prevention of recurrent instability [11]. Furthermore, selection of the appropriate prosthesis may provide protection against recurrent instability after revision THA [7,12].

Historically, large-diameter femoral heads and constrained liners have been used in the management of instability in revision THA [10]. The benefits of large-diameter femoral heads include increased jump distance and an improved head-to-neck ratio, thereby accommodating greater range of motion before impingement. Constrained liners, in contrast, rely on the mechanical constraint of the femoral head within the polyethylene liner through femoral head over-coverage, theoretically decreasing the risk of recurrent instability. Constrained devices result in an increased transmission of force to the implant-bone interface, as

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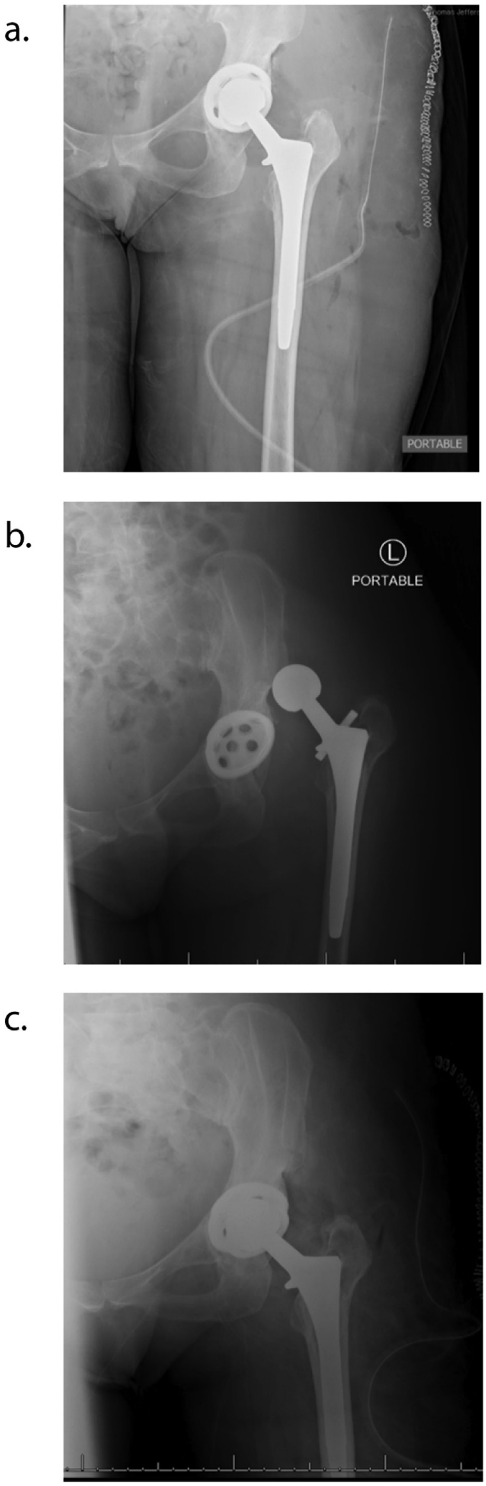

Figure 1. Example of revision total hip arthroplasty (THA) with a constrained liner, followed by subsequent instability leading to failure and re-revision THA. (a) A 66-year-old woman with a history of instability. She underwent revision to a constrained liner as her index revision surgery. (b) At 23 months postoperatively, the patient was found to have recurrent instability and failure of the constrained liner locking mechanism. (c) She subsequently underwent re-revision, using a constrained liner.

well as decreased range of motion and early impingement [13]. In addition, they have been found to be an imperfect solution for recurrent instability, with reported dissociation/instability despite the constraining mechanism [14,15].

Table 1
Demographic and preoperative factors.

Variable	Total	Dual mobility	Constrained liner
	N = 191	N = 139	N = 52
Age	62.5 (11.6)	61.6 (10.8)	64.8 (13.2)
Sex:			
Female	108 (58.1%)	76 (55.1%)	32 (66.7%)
Male	78 (41.9%)	62 (44.9%)	16 (33.3%)
CCI, age-adjusted	3.00 [2.00; 4.00]	3.00 [2.00; 4.00]	3.00 [2.00; 4.00]
Body mass index	27.9 [25.5; 32.2]	27.6 [24.2; 31.2]	28.7 [26.6; 32.3]
Laterality			
Left	74 (38.7%)	55 (39.6%)	19 (36.5%)
Right	117 (61.3%)	84 (60.4%)	33 (63.5%)

CCI, Charlson Comorbidity Index.

In recent years, the use of dual-mobility bearing surface has been explored in North America. Dual-mobility prostheses provide two articulating surfaces: one between the ceramic/metal head and polyethylene shell, and another between the polyethylene shell and metal acetabular cup. The theoretical advantages of dual-mobility bearings include decreased instability due to increased head-to-neck ratio, decreased impingement, and potentially lower wear [16,17]. Clinical outcomes of dual-mobility articulations in the setting of revision THA have been encouraging [18-21], with low reported rates of dislocation (1.5%) and intraprosthetic dislocation (0.2%) [21]. In addition, a recent study has demonstrated that the use of dual-mobility may even be effective in the treatment of failed constrained liners, potentially expanding indications for their use [22].

However, the outcomes of dual-mobility implants and constrained liner has not been specifically compared in the setting of revision THA. The purpose of this study was to investigate the outcomes of constrained liners and dual-mobility articulation in revision THA.

Material and methods

After human subject review board approval, using an institutional implant database, a consecutive series of patients who underwent revision THA with a constrained liner or dual-mobility articulation (between 2008 and 2019) were identified.

Relevant patient demographic information was collected. Both groups were compared based on baseline demographics and surgical factors. Failures were identified through chart review and defined as re-revision THA (Fig. 1).

Demographic and outcome data were analyzed using t-test, Mann-Whitney, and chi-squared testing. A bivariate analysis was used to determine risk factors for clinical failure, defined as re-revision surgery. Kaplan-Meier survival curves were generated based on date of re-revision surgery and most recent follow-up.

Results

Of the 191 patients, 139 (72%) received a dual-mobility bearing, and 52 (28%) had a constrained liner. In regard to demographic factors, the dual-mobility cohort was younger, with a lower age-adjusted Charlson Comorbidity Index. No significant difference in age, sex, body mass index, or Charlson Comorbidity Index was retrieved (Table 1). Similarly, no difference were retreived in intraoperative surgical details (Table 2)

At a mean follow-up of 14.3 months, there was no statistically significant difference in rates of dislocation (10.4% vs 14.0%, P = .667), aseptic revision (30.9% vs 46.2%, P = .073), or time to revision (3.78 vs 6 months, P = .565) between the two groups. Discharge to rehab and skilled nursing facility was higher in the constrained

Table 2
Surgical details and outcomes of constrained liners and dual-mobility implants.

Variable	Total	Dual mobility	Constrained liner	*P* value
	N = 191	N = 139	N = 52	
Surgery duration (min)	87.0 [60.0; 117]	81.0 [58.5; 113]	114 [80.0; 123]	.013
Laterality				.829
Left	74 (38.7%)	55 (39.6%)	19 (36.5%)	
Right	117 (61.3%)	84 (60.4%)	33 (63.5%)	
Length of stay	2.00 [2.00;4.00]	2.00 [1.00;3.00]	3.00 [2.00;6.00]	.008
Operation type				1.000
Inpatient	96 (99.0%)	71 (98.6%)	25 (100%)	
Outpatient	1 (1.03%)	1 (1.39%)	0 (0.00%)	
Stem revised				.323
No	79 (41.4%)	54 (38.8%)	25 (48.1%)	
Yes	112 (58.6%)	85 (61.2%)	27 (51.9%)	
Reason for revision (septic)				.555
No	157 (84.4%)	113 (83.1%)	44 (88.0%)	
Yes	29 (15.6%)	23 (16.9%)	6 (12.0%)	
Dislocations				.667
No	164 (88.6%)	121 (89.6%)	43 (86.0%)	
Yes	21 (11.4%)	14 (10.4%)	7 (14.0%)	
Adverse reactions/ALTR				1.000
No	167 (89.8%)	122 (89.7%)	45 (90.0%)	
Yes	19 (10.2%)	14 (10.3%)	5 (10.0%)	
Metallosis				.737
No	174 (93.5%)	128 (94.1%)	46 (92.0%)	
Yes	12 (6.45%)	8 (5.88%)	4 (8.00%)	
Intrahospital complication				.391
No	74 (76.3%)	57 (79.2%)	17 (68.0%)	
Yes	23 (23.7%)	15 (20.8%)	8 (32.0%)	

ALTR, adverse local tissue reaction.

liner group ($P < .001$). However, no other postoperative outcome was difference among the two groups (Table 3).

The multivariate analysis revealed constrained liners had no difference in aseptic re-revision rates when compared to dual-mobility (odds ratio 1.47, 95% confidence interval 0.84-2.52, $P = .177$) (Tables 4 and 5). Survivorship analysis found no difference in aseptic failure between the groups at 12 months ($P = .059$). Kaplan-Meier curves were not significantly different (Fig. 2).

Discussion

Instability remains a major concern after revision THA, and implant selection is one strategy to reduce the risk of further instability and failure [1,2,9,23,21,24]. Recent studies of dual-mobility implants have demonstrated good outcomes in primary [25-27] and revision THA [20,22]. Notably, several studies have examined their use in high-risk cases. Plummer et al., in a retrospective study of 36 cases of dual-mobility implants in high-risk revision THA (defined as history of instability, abductor deficiency, or intraoperative instability), reported an 11.1% revision rate and only one case of further instability [12]. In our study, we report that we found no evidence of difference among dual-mobility and constrained liners for revision THA as per risk of repeated surgery.

Management of patients with a history of multiple surgeries, abductor deficiency, and poor bone quality remains challenging, and previous studies have demonstrated increased risk of failure

Table 3
Postoperative outcomes.

Variable	Total	Dual mobility	Constrained liner	*P* value
	N = 191	N = 139	N = 52	
Discharge destination				<.001
Home	67 (35.1%)	50 (36.0%)	17 (32.7%)	
Home health	81 (42.4%)	69 (49.6%)	12 (23.1%)	
Rehab/SNF	41 (21.5%)	18 (12.9%)	23 (44.2%)	
Other hospital	2 (1.05%)	2 (1.44%)	0 (0.00%)	
Readmissions 90 d				.814
No	154 (80.6%)	111 (79.9%)	43 (82.7%)	
Yes	37 (19.4%)	28 (20.1%)	9 (17.3%)	
Time to readmission (d)	0.00 [0.00; 0.00]	0.00 [0.00; 0.00]	0.00 [0.00; 0.00]	.582
Re-revision				.073
No	124 (64.9%)	96 (69.1%)	28 (53.8%)	
Yes	67 (35.1%)	43 (30.9%)	24 (46.2%)	
Days to revision	144 [29.0; 427]	124 [35.5;352]	180 [26.0; 466]	.565
Years to revision	0.39 [0.08; 1.17]	0.34 [0.10; 0.96]	0.49 [0.07; 1.28]	.565
Re-revision for PJI				.029
No	43 (64.2%)	23 (53.5%)	20 (83.3%)	
Yes	24 (35.8%)	20 (46.5%)	4 (16.7%)	

SNF, skilled nursing facility; PJI, periprosthetic joint infection.

Table 4
Demographic information and outcomes in patients with abductor deficiency.

Variable	Estimate	*P* value	Hazard ratio	Lower 95	Upper 95
Constrained liner	0.37	.177	1.47	0.84	2.52
Age	−0.05	.008	0.95	0.92	0.99
Sex: male	−0.72	.014	0.49	0.28	0.86
CCI	0.26	.036	1.30	1.02	1.67
BMI	0.03	.193	1.03	0.99	1.08

BMI, body mass index; CCI, Charlson Comorbidity Index.

[9,10]. Kung and Ries, in their retrospective study, provided evidence that larger diameter femoral heads were not protective against instability in the setting of abductor deficiency [10]. As a result, they recommended the use of constrained liners for those patients [10]. Herman et al., in a recent meta-analysis, similarly found that larger head sizes were protective for recurrent instability overall but that constrained liners were beneficial in the setting of abductor deficiency [28]. Neither study examined dual-mobility implants, and their findings should be weighed against a large body of evidence that demonstrates relatively high rates of failure in constrained implants [13,15,28,29], acknowledging their utilization in patients of higher risk [8,9]. Recent reports of dual-mobility implants in high-risk cohorts including abductor-deficient patients suggest that they are effective in reduction of instability [12,22,30], consistent with the findings of the present study.

The findings of this study should be interpreted in the context of several important limitations. To begin, this was a nonrandomized, retrospective study. In addition, owing to sample size limitations, we were unable to perform matched-cohort or multivariate regression analyses; overall, the study is likely underpowered to detect differences in rare events such as re-revision surgery. Implant selection was at the discretion of the operating surgeon, and this introduced the risk of selection bias. As a result of disparate cohorts, we are limited in our ability to proscribe future treatment based on the observed suboptimal performance of constrained implants in this study, as they were likely associated with patients of higher risk. Finally, our study includes only short-term follow-up, and we were unable to make inferences about the longer term performance of these implants.

Conversely, this is a study consisting of a relatively large cohort examining the outcomes of these implants in revision THA. Furthermore, by identifying patients with abductor deficiency, we were able to examine a cohort of patients at elevated risk of instability and failure after revision THA. Management of instability in patients with abductor deficiency remains a challenge, without a definitive treatment strategy. Our finding indicates that, unlike large-diameter femoral heads, there may be some protective benefit to dual-mobility in abductor-deficient patients. Constrained liners, as expected, performed relatively well in these patients. While we were not able to obtain long-term data, the average follow-up period in this study is likely sufficient to capture relevant failures such as early postoperative instability.

Table 5
Assumption checks after regression modeling.

Variable	Spearman's Rho	*P* value
Constrained liner	0.051	.680
Age	−0.143	.238
Sex: male	−0.048	.701
CCI	−0.136	.215
BMI	0.048	.705
Global	NA	.857

BMI, body mass index; CCI, Charlson Comorbidity Index.

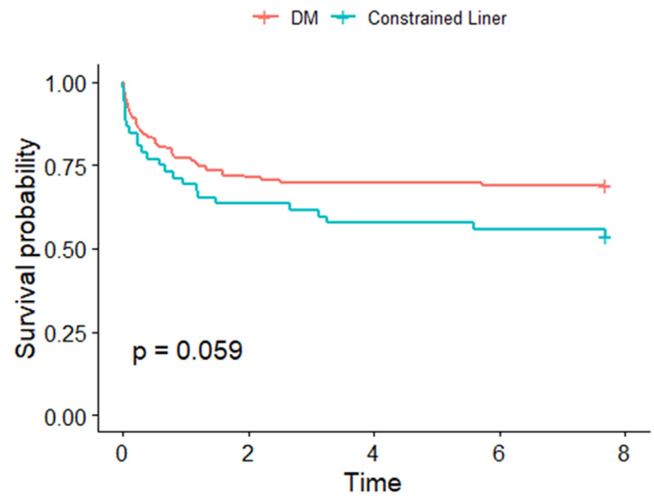

Figure 2. Kaplan-Meier survivorship curve for constrained and dual-mobility implants.

Future study on this topic would ideally help to elucidate both the short- and long-term performance of these implants. While a comparative evaluation such as a randomized trial would be ideal, a large retrospective or registry study would also be helpful. In addition, further studies that specifically examine the outcomes of dual-mobility implants after failed constrained liners would be welcome, as this clinical scenario can be particularly challenging.

In conclusion, this retrospective study demonstrates encouraging outcomes in the performance of dual-mobility implants in revision THA, acknowledging limitations of sample size and disparate cohorts. Risk factors for failure after revision THA include posterior surgical approach, use of a constrained liner, and abductor deficiency. In patients with abductor deficiency, constrained liners and dual-mobility implants performed comparably, indicating that both are potentially valid options in that setting.

Conflicts of interest

P. M. Courtney is in the speakers' bureau of or gave paid presentations for Smith & Nephew; is a paid consultant for DePuy, Hip Innovation Technology, Stryker, and Zimmer; has stock or stock options in Parvizi Surgical Innovation; and is a board or committee member of AAHKS. N. Goyal has stock or stock options in Pulse Platform LLC and receives royalties from DataTrace. J. Parvizi receives royalties from Corentec; is a paid consultant for Zimmer Biomet, Corentec, Ethicon, Tenor, KCI/3M (Acelity), Heraeus, MicroGenDx, Joinstem, Peptilogics, and Fidia Pharm; has stock or stock options in Parvizi Surgical Innovations and subsidiaries, Hip Innovation Technology, Corentec, Alphaeon/Strathsby Crown, Joint Purification Systems, Ceribell, Acumed, PRN-Veterinary, MDvaluate, Intellijoint, MicroGenDx, Nanooxygenic, Sonata, and Molecular Surface Technologies; and receives royalties from DataTrace, Elsevier, Jaypee Publishers, SLACK Incorporated, Wolters Kluwer, and Becton Dickenson.

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