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Outcomes of femoral head allograft for the management of glenoid bone defects in revision reverse shoulder arthroplasty: a case-controlled study

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Background: Revision shoulder arthroplasty often requires management of glenoid bone defects. Options include using allograft, harvesting iliac crest autograft, or using augmented metal components. The purpose of this study is to report outcomes of revision shoulder arthroplasty requiring management of glenoid bone defects with femoral head allograft in a large cohort of patients using a single reverse shoulder implant system and compare them to a matched cohort based on the indication for surgery. Outcomes of patients who had successful glenoid reconstruction were compared to those that required a re-revision, and to a control group that was revised without the need for bone graft.

Methods: This was a retrospective review of data collected from 2009 to 2018. There were 36 patients in the bone graft group and 52 in the control group. All patients underwent revision to a reverse shoulder arthroplasty to manage a failed total shoulder arthroplasty (n = 29 and 11), hemiarthroplasty (n = 1 and 24), or reverse shoulder arthroplasty (n = 6 and 17). All patients had a minimum of 2 yr of clinical follow-up. The primary endpoint was survival of baseplate fixation. Secondary outcomes included range of motion and functional outcome scores. Patients that had recurrent baseplate failure and were re-revised were compared to patients with bone graft that did not require additional surgery, and to patients who were revised without the need for bone graft. Patients who required revisions for reasons other than recurrent baseplate failure were also recorded.

Results: Five of 36 (14%) patients had recurrent baseplate failure. Mean time to failure was 12 mo. Three of 5 had successful re-implantation of another baseplate. Two of 5 were revised to a hemi arthroplasty after failure of their revisions. Preoperative American Shoulder and Elbow Surgeons scores were 31 in the grafted patients that did not require re-revision, 39 in the grafted patients that required re-revision, and 33 in the control group. Final American Shoulder and Elbow Surgeons scores were 64, 36, and 56, respectively. One patient required revision surgery not related to baseplate failure. There were no baseplate failures in the control group.

Investigation performed at the Florida Orthopaedic Institute (FOI) and Foundation for Orthopaedic Research and Education (FORE), Tampa, FL, USA.

This study was determined to be exempt from institutional review board approval.

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Conclusion: The use of femoral head allograft to manage glenoid bone defects in the revision setting produces predictable improvement in functional outcomes that is not inferior to those in patients revised without bone graft. However, there is a 14% rate of baseplate failure.

Level of evidence: Level III; Retrospective Case-Control Design; Treatment Study

Keywords: Allograft; revision; RSA; reverse shoulder arthroplasty; femoral head allograft; bulk allograft; glenoid bone defects; glenoid bone loss

The incidence of shoulder arthroplasty has increased in recent decades. In 2017, the incidence of primary anatomic shoulder arthroplasty was 12.5 cases per 100,000 individuals (40,655 cases) and the incidence of primary reverse shoulder arthroplasty (RSA) was 19.3 cases per 100,000 individuals (62,705 cases). This is compared to 9.5 cases per 100,000 individuals (29,685 cases) and 7.3 cases per 100,000 individuals (22,835 cases), respectively, in 2012.[2]

As a result, there will be a greater volume of revision shoulder arthroplasty cases in the coming decades. The majority of revision cases today are done with an RSA.[20] Such cases often require management of glenoid bone defects to achieve solid fixation of the baseplate. Whereas the normal glenoid is approximately 38 mm in height, 27 mm in width,[4,17] and 18-28 mm deep,[5] offering ample volume for baseplate fixation, loss of this relatively small volume of bone can preclude the ability to securely apply a baseplate.

Several techniques for managing this problem have been described. These include the use of the alternative spine line,[12] various bone grafting techniques[7,8,10,19] and using augmented baseplates or custom components.[3,6,16] Many studies regarding bone grafting have shown high rates of bone resorption and early radiographic and clinical failure.[9,13] However, most of the existing literature consists of relatively small case series, studies describing bone grafting in both primary and revision cases, studies describing mixed bone grafting techniques and bone graft sources, and lacks studies with a control group that did not require bone graft.

The purpose of this study was to assess clinical outcomes of and implant retention in patients who required bone grafting of glenoid defects with femoral head allograft during revision to a RSA and to compare these patients to a group that underwent revision to a RSA without the need for bone graft. Our hypotheses were 1) patients who required bone graft would have similar outcomes to those that did not require bone graft, and 2) the need for subsequent revision due to baseplate failure would be higher in patients who required bone graft.

Materials and methods

This was a retrospective review of patients who required revision of a failed hemiarthroplasty, anatomic total shoulder arthroplasty, or RSA to an RSA with bone graft of the glenoid. After obtaining IRB approval, our institutional database was queried for patients who had surgery between 2009 and 2018 and filtered based on glenoid bone graft utilization. Glenoid defects were categorized according to the Antuna classification.[1] Baseline demographics and comorbidities were recorded.

Population consisted of adult patients who underwent a single-stage revision with the use of femoral head allograft. In some cases, ‘‘off-label" use of recombinant human bone morphogenetic protein-2 (BMP-2; Infuse) was placed to augment bone graft incorporation. All included patients must have had minimum 2 yr of clinical follow-up. Patients were excluded if they were revised to something other than an RSA, underwent a staged procedure, had previous documented bone grafting of the glenoid, had bone graft that was not femoral head allograft, were revised for septic baseplate failure, or had insufficient documentation (<2-yr clinical follow-up, no operative note, no implant record; Fig. 1). These patients were compared to a group of patients who were revised without the need for bone graft, with the same inclusion and exclusion criteria otherwise. All patients were operated on by a single surgeon using one of the following implant systems RSP, RSP Monoblock, or AltiVate Reverse (DJO Surgical, Austin, TX, USA; Fig. 2) with glenosphere options with hooded rims, which can be used to aid in containment and compression of bone graft. An example of grafting technique is depicted in Fig. 3.

The primary endpoint was patient reported outcomes including range of motion (ROM) and American Shoulder and Elbow Surgeons (ASES) score. Secondary outcome was baseplate-sided failure requiring re-revision. Preoperative, immediate postoperative, and final plain film radiographs were reviewed by 3 independent, fellowship-trained reviewers for features potentially predictive of baseplate failure. These included baseplate position in the coronal plane, baseplate version, glenosphere tilt, and notching.

Statistical analysis

Continuous variables will be presented as averages and standard deviations. Categorical variables are presented as proportions. Independent and paired *t* tests were utilized to evaluate continuous variables, and Fischer exact and chi-square analyses were used to evaluate categorical variables. Alpha was set at 0.05.

Results

Patient demographics are summarized in Table I. After exclusions, there were 36 patients in the study group (bone graft cohort) and 52 in the control group.

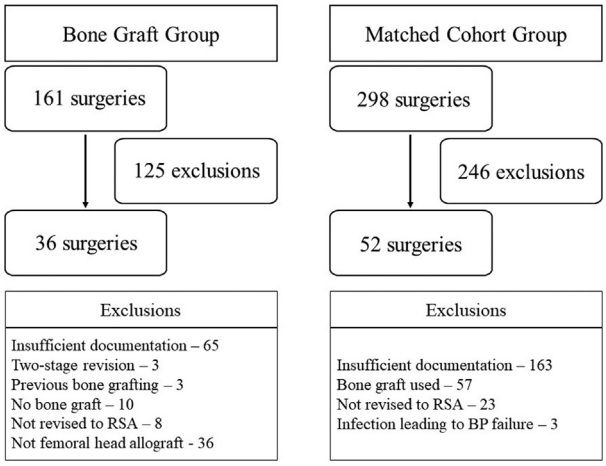

Figure 1 Study population and exclusion criteria. *RSA*, reverse shoulder arthroplasty; *BP*, baseplate.

Patients who required bone graft were more likely to have had a failed total shoulder arthroplasty whereas those who did not require bone graft were more likely to have had a failed hemiarthroplasty ($P < .001$, Appendix A). Glenoid defects in patients who required bone graft were more likely to be severe (75%, $P < .001$) and central (80.6%, $P = .291$), whereas glenoid defects in patients who did not require bone graft were more likely to be mild or moderate (92.3%) and central (86.5%, Appendix A).

In the bone graft group, 5 patients were revised for baseplate-sided failure, and 1 was revised for instability. Mean time to baseplate failure was 12 ± 9 mo. Three of the 5 had successful revision with a new baseplate. Two of the 5 were ultimately revised to a hemiarthroplasty after failure of their baseplate revisions. There were no baseplate-sided failures in the control group.

There was no difference in preoperative patient reported outcomes and ROM between the bone graft group and the control group (preoperative flexion $P = .498$, abduction $P = .668$, external rotation $P = .496$, internal rotation $P = .093$, ASES score $P = .961$). There was no difference in postoperative ROM and outcome scores between patients in the bone graft group who did not require re-revision for baseplate failure and patients in the control group (Table II). There was no difference in the use of hooded glenospheres between the patients with bone graft who had subsequent baseplate-sided failure and those who had bone graft but who did not fail ($P = 1.0$). There was no difference in the use of BMP-2 between patients who were grafted ($n = 4$) but subsequently had glenoid sided failure and patients who were grafted but did not have later glenoid-sided failure ($n = 24$; $P = 1.0$). BMP-2 was not used in patients who did not require bone graft. There was moderately high inter-rater reliability for baseplate position in the coronal plane, baseplate version, glenosphere tilt, and notching (Appendix B).

Discussion

The purpose of this study was to evaluate outcomes of patients who required bone grafting of glenoid defects with femoral head allograft during revision to an RSA, and to compare them to a cohort of patients who were revised to RSA but who did not require bone graft. Within the limitations of this study, our results demonstrate that patients who required bone graft had outcomes that were comparable to those in patients who did not require bone grafting, provided that the bone graft did not fail. In our cohort, there was a 14% glenoid-sided failure rate. Relatively few studies describe outcomes in patients who required bone grafting to manage glenoid defects while undergoing revision to RSA. Many of these describe the use of mixed bone grafting techniques and sources, making it difficult to ascertain the optimal method.

With respect to the use of autograft, most of the literature discusses primary RSA, particularly the bony increased offset-reversed shoulder arthroplasty (BIO-RSA) technique, with good clinical results and a 2% revision rate overall.[15] Few studies describe only revision cases. Kelly et al described the use of iliac crest bone graft in 12 patients out of their series of 30 revision cases. At 34 month average follow-up, ASES scores increased from 55 to 72, and all patients had improved pain and range of motion. There was no difference in ROM, Constant score, or ASES according to bone graft status, except that the bone graft group had better pain scores. There were 7 patients (23%) that required revision, but the authors do not describe whether the revised patients had bone graft or not.[11] Gupta et al described outcomes in patients who had humeral head autograft or iliac crest autograft to manage glenoid defects in both the primary and revision settings and described a classification system for glenoid bone loss. Out of 54 patients, 11 (20.3%) were revised for failed previous arthroplasty. Mean follow-up was 29.6 mo. There was 1 revision for glenoid sided failure secondary to inadequate screw purchase. The authors did not indicate if this patient initially had a revision for a failed prosthesis. The authors found no correlation between clinical outcomes and the grade of the bone defect.[8]

With respect to the use of allograft, Ozgur et al described 20 cases in which allograft from the femoral shaft, proximal femur, or proximal humerus was used in the revision setting. At final follow-up, only 9 patients had incorporated bone graft. 7 of these were femoral head/neck allografts. Seven of 8 femoral shaft allografts failed.[14] Tashjian et al described 19 patients—12 revision cases and 7 primary cases—who required femoral head allograft to reconstruct glenoid bone loss. All patients had improved functional outcome scores and ROM except for adducted external rotation. Notably, 3 of 17 patients (18%) for whom there was at least 1 yr of radiographic follow-up showed either failed incorporation or complete resorption of the

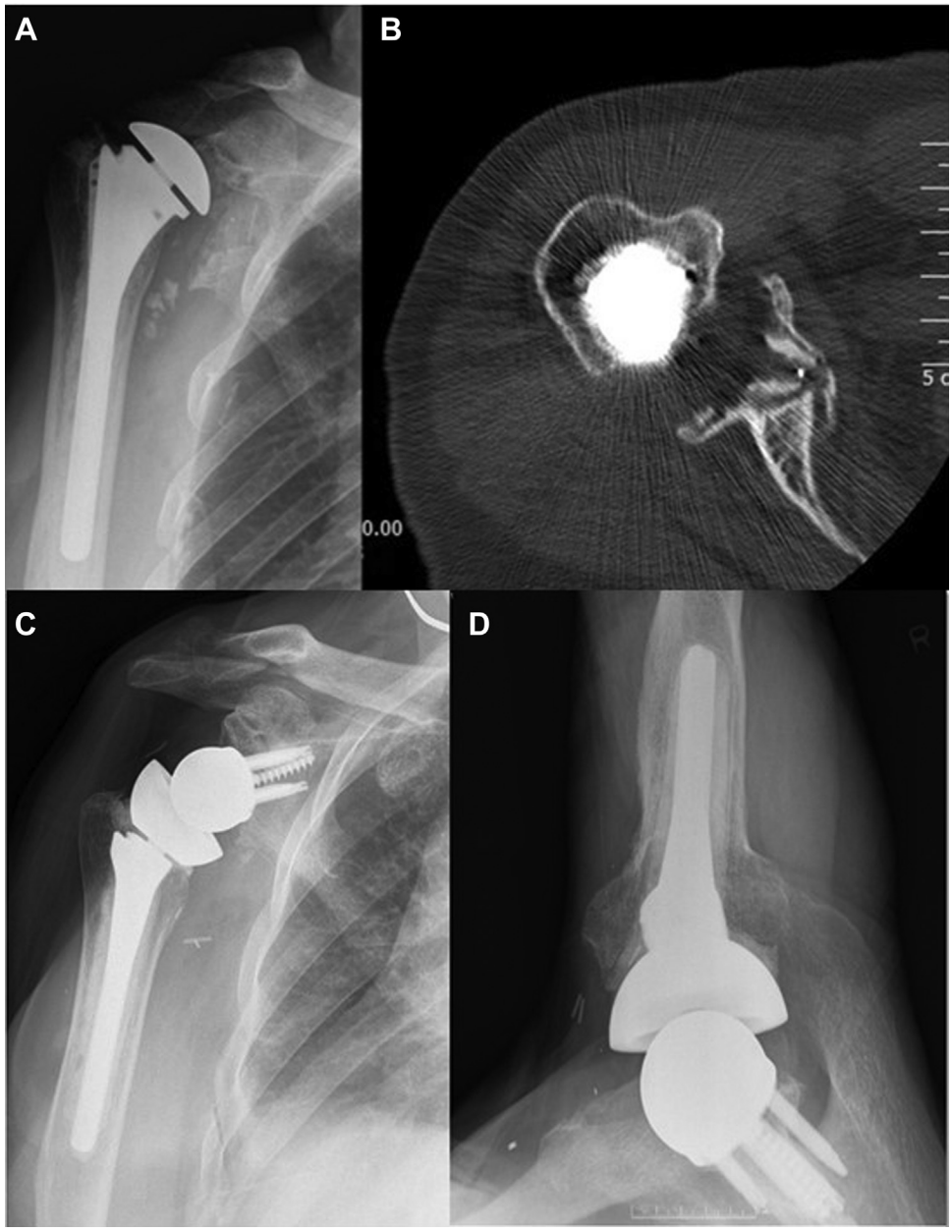

Figure 2 **(A)** Preoperative anteroposterior (AP) radiograph of a patient requiring glenoid bone grafting; **(B)** pre-revision computerized tomography (CT) of a patient with a failed anatomic total shoulder requiring glenoid bone grafting; **(C** and **D)** postoperative radiographs of a revision shoulder arthroplasty patient requiring glenoid bone grafting.

graft. Two patients had baseplate failure associated with graft failure, but they opted out of revision surgery.[18]

Several studies mix autograft and allograft cases. Wagner et al described a series of 40 patients who underwent revision to an RSA with structural and nonstructural autograft and allograft over a 5-yr period. During that same time, 102 patients were revised without bone graft. At a mean follow-up of 3.1 yr, patients had improved range of motion, pain, and functional outcome scores. Four patients (10%) required re-revision for glenoid sided failure. The 5-yr survival rate free of glenoid loosening was 89% for patients who had bone graft vs. 96% for patients who did not have bone graft, but the authors found no difference in outcomes or revision rates according to bone graft type.[19] Mahylis et al reviewed 15 patients who required structural iliac crest autograft for uncontained defects and compared them to 15 patients who had nonstructural allograft for contained defects. At 2.9 yr of follow-up, they found no difference in clinical or radiographic outcomes according to the graft type, but one patient with iliac crest graft required

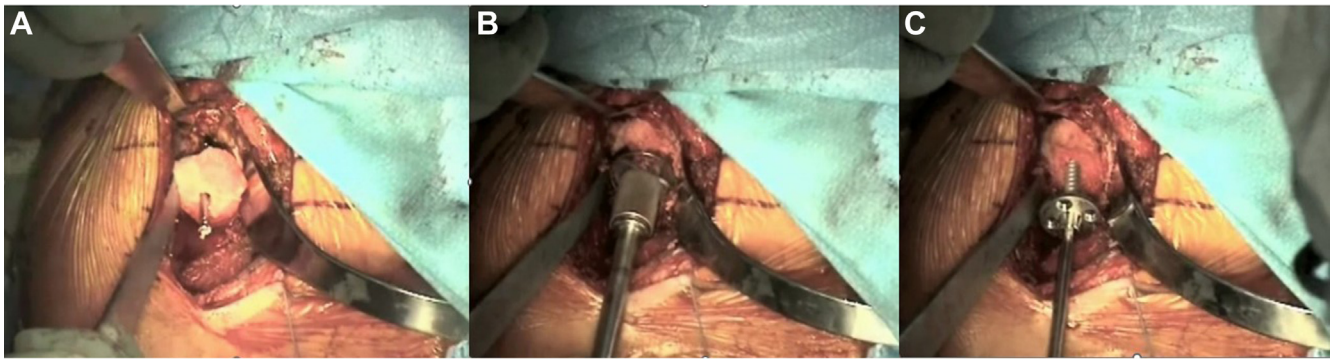

Figure 3 **(A)** The bone graft is sized and placed into the defect. Glenoid preparation proceeds with placing the guide pin and tap according to the standard procedure. K-wires may be used to hold the graft in place while it is pinned and tapped (not shown); **(B)** the reamer is introduced over the tap and the graft is reamed; **(C)** the tap is removed and the baseplate is screwed into place, compressing the graft into the defect.

Table I Demographics and comorbidities

Parameter	Study group		*P* value	Control group	*P* value
	Bone graft without failure	Failed bone graft	Bone graft without failure vs. Failed bone graft		Bone graft without failure vs. Control
N	31	5		52	
Age	69 ± 9	69 ± 9	.956	67 ± 9	.421
Female sex	35.5% (11/31)	60% (3/5)	.297	36.5% (19/52)	.923
BMI	31 ± 6	37 ± 9	.083	31 ± 5	.894
Diagnosis of diabetes	25.8% (8/31)	20% (1/5)	1	39% (20/51)*	.341
Diagnosis of RA	10% (3/31)	20% (1/5)	1	3.9% (2/51)†	.422
Confirmed tobacco use	3.2% (1/31)	0%	.787	10% (5/50)‡	.279
Number of previous surgeries	2.1 ± 1.3	1 ± 0	**<.001**	1.8 ± 1.1	.228

BMI, body mass index; *RA*, rheumatoid arthritis.
* One patient's diabetes status was unavailable for review.
† One patient's RA status was unavailable for review.
‡ Two patients' smoking statuses were unavailable for review.
Bold values indicate statistical significance.

re-revision for baseplate failure and 40% of the patients with iliac crest graft showed some graft resorption.[13] Similarly, Ho et al found high rates of radiographic failure in patients who underwent structural bone grafting with autograft or allograft for glenoid defects. Of the 37 primary and 7 revision cases, there was demonstrated improvement in ROM and functional outcome scores, but there was an 18% revision rate for baseplate failure, which occurred at a mean of 14 mo. Revision cases demonstrated a 50% rate of baseplate failure radiographically, defined as broken screws or posts or a shift in baseplate position compared to previous radiographs.[9]

Taken together, the available literature suggests that glenoid bone grafting may be a reliable technique for improving pain, ROM, and functional outcomes, but it may also carry the risk of a relatively high failure rate requiring subsequent revision. The literature also suggests that bone graft source (other than femoral shaft allograft) and defect size may not necessarily correlate with outcomes or graft survivorship, which supports the use of femoral head allograft to avoid the morbidity associated with harvesting iliac crest. To our knowledge, our study represents the largest cohort of patients who underwent glenoid bone grafting using a single technique and graft source for the management of glenoid bone loss in the revision setting only. Our work supports the suggestion that the use of allograft is a reliable way to improve pain and function, but we also showed a rate of baseplate failure that is consistent with what has been previously reported. This study also reports relatively long follow-up compared to most of the literature

Table II Range of motion and functional outcomes

Parameter	Study group		*P* value	Control group	*P* value
	Bone graft without failure	Failed bone graft	Bone graft without failure vs. Failed bone graft		Bone graft without failure vs. Control
Preoperative					
Flexion	75 ± 40	120 ± 49	**.047**	74 ± 36	.928
Abduction	65 ± 29	115 ± 49	**.005**	68 ± 36	.755
ER	30 ± 30	28 ± 32	.894	34 ± 30	.536
IR	5 ± 2	6 ± 3	.460	4 ± 3	.153
ASES	31 ± 17	39 ± 19	.336	33 ± 17	.733
Postoperative					
Flexion	126 ± 53	86 ± 57	.132	130 ± 50	.687
Abduction	121 ± 57	82 ± 44	.16	118 ± 45	.806
ER	49 ± 33	52 ± 23	.838	51 ± 30	.722
IR*	4 ± 2	3 ± 2	.459	4 ± 3	.514
ASES	64 ± 26	36 ± 39	.053	56 ± 26	.237
Delta					
Flexion	56 ± 60 **(*P* < .001)**	−28 ± 21 (*P* = .076)		55 ± 61 **(<.005)**	
Abduction	53 ± 58 **(*P* < .001)**	−28 ± 5 **(*P* = .002)**		49 ± 61 **(.001)**	
ER	16 ± 42 **(*P* < .003)**	30 ± 14 **(*P* = .024)**		17 ± 44 **(.025)**	
IR	0.1 ± 3.3 (*P* = .837)	2.3 ± 1.5 (*P* = .058)		0.1 ± 4 (.85)	
ASES	27 ± 29 **(*P* < .001)**	−3 ± 39 (*P* = .869)		23 ± 30 **(<.001)**	
Clinical follow-up (mo)	59.5 ± 29.3	10.6 ± 7.7	**<.001**	63 ± 27	.582
Radiographic follow-up (mo)	45.5 ± 33.2	12.2 ± 9.0	**<.001**	50 ± 31	.549
Use of BMP-2	77% (24/31)	80% (4/5)	1.0	0%	**<.001**
Hooded glenosphere	77% (24/31)	80% (4/5)	1.0	13.5% (7/52)	**<.001**

ER, external rotation; *IR*, internal rotation; *ASES*, American Shoulder and Elbow Surgeons; *BMP-2*, bone morphogenetic protein-2.

* Internal rotation is reported as a numerical value from 0 to 8 for the highest point the patient can reach behind the back: ipsilateral hip (0), ipsilateral back pocket (1), contralateral back pocket (2), S1 to L5 (3), T11 to L1 (4), T7 to T10 (5), T4 to T6 (6), T2 to T3 (7), and C8 to T1 (8).

Bold values indicate statistical significance.

on the topic. Weaknesses of our study include the retrospective nature of the work, and the fact that, given the relatively small number of failures, this study may lack power to demonstrate factors that are predictive of glenoid sided failure in patients who have bone grafting of a glenoid defect.

Conclusion

The use of femoral head allograft to manage glenoid bone loss when revising a failed arthroplasty to a RSA has a relatively high risk of baseplate sided failure, but it can predictably achieve functional outcomes that are not inferior to those in patients who are revised but who do not require bone graft. Future studies are needed to determine the optimal technique for managing glenoid bone loss in the revision setting.

Disclaimers:

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Conflicts of interest: Matthew J. Teusink is a paid consultant for Enovis (formerly DJO). Kaitlyn N. Christmas is a paid consultant for Enovis (formerly DJO). Mark A. Frankle receives royalties, is paid presenter or speaker, receives research support and consulting fees from Enovis (formerly DJO), and consulting fees from Synchrony Healthcare Communications. The other authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2022.12.022.

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