Conversion of a failed hip resurfacing arthroplasty to total hip arthroplasty: pearls and pitfalls

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Published online: 23 January 2016
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Abstract Surface replacement arthroplasty (SRA) remains a viable alternative to total hip arthroplasty (THA) in appropriately selected, active adults with degenerative hip disease. However, orthopedic surgeons are facing a number of scenarios where revision of one or both components of an SRA is indicated. Indications for revision vary and impact the potential outcomes of conversion of a SRA to THA. While clinical outcomes are generally favorable, a growing body of data illustrates patients who undergo conversion of a SRA to THA to be at increased risk of requiring a repeat revision surgery and experiencing functional outcomes inferior to that of a primary THA. The results of patients undergoing conversion of a SRA to THA highlight the need for careful patient selection, thorough preoperative counseling, and technical precision when performing a SRA. Furthermore, a systematic approach to the failed SRA is necessary to ensure optimal clinical results.

Keywords Surface replacement arthroplasty · Total hip arthroplasty · Metallosis · Femoral neck fracture · Aseptic loosening

Introduction

Hip resurfacing, or surface replacement arthroplasty (SRA), has been utilized in various iterations since the 1950s, with metal-on-metal implants, such as the first generation McKee-Farrar total hip arthroplasty system introduced in the 1960s [1, 2]. In the early 1990s, metal-on-metal SRA experienced a resurgence in response to concerns regarding the longevity of total hip arthroplasty (THA) in younger patients [3]. For the past 15 years, SRA has been performed in Europe and Australia, mainly by a small group of surgeons who have undergone advanced training, given the technically demanding nature of the procedure [4, 5]. In 2006, the US Food and Drug Administration (US FDA) approved the first metal-on-metal (MoM) resurfacing device for use in the USA, the Birmingham Hip Resurfacing (BHR, Smith & Nephew, Inc., Memphis, TN, U.S.A.). Subsequently, additional hip resurfacing systems were introduced in the USA, including the Conserve Hip System (Wright Medical Inc.; Memphis, TN, USA), Cormet Hip Resurfacing Prosthesis (Stryker Inc; Mahwah, NJ, USA), and the Articular Surface Replacement (ASR) hip resurfacing system (DePuy Orthopaedics Inc.; Warsaw, IN, USA) (Table 1).

Proposed advantages of SRA versus THA include proximal femoral bone preservation, physiologic loading of the proximal femur and thus less stress shielding, avoidance of potential embolization risk due to lack of femoral reaming or cementation, decreased thigh pain associated with the femoral stem in conventional THA, and the ability of the patient to resume higher demand activities [3, 6, 7]. The MoM articulation of SRA designs had two additional purported advantages when compared to the metal-on-polyethylene (MoP) articulation found in conventional THA: increased durability from the cast cobalt alloy and the ability to utilize a larger diameter femoral head, thus decreasing the risk of dislocation [8–14].

This article is part of the Topical Collection on *Hip: Metal-on-Metal*

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Table 1 Metal-on-metal surface replacement arthroplasty systems introduced in the USA

Surface replacement arthroplasty system	Manufacturer	Year system introduced	Year system recalled
Birmingham hip resurfacing	Smith and Nephew Inc. (Memphis, TN)	2006	Not applicable
Conserve hip resurfacing	Wright Medical Inc. (Memphis, TN)	2009	Not applicable
Cornet hip resurfacing	Stryker Inc. (Mawah, NJ)	2007	Not applicable
Articular surface replacement	Depuy Inc., (Warsaw, IN)	2005	2010
Durom hip resurfacing	Zimmer Inc. (Warsaw, IN)	2006	2008
Recap hip resurfacing	Biomet Inc. (Warsaw, IN)	2006	Not applicable

Disadvantages cited for SRA compared to THA include a more exacting surgical technique that requires more precise component placement, which contributed to an increased number of reported complications as the volume of hip surfacing procedures in the USA increased. Additionally, MoM SRA had limitations based on patient factors, and could not be utilized in metal sensitive patients, patients with renal disease, or women potentially intending to become pregnant. Femoral neck fracture was the most common complication noted in early reports [15, 16]. There were also reports of metal-on-metal surface wear, with an associated soft tissue reaction to particulate debris [17–21].

Revision rates of SRA have been reported to be higher than primary THA, with the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) showing an 8-year cumulative revision percentage of 5.3 % for SRA compared with 4.0 % for conventional primary THA [22]. However, revision rates for SRA vary significantly when analyzing individual implant systems and different patient subgroups. The ASR system had a revision rate of 12 % at 5 years and was voluntarily recalled from the US market in August 2010 [23]. The BHR system was found to have a 7-year revision rate of 5.1 % in a study utilizing the National Joint Registry for England and Wales, and a 7.1 % revision rate at 11 years in a study based on the Australian Joint Registry data [22, 24]. However, a study analyzing the first 650 BHRs performed in the USA identified a complication rate of 1.1 %, which is equivalent to the complication rate of primary THA [25]. In a recent systematic review, Marshall et al. determined that the overall revision and reoperation rate was higher for all metal-on-metal SRA systems when compared with THA, with revision surgery occurring earlier (mean 3.0 years) in SRA versus THA patients (mean 7.8 years) [26]. However, when discontinued or recalled SRA systems were excluded from the analysis, there was no significant difference in the revision rates between THA and MoM resurfacing arthroplasty [26].

Potential risk factors and indications for revision

Femoral neck fracture, acetabular and femoral component loosening, infection, and metallosis, with or without an

associated adverse local soft tissue reaction (ALTR), have been identified as the most common modes of failure of SRA [27]. Fracture of the femoral neck is the most common indication for revision, with an average prevalence ranging from 0.9 to 1.1 % and a mean occurrence of 18 months after initial surgery [27, 28]. Osteopenia and osteoporosis, notching of the femoral neck during the SRA procedure, and coxa vara are risk factors associated with femoral neck fracture [29]. Gender, age at time of surgery, and implant factors, including component size and position, have been identified as risk factors for revision following SRA. In a 2010 review of 5000 Birmingham Hip Resurfacing patients, Carrothers et al. found that female gender was an independent risk factor for failure, with revision rates in women significantly increased compared to males (5.7 vs 2.6 %, $p < 0.001$) [27]. Numerous long-term follow-up studies have also shown a 95 to 98 % survival rate of BHR at 10 years in male patients [30–32]. Furthermore, increased age is considered a potential risk factor of complications following SRA [33, 34]. Data from an Australian registry study highlighted an increased risk of revision in patients over the age of 55 years [35]. Older patients have an increased likelihood of poor bone quality, potentially placing them at a higher risk for complications such as femoral neck fracture or aseptic component loosening [33, 36, 37]. THA is an established procedure with a good track record of survival in the elderly population, and remains the treatment of choice for most surgeons when considering hip arthroplasty in an older patient [22, 24, 38]. Implant malposition is another risk factor for revision, with multiple studies identifying malposition of components to be directly associated with an increased incidence of aseptic loosening and elevated rate of metal ion release [39, 40]. Lastly, numerous studies have shown that decreased femoral component size is associated with increased release of metal ions, with one review showing a greater than 460 % increase in the incidence of failure for every 4 mm decrease in femoral component diameter [40–42]. Locally destructive adverse tissue reactions have been noted to occur in association with elevated metal ion levels, with studies estimating a 0.1 to 1 % prevalence in all patients undergoing metal-on-metal hip resurfacing [20, 43] [44].

Evaluation of the painful SRA

A systematic approach must be utilized when evaluating a patient with a prior surface replacement arthroplasty. A thorough history and physical exam, accompanied by any indicated imaging studies, is required to rule out causes of pain from nearby anatomic structures. Serial radiographs can be used to monitor component position and evaluate for implant loosening. Radiolucent lines around the acetabular or femoral components and reactive sclerosis around the stem of the femoral component are classic radiographic signs of potential implant loosening. A bone scan or metal artifact reduction magnetic resonance imaging scan can be utilized to evaluate for implant loosening. More recently, single positron emission computed tomography (SPECT/CT) has been shown to have a higher specificity and sensitivity when compared with a bone scan to detect aseptic loosening in the setting of a painful arthroplasty [45].

In a patient presenting with pain following SRA, first on the differential diagnosis remains infection. The erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) are typically elevated in the setting of prosthetic joint infection (PJI). However, in the setting of a metal-on-metal resurfacing arthroplasty, the ESR and CRP can be chronically elevated, likely due to a secondary reaction to metal debris [46]. Aspiration of the joint in question, with synovial fluid analysis and culture, is a critical step when evaluating for possible PJI. Parvizi et al., in a study evaluating PJI following total hip arthroplasty, found that a synovial fluid cell count of >1760 cells/ μL had a positive predictive value of 99 % and negative predictive value of 88 %, and a neutrophil percentage of >73 % had a positive predictive value of 96 % and a negative predictive value of 91 % [47]. The infecting organism was also successfully cultured from the synovial aspirate in 77 % of the cases from their cohort [47]. It is worth noting that the presence of metal ions can distort automated cell counts, therefore it is important to order a manual cell count when evaluating synovial fluid in the setting of a MoM arthroplasty [48, 49].

In addition, metal debris and adverse local tissue reactions are potential sources of pain following SRA [20]. In 2010, the UK Medicines and Healthcare products Regulatory Agency published a report stating that a serum cobalt or chromium level of ≥ 7 parts per billion represented a threshold where more frequent monitoring or advanced imaging should be utilized for surveillance [50]. However, Hart et al. found that blood cobalt levels were significantly elevated in patients with a failed MoM hip arthroplasty (8.2 vs 2.5 $\mu\text{g/L}$) when compared to an unrevised cohort, and recommended against utilizing the cutoff of 7 $\mu\text{g/L}$ as an isolated indication for revision as it had a positive predictive value of 0.75 and a negative predictive value of 0.82 when evaluating for SRA failure [51]. Adverse local tissue reactions (ALTR) or pseudotumors are

also a concern following SRA and can be present in both asymptomatic and symptomatic patients, and in the presence or absence of elevated metal ion levels [20]. These soft tissue lesions can destroy local bone, soft tissue, and compress adjacent neurovascular structures. When compared with the effects of conventional polyethylene debris, metal particles from MoM wear impact soft tissue to a greater degree than bone. Thus, it is imperative to understand the size and relationship of a pseudotumor to the surrounding anatomic structures prior to undertaking revision surgery. Nam et al. performed a systematic literature review and evaluated a number of advanced imaging modalities to determine the specific advantages and limitations associated with each when diagnosing wear-related corrosion problems following hip arthroplasty [52]. Ultrasound (US) is readily available, cost effective, and easily accessible, but results are operator dependent and there is a paucity of data on the ability of US to accurately assess the severity of soft tissue destruction [52]. Computed tomography (CT) provides additional information regarding component position, but lacks the ability to provide fine soft tissue detail and exposes patients to ionizing radiation. Magnetic resonance imaging (MRI) provides the most specific detail on soft tissue structure and severity of local tissue reaction, however it is associated with the highest cost and optimal data collection requires the use of specific metal artifact reduction sequences that may not be readily accessible for all patients [52]. Thus, selection of an imaging modality should in part be based on what is available at each surgeon's institution and their institution's experience.

Potential revision options

Potential revision strategies of surface replacement arthroplasty depend on the revision indication (Table 2). In the setting of infection, the gold standard treatment classically involves a two-stage exchange [53]. Treatment involves removal of all prior implants as well as an aggressive debridement of any devitalized or necrotic soft tissue [54]. A temporary prosthesis or spacer, typically containing antibiotic-laden cement, is placed at the time of resection arthroplasty. Often, this involves placement of an antibiotic-laden stem into the intramedullary canal of the femur with either a hemiarthroplasty femoral head or cemented acetabular liner to maintain soft tissue tension and length. Recently, a novel technique has been described specifically for the infected surface replacement arthroplasty in which an irrigation bulb and metal medicine cup are covered with antibiotic-laden cement and fixed to the native femoral head [55]. The primary potential advantage is avoidance of introducing bacteria into the femoral intramedullary canal, although long-term results in a large series of patients with this technique have not been reported. The patient then undergoes a course of intravenous antibiotics

Table 2 Surface replacement arthroplasty (SRA) revision options and indications

Extent of revision	Indications	Revision options	Technical considerations
Isolated femoral revision	(1) Femoral neck fracture (2) Aseptic loosening (3) Metallosis with malpositioned femoral component	Conversion to femoral stem with large metal head or dual mobility femoral component	Concerns regarding metal-on-metal (MOM) corrosion or polyethylene wear Dual mobility not currently FDA-approved for use with a SRA acetabular component
Isolated acetabular revision	(1) Wear/osteolysis (2) Aseptic loosening (3) Malposition, impingement	Revise to large hemispherical cup with polyethylene liner Exchange of SRA acetabular component	Must perform through synovectomy and debridement. Supplement with multiple screw fixation; consider bone grafting cystic or lytic lesions. In the authors opinion, this is a suboptimal option given the increased risk for ongoing wear from residual metal ions Concerns with acetabular component fixation
Conversion to total hip arthroplasty	(1) Infection (2) Metallosis (3) Adverse local tissue reaction	Two-staged revision Perform thorough irrigation and debridement Perform thorough irrigation and debridement	Check metal ion levels in addition to infectious labs before staged reimplantation (can have altered relationships) Our preferred treatment for metallosis. Must remove all of debris and affected tissue; closely track metal ions and clinical symptoms postoperatively Remove all debris and affected tissue; Our preference is to use ceramic or oxidized zirconia femoral heads with titanium-alloy acetabular and femoral components

(typically 6 weeks) tailored to microbe sensitivities from pre-operative or intraoperative cultures. Inflammatory markers (ESR and CRP) are monitored during and after antibiotic treatment. Aspiration of the affected joint is often performed for synovial fluid analysis and culture prior to proceeding with reimplantation after antibiotics have been discontinued for at least 2 weeks. At the time of reimplantation, revision acetabular components are often utilized due to the loss and compromised quality of the bone and surrounding soft tissues, while a primary femoral component can be utilized in the majority of cases. More recently, there has been increased interest in single stage explantation, debridement, and reconstruction for the chronically infected arthroplasty, with high rates of clinical success described for a select patient population [56]. In the setting of an infected SRA, the protocol at our institution is still to perform a two-stage exchange, utilizing an antibiotic-impregnated temporary prosthesis, and conversion to a total hip arthroplasty at the time of reimplantation.

In the setting of component loosening, revision options vary based on the implant(s) that have failed. In the setting of a failed femoral component due to either femoral neck fracture or aseptic loosening, with a well-fixed acetabular shell, an isolated femoral revision has been described [57, 58•]. The advantages of femoral-sided revision with retention of the acetabular shell include a faster operative time (versus both femoral and acetabular revision), potentially decreased dislocation risk due to use of a large diameter femoral head, and preservation of acetabular bone stock. One option

includes the use of a primary (or revision) femoral component with a large diameter metal femoral head, although this has fallen out of favor due to concerns regarding MoM THA and corrosion-related complications. A second option includes the use of a primary (or revision) femoral component with a dual mobility femoral head, with a smaller diameter femoral head within a larger, polyethylene outer bearing. However, the Food and Drug Administration (FDA) has not approved the use of a polyethylene dual mobility component with a retained SRA acetabular component, and potential concerns exist including implant mismatch, where issues with coverage angles and edge loading can lead to subsequent polyethylene wear. Conversion of both the femoral and acetabular components remains the primary option in the setting of femoral or acetabular component failure [57]. There are reports of isolated revision of the acetabular shell, with retention of the well-fixed femoral component however this report included a very small number of patients and lacked long-term follow-up [58•]. If both the femoral and acetabular components have failed, then conversion to THA is recommended.

Femoral neck fracture following SRA can be treated very similarly to aseptic loosening of the femoral component. In the setting of a well-fixed and well-positioned acetabular component, a femoral-sided revision to a primary THA implant can be performed, with the same potential risks and benefits as described above. If there is concern about concomitant acetabular component loosening, or a malpositioned acetabular component, then complete conversion to THA is recommended.

There are multiple options when planning for revision of a painful SRA with elevated metal ion levels, with or without an associated ALTR. Pritchett reported on 76 acetabular-sided SRA revisions, utilizing either a polyethylene or metal articular surface, for adverse tissue reaction associated with elevated metal ions and showed a 97 % clinical success rate, as defined by implant retention, at a mean follow-up of 65 months [59•]. Isolated femoral-sided revision for metallosis has also been described [57, 58•, 59•]. While potentially faster and less technically demanding, retention of the acetabular shell in the setting of metallosis is associated with potential drawbacks. Concerns remain regarding implant mismatch, increased polyethylene wear if a dual mobility bearing is used, and maintenance of a potential source of metal ions with retention of a monoblock acetabular component. Complete revision of both the acetabular and femoral components to a THA absent of potential sources of cobalt and chromium has been shown to produce good short-term clinical results [60]. Benefits of conversion to THA include lack of concern for implant mismatch, and elimination of the primary sources of cobalt or chromium ions if titanium-alloy femoral and acetabular components, and ceramic or Oxinium™ (Smith and Nephew Inc., Memphis, TN, USA) femoral heads are utilized. Potential drawbacks include loss of bone stock secondary to removal of SRA implants, and decreased stability given the smaller femoral head diameter often utilized in THA when compared with SRA. Figure 1 illustrates an example of a patient who underwent complete revision of SRA to primary THA for instability. While instability is a relatively uncommon indication for revision of a SRA, this example highlights the efficacy of complete conversion of SRA to THA.

Technical considerations

There are multiple technical aspects to consider when performing revision surgery in the setting of a prior surface replacement arthroplasty. In the setting of metallosis, a thorough understanding of the characteristics and anatomic relationships of an associated pseudotumor is essential as this soft tissue mass can distort normal surgical landmarks. In their report on revision of 55 SRAs over a 5-year period, Su et al., describe some of the technical aspects associated with revision surgery [58•]. All reported revisions were performed via a posterolateral approach. When the surgical plan included femoral revision, the hip was dislocated and femoral neck osteotomy could be made according to the preoperative template. Often, the femoral osteotomy can be made utilizing a reciprocating saw blade around the femoral stem of the resurfacing component. After the femoral neck osteotomy, acetabular exposure is similar to that of a primary THA. In rare cases where the femoral component was retained, an extensive capsular release was performed after dislocation of the

hip, and the femoral head was positioned anterior and superior to the acetabulum to enable acetabular exposure. In cases where the acetabular component was removed, use of a fulcrum consisting of either a large-ball adapter or trial acetabular liner and curved osteotomes enabled relatively easy removal of the acetabular shell with minimal bone loss [58•]. For patients with metallosis or pseudotumor, thorough debridement of metal debris and inflammatory soft tissue was performed. Any cystic or lytic osseous lesions were packed with bone graft. The posterior capsule and short external rotators were repaired, and patients were maintained on posterior hip precautions for 6 weeks postoperatively [58•].

It is important for the surgeon to also consider the potential extent of soft tissue damage that has occurred in the setting of an aggressive, adverse local tissue reaction, and its impact on hip stability and function. Extensive osteolysis may require the use of bone grafting along with supplemental fixation especially in the setting of greater trochanter involvement. Preoperative assessment of abductor strength is essential. If the abductor mechanism has been significantly damaged, a dual mobility implant may be considered to improve implant stability or alternative soft tissue reconstructions may be considered including transfer of the gluteus maximus or Achilles tendon allograft [61, 62]. Furthermore, although theoretically concerning in the setting of a recent acetabular reconstruction, a constrained acetabular liner may be considered if intraoperative stability of a THA cannot be achieved due to soft tissue destruction.

Outcomes of conversion of SRA to THA

Multiple studies have evaluated the clinical outcome of conversion of SRA to total hip arthroplasty. Su et al. found that clinical outcomes of conversion of a SRA to a THA was related to the indication for revision [58•]. They showed the highest postoperative function, as determined by the Harris hip score (HHS), in patients who underwent conversion for femoral neck fracture or implant loosening. These patients had a mean HHS of 99 (range 96 to 100) at a mean follow-up of 2.3 years. The worst outcomes were seen in patients who underwent revision for a combined diagnosis of unexplained pain/metal sensitivity. This patient cohort had an average postoperative HHS of 86.9, which was significantly lower than patients revised for a mechanical etiology, such as femoral neck fracture or implant loosening ($p=0.029$) [58•].

Revision of a single component of an SRA, with retention of the remaining components, has been associated with mixed clinical results. Ball et al., in a 2007 study comparing 21 patients undergoing conversion of SRA to THA to patients undergoing primary THA, found that in the 18 patients who

Fig. 1 Revision of surface replacement arthroplasty to total hip arthroplasty. **a** Anteroposterior (AP) pelvis radiograph after left hip surface replacement arthroplasty (SRA). **b** Cross-table lateral radiograph of the left hip demonstrating 13° of anteversion in the acetabular component. **c** The patient felt a “pop” while performing yard work and subsequent radiograph demonstrates a posterior-superior dislocation without fracture. The patient was successfully closed reduced in the emergency department, but went on to have additional instability events. **d** AP pelvis radiograph 6 weeks after full SRA conversion to total hip arthroplasty utilizing a dual mobility ceramic-in-polyethylene head, a highly porous metal multi-hole cup and a medial-lateral tapered cementless femoral stem

underwent femoral-sided revision only there was no clinical difference at a mean 46-month follow-up with regard to the mean Harris hip score; the University of California at Los Angeles pain, walking, and activity score; or the SF-12 score [57]. Additionally, they noted no instances of aseptic loosening of either the femoral or acetabular components, and no dislocation events following conversion. Similarly, a study of 90 single component revisions (76 acetabular and 14 femoral) for adverse soft tissue reaction demonstrated a 97 % success rate at a mean follow-up interval of 61 months [59].

This study was unique in that a dual mobility polyethylene femoral head was utilized for all femoral-sided revisions and a polyethylene articular surface was used in acetabular revisions where the retained femoral head had a diameter ≤ 45 mm [59]. Conversely, data on a large series of patients from the Australian Joint Replacement Registry highlights a cumulative 5-year re-revision rate of 20 % with acetabular-sided only revisions and a 7 % rate with femoral-sided revisions, which was more than double the revision rate of primary THA over the study period [63].

Complete revision of both the acetabular and femoral components of SRA to total hip arthroplasty has varying clinical outcomes reported across multiple studies. Wong et al., in a registry study of 882 SRA revisions, noted a 10-year cumulative re-revision rate of 26 % following prior SRA revision [64•]. They noted no difference in re-revision rates and clinical outcome between the acetabular-sided, femoral-sided, or combined acetabular and femoral-sided (conversion to THA) cohorts, a finding that correlated with the results of the prior study by Su et al. [58•]. Eswaramoorthy et al. showed that clinical outcomes in patients undergoing conversion of SRA to THA had clinical results comparable to primary THA, however the clinical scores were significantly worse when compared with patients undergoing primary SRA [65]. Sandiford, in a review of 25 patients undergoing conversion of SRA to THA, found significant postoperative increases in Oxford, Harris, and WOMAC hip scores, with clinical results similar to revision THA [60].

Revision of SRA for symptomatic metallosis or pseudotumor is associated with a reliable reduction of cobalt ion levels below the 7 µg/L threshold, while one study reported a decrease in chromium ions to less than 7 µg/L in 88 % of patients at a mean of 3 years follow-up [66]. Reports on clinical outcomes following SRA revision for complications associated with metal wear are mixed, with some studies touting midterm clinical success rates as high as 97 %, while other data shows that revision for metallosis is associated with a significantly worse outcome when compared with revision for mechanical etiologies [58•, 59•].

Conclusion

Orthopedic surgeons are facing a number of scenarios where revision of one or both components of an SRA is indicated. While clinical outcomes and re-revision rates are generally favorable, there is a growing body of data which illustrates that patients who undergo conversion of SRA to THA are at an increased risk of requiring repeat revision surgery or experiencing poor functional outcomes when compared with patients undergoing primary THA. In addition, the clinical outcome of conversion of SRA to THA is dependent on the indication for revision, with patients undergoing revision for mechanical etiologies exhibiting better results than patients being treated with revision for complications associated with metal-on-metal wear. The results of THA following conversion from SRA highlight the need for careful patient selection, thorough preoperative counseling, and technical precision when performing surface replacement

arthroplasty. Furthermore, a systematic approach to the failed SRA is necessary to ensure optimal clinical results.

Compliance with ethical standards

Conflict of interest Jacob A. Haynes and Jeffrey B. Stambough declare that they have no conflict of interest.

Robert L. Barrack declares that he has received grants, personal fees, royalties, research support, and consultant fees from Stryker, grants from Biomet, grants from Medical Compression Systems, Inc., grants from National Institutes of Health (NIAMS & NICHD), grants from Smith & Nephew, Inc., grants from Wright Medical Technology, royalties or material support from The McGraw-Hill Companies, Inc., and royalties or material support from Wolters Kluwer Health-Lippincott Williams & Wilkins, outside the submitted work.

Denis Nam reports stock or stock options from OrthAlign, Inc., consultant fees from KCI, and research for EOS Imaging, outside the submitted work.

Human and animal rights and informed consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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