Dual-Mobility Acetabular Components in Total Hip Arthroplasty

Benjamin A. McArthur, MD, Denis Nam, MD, Michael B. Cross, MD, Geoffrey H. Westrich, MD, and Thomas P. Sculco, MD

Abstract

With dislocation being one of the most serious complications of total hip arthroplasty, prevention of recurrent instability has been the driving force behind several implant designs, including large-diameter heads, metal-on-metal bearing surfaces, and constrained acetabular components. Dual-articulation acetabular component design was similarly conceived in an effort to reduce postoperative dislocation risk. This design, developed in France in 1975 and popularized in Europe, was recently approved in the United States and represents a new surgical option for United States orthopedic surgeons performing total hip arthroplasty.

In this article, we review the dual-articulation design in terms of its history, biomechanical concepts, published indications, contraindications, outcomes, and complications based on more than 20 years of largely French clinical experience.

Dislocation is a common and potentially disabling complication of total hip arthroplasty (THA). Incidence ranges from 0.2% to 7% for primary THA and from 10% to 25% for revision THA.[1] As dislocations are potentially dangerous, and recurrent dislocations remain one of the most common indications for revision surgery, preventing postoperative instability has been a major focus in implant design and innovation. Indeed, metal-on-metal bearing surfaces, highly cross-linked polyethylene (HCLPE) coupled with large-diameter modular heads, and hip resurfacing were all developed in attempts to improve implant stability and decrease dislocation rates. As with any implant design, each of these options has its advantages and disadvantages, the latter limiting indications for use. Mobile-bearing or dual-mobility (DM) socket design, which has been used abroad for more than 30 years, was recently introduced to the United States market.

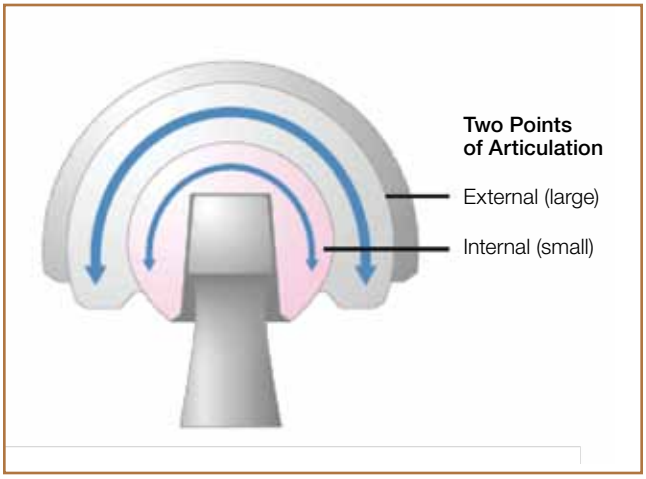

Figure 1. Dual-mobility design has 2 concentric articulations: large-diameter mobile-bearing polyethylene articulation with polished metal cup and smaller constrained articulation between metal femoral head and polyethylene liner.

History

Developed by Bousquet in 1975 to reduce postoperative dislocations, the DM design has 2 aims.[2] One aim is to obtain maximum stability: The implanted component has a large head and thus a favorable head–neck ratio, which reduces the risk for component impingement, according to the theory of McKee and Watson-Farrar.[3] The other aim is to operate on the low-friction arthroplasty principle described by Charnley.[4] The design has 2 concentric articulations: a large-diameter polyethylene (PE) articulation with a polished metal cup and a smaller constrained articulation between a modular femoral head and the PE liner (**Figure 1**). Thus, the DM design consists of a mobile-bearing PE articulating with both the femoral head and the acetabular socket.

Since its initial conception, the design has evolved a number of times on the basis of clinical experience and improvements in implant engineering. Today, several modern DM prostheses are available in the United States, and each has its own set of unique proprietary characteristics, allowing the orthopedic surgeon multiple choices in design features. Among the re-

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cently available products are the Anatomic Dual Mobility (ADM) (Stryker Orthopaedics, Mahwah, New Jersey) and Modular Dual Mobility (MDM) (Stryker Orthopaedics, Mahwah, New Jersey) designs, the POLARCUP (Smith & Nephew, Memphis, Tennessee), and the Active Articulation (Biomet Orthopaedics, Warsaw, Indiana). In addition, the first DM components designed, the Novae TH cups (SERF, Décines Cedex, France), have been modified, and now several modern Novae designs are available through a distribution agreement with OMNIlife Science (East Taunton, Massachusetts).

Early sockets, the Novae 1 cup in particular, were coated with plasma-sprayed porous alumina on the convex surface for osseointegration.[5] Although the cumulative survival rate was initially 95.4% at 10- and 12-year follow-up,[5] subsequent reports noted the primary cause of failure to be cup fixation,[6] and in later designs the porous surface was modified, exchanging the plasma-sprayed alumina for a titanium spray with hydroxyapatite coating.[7] The Novae cups currently available include cemented (Stick) and press-fit (Sunfit TH, Coptos TH, E TH) varieties. The Sunfit TH is a standard hemispherical cup; the E TH and Coptos TH include smooth-headed pegs and one (E TH) or more (Coptos TH) flanges for additional screw fixation.

Proponents of the ADM cup note that DM designs using cylindrospherical cups may be associated with a high incidence of inguinal pain related to iliopsoas tendon impingement on the anterior rim.[7] The ADM cup includes a curved depression anteriorly, designed to align with the iliopsoas groove of the acetabulum and thereby prevent impingement.[8] The MDM cup allows for insertion of a multihole cup for augmented screw fixation, and a modular metal liner fits into the cup to articulate with the mobile-bearing PE.

The Polar Cup includes optional peg holes as well as a flange that can be used for periacetabular screw fixation. A unique feature of the Active Articulation design is its use of vitamin E–impregnated HCLPE to protect the mobile-bearing from oxidation.

Initial reports described use of a 22.2-mm femoral head captured within the mobile-bearing PE[5]—the primary rationale for a smaller head being a reduction in volumetric PE wear. With advances in manufacturing, however, conventional PE has been exchanged for HCLPE, leading to significantly improved wear rates and use of larger, 28-mm femoral heads. These increase range of motion (ROM) before neck impingement on the liner, and thereby may reduce the risk for intraprosthetic dislocation.[8,9] Furthermore, newer generation liners have a more robust capture mechanism, such that femoral head insertion is completed with a vise on the back table, providing an additional barrier to intraprosthetic dislocation. Of note, United States FDA approval is being sought for several DM designs currently available in Europe, so more options are likely to appear in the United States.

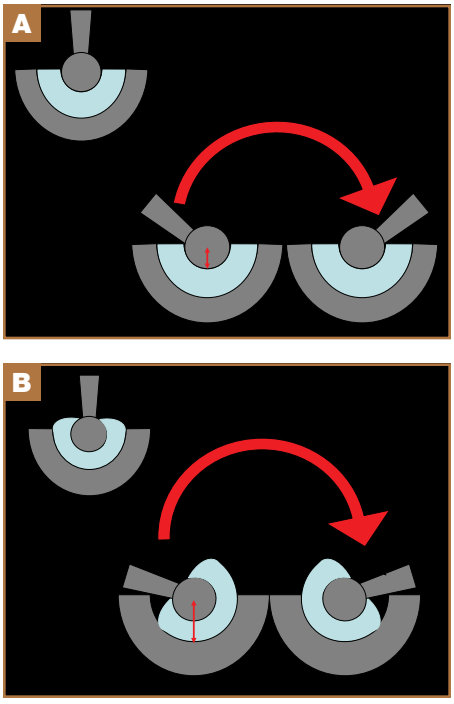

Figure 2. Standard THR (A) is associated with decreased ROM before impingement as well as decreased jump distance, compared with dual-mobility designs (B).

Design Theory and Biomechanics

The DM articulation is designed to increase impingement-free ROM by improving the head–neck ratio. The femoral head is captured within the liner such that the large-diameter PE essentially functions as a large femoral head. Thus, the mobile-bearing insert reproduces the mechanics of a bipolar hemiarthroplasty while avoiding the groin pain associated with an unresurfaced acetabulum. In addition to increasing impingement-free ROM, the large bearing surface results in a significantly increased jump distance once impingement begins, thereby allowing more of a window to react and reducing dislocation risk (**Figures 2A, 2B**).

Indications and Contraindications

Although DM components are relatively new to the United States market, there is a considerable body of literature derived from more than 30 years of French experience, and a number of indications and contraindications have been identified. Boyer and colleagues[10] recently published a 22-year follow-up on implantation of 240 DM components for primary THA. They reported no dislocations and suggested that, though DM components have traditionally been advocated for patients over 60, use might be extended to patients over 50, based on their experience.

DM components have also been advocated for use in patients with increased dislocation risk, including those undergoing revision THA for recurrent instability,[11] revision THA for all other causes,[12] THA after femoral neck fracture,[13] and THA after tumor resection.[14] Initial indications for DM components at our institution were for primary THA in elderly women with ligamentous laxity and revision THA in the setting of recurrent dislocations despite appropriate component position. However, DM components are increasingly being used in younger patients. For many surgeons, hip resurfacing has fallen out of favor, because of adverse soft-tissue reactions from metal ions. As contemporary DM components allow stability similar to that allowed by hip resurfacing and with minimal risk for metal ion issues, they are increasingly

being implanted in young, active patients.

Although no absolute contraindications have been identified, some authors have advised caution in using these components in younger patients, as the DM surface design could theoretically result in increased PE wear debris and resultant particle-induced osteolysis.[2,15] Nonetheless, use of HCLPE inserts and of femoral heads relatively small in diameter has been associated with favorable wear characteristics, and laboratory analysis of retrieved components suggests that it is the inner bearing that is responsible for the majority of ROM, with less motion occurring over the larger bearing surface.[16] Implants removed after a mean duration of 8 years had wear rates similar to those of conventional metal-on-PE articulations.[16] Newer DM designs using a 28-mm head against second-generation HCLPE have been shown in vitro to exhibit slightly less wear than a contemporary design with HCLPE and a large metal head, even when inclined at an angle of 65°.[17] Nonetheless, Leiber-Wackenheim and colleagues[11] recommended against DM components in young and active patients, as these patients seem to be at increased risk for intraprosthetic dislocation.

Table I. Dislocation Rates for Dual-Mobility Components

Patient Population	Investigator	Dislocation Rate
Primary THA	Boyer and colleagues[10] Leclercq and colleagues,[7] Bouchet and colleagues,[2] Philippot and colleagues[12]	0%-0.9%
Revision for instability	Leiber-Wackenheim and colleagues,[11] Philippot and colleagues,[12] Guyen and colleagues[15]	0%-1.9%
Revision for deep infection	Philippot and colleagues[12]	9%
Revision for aseptic loosening	Philippot and colleagues[12]	2.9%
Revision, all causes	Langlais and colleagues,[33] Philippot and colleagues[12]	1.1%, 3.7%
THA after femoral neck fracture	Tarasevicius and colleagues[13]	0%
THA after tumor resection	Philippeau and colleagues[14]	9.8%

Abbreviation: THA, total hip arthroplasty.

Outcomes

Regarding dislocation rate, most series have demonstrated considerable benefit with use of DM components. Bouchet and colleagues[2] compared dislocation rates between 105 DM and 108 conventional components with 28-mm heads for primary THA. Early dislocations occurred in 5 (4.6%) of the conventional components and none of the DM components (P = .059). The main drawback of their study is its short-term follow-up (minimum, 1 year; mean, 2 years). In contrast, the 22-year follow-up study of DM components in primary THA, published by Boyer and colleagues,[10] represents the longest follow-up in the literature. As mentioned, they reported no prosthetic dislocations in their series. Survival rates for cup and liner were reported to be 81.4% at 20 years and 80% at final follow-up. Global survival rates based on the Kaplan-Meier survival curves were 75.4% at 20 years and 73.9% at final follow-up—rates comparable to those in standard THA at the time.[18-31] Main causes of failure included aseptic loosening (8.3%), intraprosthetic dislocation (4.1%), excessive PE wear necessitating liner exchange (2%), and loss of femoral fixation (2%). The revision rate was highest for patients younger than 30 at time of index surgery, with rates up to 45% for cup or liner revision. The revision rate for patients between 50 and 70 years old was roughly 10%. Of note, the implants used in this study were first-generation cementless Novae cups with conventional PE, a 22.2-mm head, and a cementless screwed femoral stem, so comparison with contemporary designs is difficult.

Several studies have assessed the performance of DM components in patients prone to recurrent dislocation (**Table I**).[2,7,10-14,32,33] Leiber-Wackenheim and colleagues[11] retrospectively reviewed the midterm (8-year) outcomes of 59 patients who underwent revision for recurrent dislocation with conversion to DM components between 1995 and 2001. The authors noted 1 (1.7%) early dislocation without recurrence, in a patient with multiple sclerosis, managed with closed reduction under general anesthesia. There was no osteolysis or fixation failure at final follow-up. A shortcoming of the series is that malorientation of the acetabular component was noted before surgery in 47% of the cases, so the increased stability noted after revision could have been related to improved component position alone.[14] Guyen and colleagues[15] reported on a similar series, of 54 patients revised for instability, but did not identify component malposition as a cause of dislocation in any patient. They reported similar outcomes at a mean follow-up of 4 years: 1 recurrent dislocation, managed with closed reduction, and 2 intraprosthetic dislocations, which went on to revision. No cases of osteolysis or loss of fixation were noted.

Philippot and colleagues[12] reviewed the outcomes of 163 revision THAs managed with conversion to DM components. The total postoperative dislocation rate at final follow-up was 3.7%, and the 7-year cup survivorship rate was 96.1%. Dislocation rates were 2.9% for revisions for aseptic loosening (3 cases), 9% for revisions for infection (3 cases), and 0% for revision for recurrent instability. All were managed with closed reduction under general anesthesia, and no recurrence was noted after early dislocation. The overall re-revision rate for all causes was 6.7% at a mean (SD) follow-up of 60 (17.6) months. Cup-fixation failure necessitating revision occurred in 2 cases (1.2%). Similar rates of postoperative instability and component loosening after revision surgery have been reported in other midterm case series.[33,34]

Use of DM components in patients undergoing THA after tumor resection was evaluated by Philippeau and col-

leagues[14] in a retrospective series of 71 patients with bony lesions of the hip. The postoperative dislocation rate was 9.8%. The most significant predictor of postoperative instability was surgical management of the abductors, with dislocation rates of 3.5% with abductor conservation, 9.5% with abductor sectioning/reinsertion, and 18% with gluteus medius muscle or nerve resection. As such, we suggest that a relative contraindication to DM components is an incompetent or absent abductor mechanism. In this setting, a constrained component should be used.

Several surgeons at our institution have begun to use DM components in select patient populations. Since May 2010, surgeons at our hospital have implanted 402 ADM and 51 MDM components. To our knowledge, 3 components required early revision—1 ADM component for infection, and 2 MDM components used in revisions, 1 for recurrent dislocation in a patient with incompetent abductors, and 1 for early loosening of the acetabular component after an intraoperative acetabular fracture.

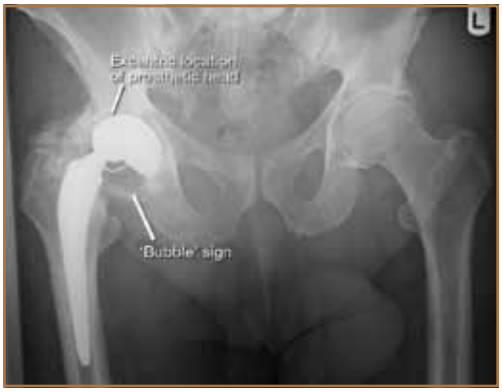

Figure 3. Characteristic radiographic findings in setting of intraprosthetic dislocation include eccentric location of femoral head within cup and so-called bubble sign, which represents empty polyethylene liner. Reprinted from *The Journal of Arthroplasty*, 27/3, Mohammed R, Cnudde P, Severe metallosis owing to intraprosthetic dislocation in a failed dual-mobility cup primary total hip arthroplasty, 493.e1-e3, 2012, with permission from Elsevier.

Complications

Accelerated wear, component loosening, and intraprosthetic dislocation represent the major complications associated with DM components. Although presence of 2 bearing surfaces might be expected to increase wear and particle load, the current literature provides little evidence of this occurring, and in vitro data for a contemporary DM design would suggest otherwise. In their 240-patient series, Boyer and colleagues[10] reported that only 5 patients (2%) required revision for excessive PE wear at a mean follow-up of 17 years, but this was with first-generation, conventional gamma/air-sterilized PE.[10] Current designs using HCLPE boast a 97% reduction in wear rates compared with conventional PE.[8]

Acetabular component loosening has been cited as a significant complication in DM components. Opponents of the DM design argue that use of screwless fixation, particularly in the setting of limited bone stock, predisposes these components to early failure, limiting use in revision cases.[35] Furthermore, much as with a monoblock acetabular component, it may be difficult to tell when a DM cup is fully seated at time of insertion, as some models do not have screw holes, and thus the acetabular bony surface is not visible. In their midterm (10-year) follow-up study, Farizon and colleagues[5] reported a 2.9% incidence of revision for mechanical loosening. Boyer and colleagues[10] reported aseptic loosening in 8.3% of their DM components at 22 years, with revisions occurring at a mean (SD) of 11 years 5 months (5 years). The authors pointed out that first-generation porous coating was suboptimal and has been supplanted by newer porous surfaces. Long-term follow-up data on newer models are not yet available. Nonetheless, midterm and long-term cup survivorship reported in multiple case series remains in the range of 80% to 96% (**Table II**).[5,6,10]

Intraprosthetic dislocation is a complication unique to this design. Also referred to as *retentive failure* (RF), intraprosthetic dislocation is a failure of the PE liner to maintain capture of the femoral head. Thus, it is a dislocation of the smaller articulation in this dual-articulation system. Incidence of RF has been reported to be 0% to 5.3%, depending on series, and appears to increase over longer follow-up (**Table III**).[6,10,11,36] Philippot and colleagues reported 2 RFs in 106 prostheses (1.9%) at a mean follow-up of 10 years[36] and, in a subsequent publication, 23 RFs in 438 prostheses (5.3%) at a mean follow-up of 17 years.[6] The phenomenon seems to be wear-related, wherein repetitive

Table II. **Survival Rates for Dual-Mobility Cups**

Investigator	N	Follow-Up, y	Survival Rate
Boyer et al[10]	240	22	80%
Philippot et al[6]	438	15	96.3%
Farizon et al[5]	135	10	95.4%

Table III. **Intraprosthetic Dislocation (Retentive Failure) Rates**

Investigator	N	Follow-Up, y	Dislocation Rate	Head Size, mm
Leiber-Wackenheim et al[11]	59	8	0%	28
Boyer et al[10]	240	22	4.10%	22
Philippot et al[6]	438	17	5.30%	22
Philippot et al[36]	106	10	1.90%	22

impingement of the neck on the PE rim causes progressive wear in the capture mechanism leading to eventual femoral head escape. Management depends on the stage at which RF is identified. Although management is always surgical, early identification can often be managed with exchange of only the modular head and the liner. If diagnosis or management is delayed, however, revision of the acetabular component may be required, as the femoral head tends to cause high-contact pressure and rapid wear of the polished metal acetabular bearing surface. Mohammed and Cnudde[37] reported a case of severe metallosis, after RF of a DM component, that required debridement and revision of all components. Lecuire and colleagues[38] described a series of 7 patients with RF that occurred, on average, 10 years after implantation. Six of the patients were treated early, with isolated liner exchange; the seventh underwent late surgery in which both the liner and the shell had to be revised. Patients with RF may present with complaints of vague groin pain followed by an acute feeling of giving way. However, because the femoral head articulates with the metal shell, patients may remain ambulatory, though leg length is shortened and ROM limited. Radiographs show an eccentric location of the femoral head, and the characteristic "bubble sign" representing the abnormal position of the PE liner (**Figure 3**).[37] Of note, Leiber-Wackenheim and colleagues[11] reported no cases of RF at a mean follow-up of 8 years in a cohort of patients with 28-mm femoral heads, which provide a more favorable head–neck ratio at the inner articulation than the standard 22.2-mm heads initially used by Boyer and colleagues,[10] Philippot and colleagues,[32] and others. Longer term follow-up is required to determine whether 28-mm heads with new HCLPE capture mechanisms will decrease the RF rate in these patients.

Conclusion

Mobile-bearing acetabular components represent a novel instrument for United States orthopedic surgeons. Proponents have cited reduced dislocation rates in both primary and revision THA as well as THA performed in patient subgroups at risk for postoperative instability. Published dislocation rates compare favorably with those of conventional components in most series. Nonetheless, concerns have been raised regarding aseptic loosening, accelerated wear, and the unique complication of intraprosthetic dislocation.[35] The current literature suggests that DM components may be a useful addition to the armamentarium of the orthopedic surgeon, particularly when managing patients prone to dislocation after THA. Although these prostheses have been used abroad for more than 30 years, and a substantial body of literature describes their midterm and long-term performance, several recent modifications in implant design have been implemented, and they may improve or alter the associated long-term outcomes. As hip resurfacing has fallen out of favor among many orthopedic surgeons, DM prostheses may ultimately become the prosthesis of choice for younger, more active patients. However, longer term follow-up and prospective level one studies are needed to fully evaluate the current design.

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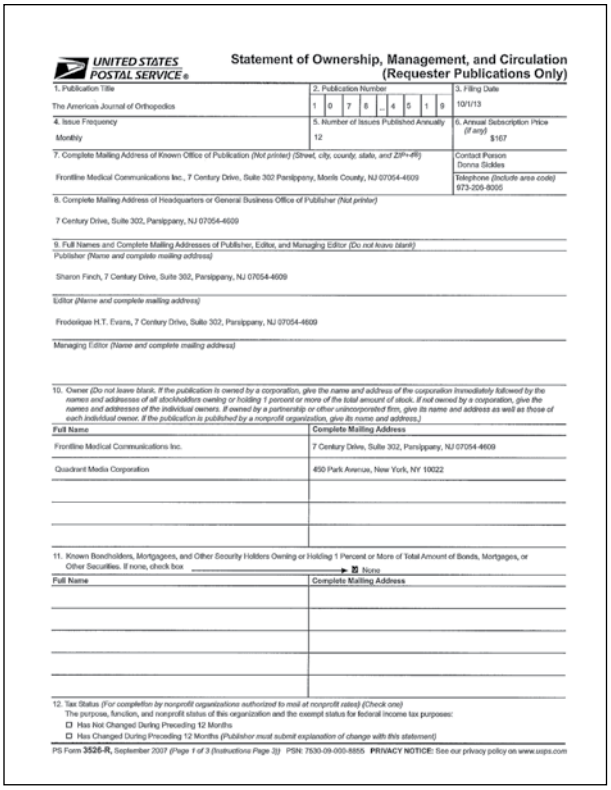

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4. Issue Frequency	5. Number of Issues Published Annually	6. Annual Subscription Price (If any)
Monthly	12	$167

7. Complete Mailing Address of Known Office of Publication (Not printer) (Street, city, county, state, and ZIP+4®) — Contact Person: Donna Sickles
Frontline Medical Communications Inc., 7 Century Drive, Suite 302 Parsippany, Morris County, NJ 07054-4609 — Telephone (Include area code): 973-206-8005

8. Complete Mailing Address of Headquarters or General Business Office of Publisher (Not printer)
7 Century Drive, Suite 302, Parsippany, NJ 07054-4609

9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor (Do not leave blank)
Publisher (Name and complete mailing address)
Sharon Finch, 7 Century Drive, Suite 302, Parsippany, NJ 07054-4609
Editor (Name and complete mailing address)
Frederique H.T. Evans, 7 Century Drive, Suite 302, Parsippany, NJ 07054-4609
Managing Editor (Name and complete mailing address)

10. Owner (Do not leave blank. If the publication is owned by a corporation, give the name and address of the corporation immediately followed by the names and addresses of all stockholders owning or holding 1 percent or more of the total amount of stock. If not owned by a corporation, give the names and addresses of the individual owners. If owned by a partnership or other unincorporated firm, give its name and address as well as those of each individual owner. If the publication is published by a nonprofit organization, give its name and address.)

Full Name	Complete Mailing Address
Frontline Medical Communications Inc.	7 Century Drive, Suite 302, Parsippany, NJ 07054-4609
Quadrant Media Corporation	450 Park Avenue, New York, NY 10022

11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages, or Other Securities. If none, check box → ☒ None

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12. Tax Status (For completion by nonprofit organizations authorized to mail at nonprofit rates) (Check one)
The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes:
☐ Has Not Changed During Preceding 12 Months
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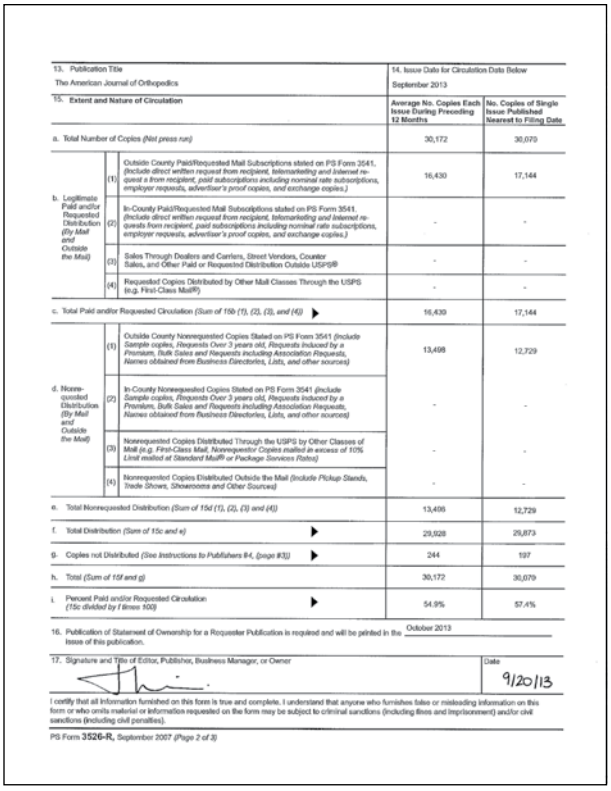

13. Publication Title	14. Issue Date for Circulation Data Below
The American Journal of Orthopedics	September 2013

15. Extent and Nature of Circulation			Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Total Number of Copies (Net press run)			30,172	30,079
b. Legitimate Paid and/or Requested Distribution (By Mail and Outside the Mail)	(1)	Outside County Paid/Requested Mail Subscriptions stated on PS Form 3541. (Include direct written request from recipient, telemarketing and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)	16,430	17,144
	(2)	In-County Paid/Requested Mail Subscriptions stated on PS Form 3541. (Include direct written request from recipient, telemarketing and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)	-	-
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d. Nonrequested Distribution (By Mail and Outside the Mail)	(1)	Outside County Nonrequested Copies Stated on PS Form 3541 (Include Sample copies, Requests Over 3 years old, Requests Induced by a Premium, Bulk Sales and Requests including Association Requests, Names obtained from Business Directories, Lists, and other sources)	13,498	12,729
	(2)	In-County Nonrequested Copies Stated on PS Form 3541 (Include Sample copies, Requests Over 3 years old, Requests Induced by a Premium, Bulk Sales and Requests including Association Requests, Names obtained from Business Directories, Lists, and other sources)	-	-
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e. Total Nonrequested Distribution (Sum of 15d (1), (2), (3) and (4))			13,498	12,729
f. Total Distribution (Sum of 15c and e) ▶			29,928	29,873
g. Copies not Distributed (See Instructions to Publishers #4, (page #3)) ▶			244	197
h. Total (Sum of 15f and g)			30,172	30,079
i. Percent Paid and/or Requested Circulation (15c divided by f times 100) ▶			54.9%	57.4%

16. Publication of Statement of Ownership for a Requester Publication is required and will be printed in the October 2013 issue of this publication.

17. Signature and Title of Editor, Publisher, Business Manager, or Owner — Date: 9/20/13

I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).

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