



## Original Research

## Trends in Osteopathic Authorship in Orthopedic Publications and Its Impact on Adult Reconstruction Match Rates

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## ABSTRACT

**Background:** Doctors of osteopathy (D.O.) have historically been underrepresented in the orthopedic literature. As adult reconstruction (AR) continues to rank among the most competitive orthopedic fellowships, participation in research likely serves a key role for successfully matching. This study sought to identify trends in D.O. orthopedic publications and assess for correlations between these trends and osteopathic AR match results.

**Methods:** The top 10 orthopedic surgery journals based on impact factor were selected for analysis. Articles published between 2010 and 2021 were screened to assess for publications with a D.O. author, as well as authorship position. A total of 29,499 articles were available for final analysis. Data from the San Francisco Residency and Fellowship Match Services were also reviewed to evaluate the number of osteopathic applicants and their match rates during the same study period. Trends in D.O. publications and osteopathic AR match rates were then assessed for any correlations.

**Results:** From 2010 to 2021, there was a significant increase in orthopedic and arthroplasty-related publications with a D.O. author ( $P < .0001$ ), as well as D.O. first ( $P = .0006$ ) and senior authorship positions ( $P = .009$ ). Osteopathic match rate significantly increased during the study period ( $P = .003$ ). There was a strong correlation between the increase in osteopathic match rate and arthroplasty-related publications with a D.O. author ( $r = 0.76$ ).

**Conclusions:** From 2010 to 2021, there was an upward trend of osteopathic orthopedic publications. This increase is strongly correlated with an increase in osteopathic AR match rate. Our findings suggest that authorship in publications may play a key role in successfully matching into an AR fellowship.

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## Introduction

Osteopathic physicians have traditionally been considered a minority group in the medical field. As of 2021, there were only 38 accredited osteopathic medical schools compared to 154 accredited allopathic medical schools in the United States [1]. The disparity in the number of physicians with a Doctor of Osteopathy (D.O.) degree compared to a Medical Doctor (M.D.) degree is even more pronounced in orthopedic surgery. For example, the American Medical

Association's 2020 Physician Specialty Data Report indicated that out of 19,069 orthopedic surgeons in the United States, only 1069 were osteopathic physicians (5.6%) [2]. With greater than 90% of graduating orthopedic surgical residents pursuing advanced training in a subspecialty fellowship, the discrepancy between D.O.s and M.D.s who are fellowship trained is further magnified as most applicants applying for fellowships are allopathic candidates [3,4].

Adult reconstruction (AR) fellowship positions continue to rank among the most competitive orthopedic surgical subspecialties over the last several years, with position fill rates routinely above 96% [4]. In 2021, there were 233 allopathic physicians compared to only 26 osteopathic physicians applying for 202 AR fellowship positions. Of the 201 positions filled, only 19 of these were matched

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to osteopathic applicants [4,5]. As such, participation in research and authorship of peer-reviewed publications have become a key criterion among orthopedic surgery fellowship directors when considering applicants [6]. In fact, the Accreditation Council for Graduate Medical Education (ACGME) currently mandates that medical trainees incorporate research and scholarly activities into their curriculum and requires residency programs to implement this in order to maintain accreditation. It is important to mention that although the American Osteopathic Association and ACGME merger that recently occurred may influence the volume of D.O. publications in the future due to these aforementioned mandates, all the data for this paper were collected prior to the merger.

The importance of research and authorship in publications on match rates has been well documented in other medical/surgical subspecialties [7–12], and there are no studies analyzing how much D.O.s are publishing in the orthopedic literature and how this may impact successfully matching into an AR fellowship. Therefore, the purposes of this study were to identify any trends in the quantity of orthopedic publications with a D.O. author in both the general orthopedic and arthroplasty literature from 2010 to 2021 and identify any correlations between D.O. publication trends and AR match results during the same time period. Secondary objectives were to analyze the number of AR osteopathic and allopathic applicants from 2010 to 2021 and to identify any trends in applicant numbers and match rates.

## Material and methods

The present study was exempt from institutional review board review. All orthopedic journals were queried utilizing the Clarivate Analytics database. Eighty-one unique orthopedic journals were identified. Journals that did not consistently have hip and/or knee arthroplasty-related publications were excluded. This yielded a total of 21 journals (Fig. 1). The top 10 journals based on their 2020 Journal Impact Factor (IF) were then selected for final analysis (Table 1). All published articles in each journal (including supplementary editions) from 2010 to 2021 were included in a review to identify authors with a D.O. degree. The 10 journals were divided among the 5 authors for manual data collection of each journal. All data were collected and entered into an Excel spreadsheet. After excluding abstracts, letters to editors, author responses, introductions and commentaries, symposia, and podcasts, a total of 29,499 articles were available for final analysis (Table 2). The authors of each article were assessed for a D.O. degree from the PDF version of the study. If the type of medical degree/credentialing was not listed in the original study, a simple internet search was conducted to confirm what degree the author held based on their location and affiliated institution. Once an osteopathic author was identified in a publication, their authorship order (ie, first, middle, or senior author) along with whether the article was relevant to the field of hip or knee arthroplasty was documented [13].

The number of articles with an osteopathic author was calculated for each year across all 10 journals. Articles with greater than 1 osteopathic author were considered as a single publication. Trends in publications with a D.O. author from 2010 to 2021, as well as authorship position (first vs senior), were then analyzed for each year. We chose to only analyze first and senior authorship positions since middle authors generally have a more supportive role during the research project. Subanalysis was also performed for hip/knee arthroplasty-related publications.

Data from the San Francisco (SF) Residency and Fellowship Match Services and the American Association of Hip and Knee Surgeons pertaining to AR fellowship application and match rate were obtained from 2010 to 2021. Each year was assessed for the number of allopathic and osteopathic applicants, as well as their

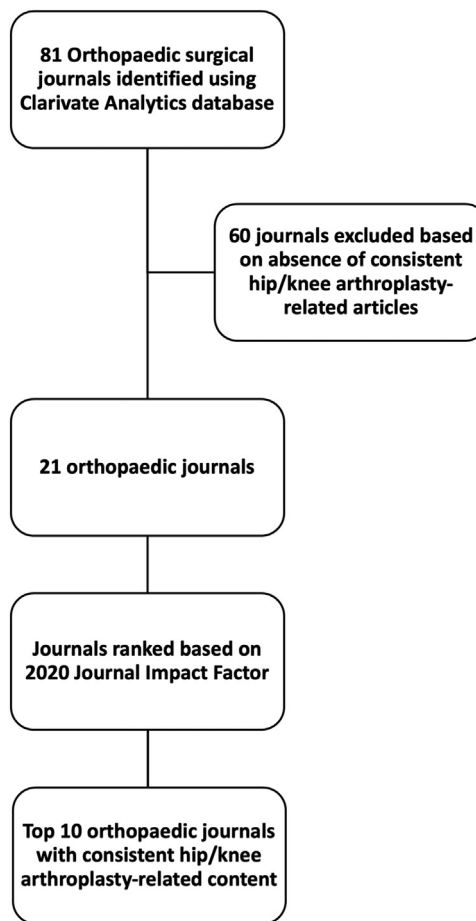


Figure 1. Flowchart on journals selected for analysis.

respective match rates. Overall, AR match rate was also calculated for each year. Trends in publications with a D.O. author, D.O. authorship position, and osteopathic AR match rates through the SF Match were then analyzed to assess for any correlation.

## Statistical analysis

Descriptive statistics are provided for the SF Match data. Pearson correlation coefficients were calculated to explain the linear relationship between time (in years) vs publications, authorship positions, fellowship application, and match rates. The relationship between 2 variables was considered strong when the correlation coefficient was larger than 0.7 and moderate when the coefficient is

Table 1  
Journal list<sup>a</sup>.

Journal name	Impact factor
The Journal of Bone and Joint Surgery—American Volume	5.284
The Bone & Joint Journal	5.082
The Journal of Arthroplasty	4.757
Clinical Orthopaedics and Related Research	4.291
Acta Orthopaedica	3.717
Journal of the American Academy of Orthopaedic Surgeons	3.008
Journal of Knee Surgery	2.757
Journal of Orthopaedic Surgery and Research	2.359
The Knee	2.199
HIP International	2.135

<sup>a</sup> Obtained from Clarivate Analytics 2020 Journal Impact Factor Report, [www.clarivate.com](http://www.clarivate.com).

**Table 2**  
Articles reviewed per journal.

Journal name	Articles reviewed
The Journal of Bone and Joint Surgery - American Volume	4324
The Bone & Joint Journal	3197
The Journal of Arthroplasty	6212
Journal of Orthopaedic Surgery and Research	3918
The Knee	2098
Clinical Orthopaedics and Related Research	3918
Journal of the American Academy of Orthopaedic Surgeons	1848
HIP International	1305
Journal of Knee Surgery	1297
Acta Orthopaedica	1382
Total	29,499

between 0.5 and 0.7. A linear regression model was calculated along with the confidence limits. Coefficient estimates of the linear model were used to calculate predicted future estimates over time. A  $P$  value  $< .05$  was deemed to be statistically significant. All statistical analyses were conducted using JMP software (version 14.3.0; SAS Institute Inc., Cary, NC).

## Results

From 2010 to 2021, a total of 29,499 journal articles from the top 10 orthopedic surgery journals were reviewed. Overall, there was a statistically significant increase in publications with a D.O. author from 14 publications in 2010 to 91 publications in 2021 ( $P < .0001$ ; Fig. 2). Figure 3 shows the percentage of D.O. articles over total publications from the 10 journals that were reviewed from 2010 to 2021. More specifically, there was also a statistically significant increase in arthroplasty-related publications with a D.O. author from 2 in 2010 to 53 in 2021 ( $P < .0001$ ). The number of publications with a D.O. first author ( $P = .0006$ ), as well as a senior author with an osteopathic background ( $P = .009$ ), also significantly increased during the study period (Table 3, Fig. 4).

We found a strong correlation between the increase in publications with a D.O. author and the increase in D.O. first authorship during the study period ( $r = 0.96$ ). Similarly, there was a strong correlation between the increase in publications with a D.O. author and the increase in D.O. senior authorship ( $r = 0.76$ ). A strong correlation was also found between the increase in total arthroplasty-related publications with a D.O. author and the

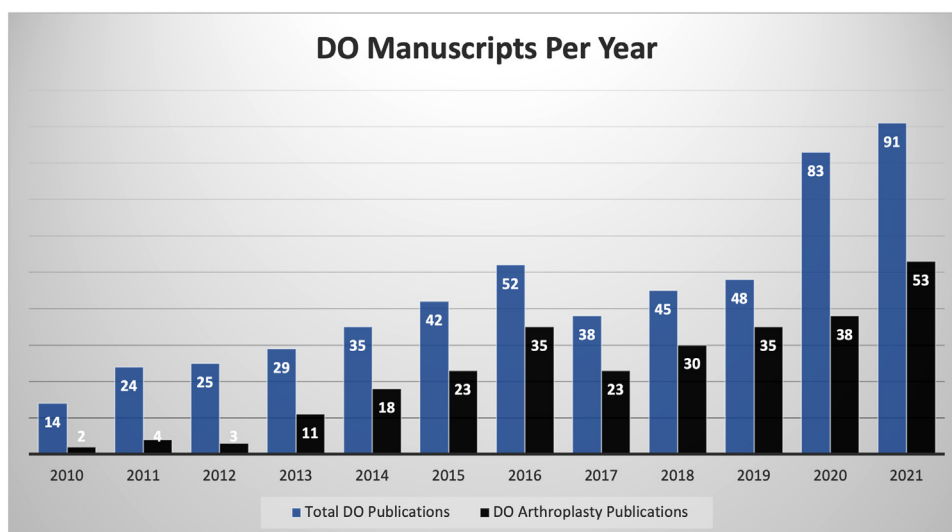
increase in D.O. first authorship ( $r = 0.88$ ) and D.O. senior authorship ( $r = 0.79$ ). A strong correlation was found between the increase in total arthroplasty-related publications with a D.O. author and the increase in total publications with a D.O. author ( $r = 0.93$ ). Lastly, an analysis was performed to assess for a correlation between publication rate over time and match rate over time. This analysis was performed for both D.O.s and M.D.s. Total D.O. publications over the study period moderately correlated with D.O. match rate ( $r = 0.69$ ;  $P = .0139$ ), while the same was not true for M.D.s. There was no correlation between publication rate and match rate for M.D.s ( $r = 0.456$ ;  $P = .1359$ ).

The SF Match results for AR were analyzed between 2010 and 2021 (Table 4). There was a statically significant increase in allopathic applicants over the study period from 163 applicants in 2010 to 233 applicants in 2021 ( $P = .03$ ). Osteopathic applicants increased from 10 in 2010 to 26 in 2021 although this was not found to be statically significant ( $P = .53$ ). Interestingly, the osteopathic match rate did significantly increase over time from 7.3% (8 out of 109) in 2010 to 9.5% (19 out of 201) in 2021 ( $P = .003$ ). The significant increase in osteopathic match rate was found to be strongly correlated with the total number of osteopathic publications ( $r = 0.69$ ), as well as with arthroplasty-related publications ( $r = 0.76$ ).

Finally, a linear regression analysis was performed based on the data collected and determined that by 2030, there will be a continual increasing trend of orthopedic publications with a D.O. author. Similarly, arthroplasty-related publications with a D.O. author, as well as D.O. first- and senior-authorship positions, will also continue to increase (Table 5).

## Discussion

There continues to be a strong emphasis on participation in research and scholarly activity among medical trainees. Competitive medical and surgical residencies oftentimes view research and authorship in publications a key criterion when considering an applicant for a residency and/or fellowship position. In a recent study using data from the National Resident Matching Program and SF Match from 2007 to 2014, Borsting et al. found an increasing mean number of research experiences, presentations, and abstracts among U.S. senior applicants for a plastic surgery residency [7]. Similarly, Stratman et al. found that 39 out of 157 (25%) candidates who listed publications on their Electronic Residency Application



**Figure 2.** D.O. manuscripts and D.O. arthroplasty publications stratified by year.

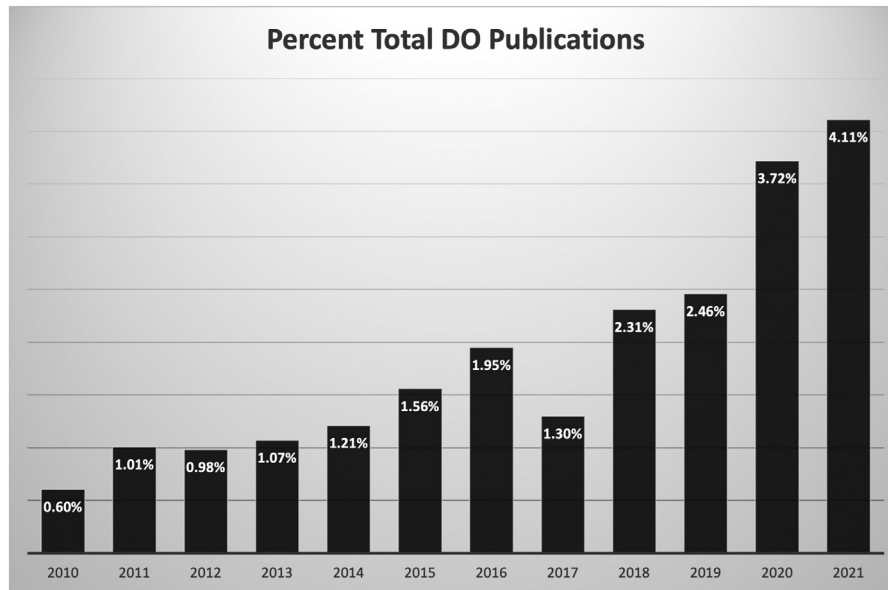


Figure 3. Percentage of D.O. publications compared to total publications.

Service applications matched into a dermatology residency compared to only 7 out of 64 (11%) applicants who listed no publications [12]. The historical lack of standardized research requirements and mentorship among osteopathic residency programs may have D.O. applicants at a disadvantage when applying to AR fellowships compared to their allopathic colleagues [14].

Over the past several years, AR fellowships have become one of the most competitive orthopedic subspecialties. Position-fill rates for AR fellowships have consistently remained above 90% since 2015 [5]. For example, 201 out of 202 AR fellowship positions filled in 2021. With more applicants than positions offered every year since 2015, it has become evident that participation in research and/or authorship in peer-reviewed publications have become key components for consideration and acceptance into an AR fellowship.

Our study found a significant increase in orthopedic publications with a D.O. author. This can be partially attributed to the steady increase in the number of osteopathic medical schools from 32 schools in 2010 to 62 schools in 2023 [1]. The recent American Osteopathic Association-ACGME merger [15] will also likely result in more osteopathic publications in the orthopedic literature. The ACGME has provided specific mandates regarding minimum research requirements for each orthopedic resident in order for the residency program to maintain accreditation including (1) a minimum of 60 days of protected research for each resident, (2) basics of research design to be included in didactics, and (3) resident participation in scholarly activities during their time in the program [16]. Our findings are supported by a recent editorial by Nace et al. who reported a significant increase in the number of podium presentations given by a D.O. at the American Academy of Orthopaedic

Surgeons annual meeting from 2013 to 2021 [17]. In 2021, nearly 10% of hip and knee arthroplasty presentations were from D.O. authors.

During our study period, we also found a significant increase in orthopedic publications with D.O.s in the first and senior author positions. Typically, the first author contributes most to the generation and scripting of the manuscript while the senior author takes on the lead role in project development and research design [13]. For example, a resident or medical trainee will often be cited as the first author on a project while the attending physician is cited as the last or senior author. D.O.s in the senior authorship position have been increasing. As more D.O.s successfully match into AR fellowships, this will lead to more D.O. arthroplasty surgeons who will continue to contribute to the growing body of arthroplasty literature in the senior position. For example, there were only 8 osteopathic AR fellows in 2010 compared to 19 osteopathic AR fellows in 2021. In our study, we found a strong correlation between the increase in D.O. senior authorship position and the increase in both overall orthopedic publications and arthroplasty-related publications with a D.O. author. We also found a strong correlation between the increase in D.O. first authorship and the increase in both overall orthopedic publications as well as arthroplasty-related publications. These strong correlations suggest that both medical trainees and attendings are publishing in the orthopedic and arthroplasty literature. Interestingly, the importance of authorship position on a candidate's application has been poorly defined. In a study involving 193 orthopedic fellowship directors, only 8 (4.82%) viewed papers in which the applicant was the first author as important [6]. Finally, we found a moderate correlation of D.O. publications over the study period and match rate over time ( $r = 0.69$ ;  $P = .0139$ ). We were unable to find a correlation for total M.D. publications and match rate over the same study period ( $r = -0.456$ ;  $P = .1359$ ). However, any type of statistical analyses on the allopathic cohort would likely be skewed since most publications with a D.O. author also have an M.D. co-author. This would result in a form of "cross-over bias" as these articles would count as both osteopathic and allopathic publications.

Using data from the SF Match, we found an increase in the number of allopathic and osteopathic candidates applying to AR fellowships although the increase in osteopathic applicants did not reach statistical significance. A concomitant increase in the number

Table 3  
Publication trends.

	2010	2021
D.O. publications	14	91
AR-related D.O. publications	2	53
D.O. first authors	5	42
D.O. senior authors	3	10

AR, adult reconstruction.

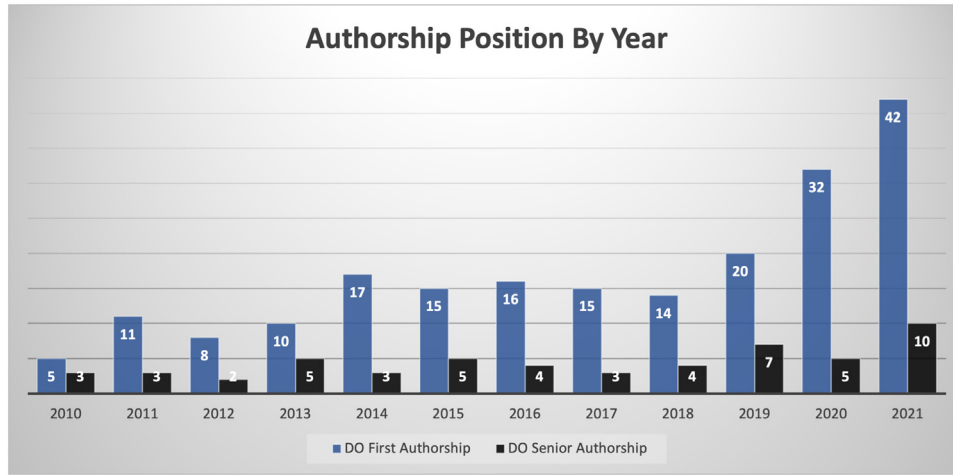


Figure 4. D.O. authorship position per year stratified by first or senior authorship position.

of AR fellowship positions offered during the same time period may have been a contributing factor as prospective candidates may be more likely to apply if they perceive their chances of matching are higher. For example, in 2022, there were 217 AR fellowship positions offered through the SF Match compared to only 160 positions in 2015 [5]. Even though the number of osteopathic applicants and positions offered both increased, we were surprised to find a significant increase in D.O. match rate. Perhaps the most interesting finding of our study was the correlation found between the increase in D.O. match rate and the increase in the number of D.O. publications. This suggests that authorship in orthopedic publications in high IF journals may help strengthen a D.O.’s application into a competitive AR fellowship. In fact, an even higher correlation was found between the increase in arthroplasty-related D.O. publications and D.O. match rate into AR, which suggests that subspecialty-specific publications may further increase the chances of successfully matching. In a study by Grabowski et al., publications/presentations as a resident and subspecialty-specific research were both among the top 5 most important criteria when selecting applicants for an interview. More specifically, Grabowski et al [6] found that AR was the only orthopedic subspecialty in which program directors found publications to be one of the 3 most important preinterview and postinterview criteria for ranking candidates. Furthermore, peer-reviewed publications were the

second most important selection criteria among AR fellowship directors [6]. While the correlation between publication and increased match rate does not denote causation, the findings of Grabowski’s et al indicate that fellowship program directors do find value in publications.

We believe the results of our study emphasize the importance of participation in research and authorship in publications during residency as these types of scholarly activities have been shown to increase the chances of an applicant matching into an AR fellowship. In addition, we believe our findings are not just applicable to AR fellowships but to any competitive fellowship/residency after medical school. With the recent transition of the United States Medical Licensing Examination and Comprehensive Osteopathic Medical Licensing Examination to a pass/fail grading system, the importance of other key objective selection criteria when selecting applicants including publications, poster presentations, and other scholarly activity becomes even more apparent [18,19]. To our knowledge, this is the first study to analyze the trend in orthopedic and subspecialty-specific publications with a D.O. author and the impact these publications have on osteopathic AR fellowship match rates.

This study is not without limitations. First, we only included orthopedic journals that consistently included arthroplasty-related publications with an IF of 2 or greater. We chose this methodology as residents are more likely to participate in research and publish in their desired subspecialty [20]. Including journals not related to AR would likely skew the true correlation to AR match rate. However, we analyzed 29,499 peer-reviewed articles across 10 high IF orthopedic surgical journals, which provides a large sample size. We also acknowledge that our methodology does not allow for differentiation between whether the osteopathic author is a resident or attending physician since the senior authorship position is usually determined based on the level of contribution to the study rather than the level of training. Because our study only focused on AR, future studies analyzing publication trends and correlation to match rates in other orthopedic subspecialties can help identify whether our findings are applicable to applicants seeking other orthopedic surgical fellowships. Second, our study was unable to analyze other types of scholarly activity other than published articles. Residents often participate in research through poster presentations, podium presentations, and book chapter publications. Unfortunately, none of these activities would be included in our analysis although some would argue that “research experience” is

Table 4  
Adult reconstruction fellowship match data.

Match year	Allopathic applicants			Osteopathic applicants		
	Applied	Matched	Match rate	Applied	Matched	Match rate
2010	163	101	62%	10	8	80%
2011	181	98	54%	15	8	53%
2012	204	95	46.6%	23	16	69.6%
2013	112	112	100%	31	17	54.8%
2014	219	127	58%	18	12	66.7%
2015	222	132	59.5%	23	16	69.6%
2016	226	140	61.9%	28	20	71.4%
2017	245	155	63%	25	14	56%
2018	225	158	70%	22	19	86.4%
2019	203	170	83.7%	25	19	76%
2020	237	193	81%	25	19	76%
2021	233	182	78%	26	19	73%

Provided by the American association of hip and knee surgeons (AAHKS).

**Table 5**  
Linear regression analysis.

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total D.O. publications/yr	82	87	93	99	104	110	116	122	127
Total D.O. AR publications/yr	50	55	59	63	67	72	76	80	84
D.O. first author	33	35	38	40	43	45	47	50	52
D.O. senior author	7	8	8	9	9	9	10	10	11
M.D. applied	249	256	262	269	276	282	289	296	302
M.D. matched	197	206	215	225	234	243	252	261	270
D.O. matched	22	22	23	24	25	26	27	28	29

D.O., doctor of osteopathy; M.D., medical doctor; AR, adult reconstruction.  
D.O. application rate was not statistically significant and therefore unable to assess via linear regression analysis.

not synonymous with authorship on a peer-reviewed publication [6,8,11]. Second, authors who were osteopathic medical students at the time of their publication were not included in our analysis as our methodology would be unable to identify them as “D.O.s”. As a result, our data may slightly underrepresent the increasing trend of publications with a D.O. author. However, our upward trend of D.O. authors and strong correlations with AR match rate data would only be further strengthened with the inclusion of more overall D.O. publications since these osteopathic medical students would all eventually graduate and become D.O.s.

**Conclusions**

Over the last 11 years, our study identified a significant upward trend of publications with a D.O. author in the orthopedic surgical literature, as well as in arthroplasty-related publications. With a growing number of D.O.s entering orthopedic residencies and AR fellowships, we expect to see this upward trend continue into the foreseeable future. We believe that participation in research and authorship in orthopedic and arthroplasty-related peer-reviewed publications will remain a key selection criterion among AR fellowship directors. The significant increase in SF Match rate for osteopathic physicians entering into AR fellowships over the last 11 years supports our findings. However, we fully acknowledge that our data simply establish a correlation, not causation. Nonetheless, we believe this information may not only be used to guide prospective AR fellowship applicants but also any applicant applying to a competitive medical or surgical fellowship/residency.

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**Conflicts of interest**

The senior author, Dr. Eddie Wu, is on the Editorial Board of *The Journal of Arthroplasty*. The authors declare no other disclosures to report.

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