



# Current Trends of Research Productivity among Students Matching at Top Ophthalmology Programs

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## Abstract

**Importance** San Francisco Match publishes no data on the research output of matched applicants to an ophthalmology residency.

**Objective** The aim of this study was to examine the temporal trends in publication volume by medical students who successfully matched into a top ophthalmology residency.

**Methods** This retrospective case series compared all residents in the top 30 ophthalmology residency programs from the class of 2022 and 2017. Publication volume from before September 15th of the residents' fourth year of medical school was recorded using PubMed and Google Scholar. We recorded total number of publications (any authorship), first/second author publications, and ophthalmology-specific publications. Using Welch's *t*-test, publication volumes were statistically compared against all others.

**Results** One-hundred sixty-one residents from the class of 2022 and 145 residents from the class of 2017 were included. Total publications per matched applicant (mean  $\pm$  standard deviation) were  $3.04 \pm 0.35$  for the class of 2022 and  $1.67 \pm 0.23$  for the class of 2017. Mean publications in ophthalmology journals were  $1.07 \pm 0.20$  (2022) and  $0.58 \pm 0.13$  (2017); mean first author publications were  $1.00 \pm 0.13$  (2022) and  $0.64 \pm 0.11$  (2017) and mean second author publications were  $0.70 \pm 0.10$  (2022) and  $0.37 \pm 0.06$  (2017). Research productivity in all four metrics (total, ophthalmology journals, first author, and second author publications) was significantly higher for the class of 2022 than the class of 2017 ( $p = 0.001$ ;  $p = 0.03$ ;  $p = 0.03$ ;  $p = 0.02$ , respectively) supporting the trend of increasing research output among students. Applicants with PhD degrees had statistically more total and first author publications in 2017 ( $p = 0.01$ ;  $p = 0.045$ ), but only more first author publications in 2022 ( $p = 0.01$ ). International applicants produced significantly more total publications in 2022 ( $p < 0.001$ ).

**Conclusions** Overall, after a 5-year period, the authors found matched applicants had significantly increased publications compared with those at the beginning of the period. We also identified several applicant factors that may have variable effects on research publication. This analysis emphasizes the growing importance of research in the match process and can help future applicants navigate the ophthalmology match.

## Keywords

- ▶ ophthalmology residency
- ▶ San Francisco Match
- ▶ publications
- ▶ research productivity
- ▶ medical school

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High average board scores and more applicants than available positions make ophthalmology one of the most competitive specialties.<sup>1</sup> According to the 2019 San Francisco (SF) Match “Ophthalmology Residency Match Summary Report,” 790 resident applicants applied to only 484 spots, with an overall match rate of 75%<sup>1</sup>; in comparison, urology had a match rate of 85%,<sup>2</sup> orthopaedic surgery had a match rate of 77%,<sup>3</sup> and plastic surgery had a match rate of 81%.<sup>4</sup> Previous studies have evaluated the importance of objective aspects of the ophthalmology residency application such as the United States Medical Licensing Examination (USMLE) step 1 scores, Alpha Omega Alpha (AOA) Medical Honor Society status, as well as clinical grades.<sup>5</sup> Indeed, both higher USMLE step 1 scores and AOA status were independent predictors associated with successfully matching.<sup>5–7</sup> Apart from academic performance and board scores, research also plays an important factor in evaluating potential applicants, reflecting passion and knowledge toward the field as well as future professional interests and goals. In a survey of residency program directors, chairpersons, and members of the residency selection committee, research was strongly recommended to improve the strength of ophthalmology applications.<sup>8</sup>

As research becomes increasingly used as a distinguishing feature for potential applicants, it is important to establish baseline research output data in ophthalmology for students, mentors, and program directors. This is also particularly relevant because the effects of the coronavirus disease 2019 (COVID-19) pandemic may also hinder research activity and productivity. Each year, SF Match releases an ophthalmology residency match summary report detailing different metrics of matched and unmatched applicants. However, this dataset fails to include the publication rate among prospective applicants. Currently, studies have only evaluated the impact of paper publications on rank of residency program matched. One of the shortcomings to this approach is that it does not fully capture all research done by medical students and may not accurately reflect student applications.

The SF residency application includes all abstracts, presentations, and manuscripts as research, which this study aims to accurately capture and quantify.<sup>3</sup> Using this definition of research, studies on other competitive specialties have begun quantifying and analyzing respective applicant profiles.<sup>4,9–14</sup> Wadhwa et al sought to quantify peer-reviewed publications in matched applicants to neurosurgery, while Campbell et al looked at matched applicants to orthopaedic surgery.<sup>9,11</sup> So far, no studies have fully captured research profiles of matched applicants to ophthalmology. Thus, establishing baseline data for ophthalmology applicant research output is valuable.

The purpose of this original study was twofold. First, the authors aimed to provide a comprehensive analysis on the true number of publications (abstracts, presentations, and manuscripts) by medical students who successfully matched into ophthalmology. Specifically, the authors documented publication number, impact of medical school and residency program reputation, MD versus MD/PhD status, gender, and geographical distribution on research output. Second, the

authors also compared publication rates between the residency class of 2022 and the class of 2017, focusing on temporal trends and shifts on applicant research output.

## Methods

### Study Population

The Doximity Residency Navigator, sorted by reputation, as well as US News and World Report “Best Hospitals for Ophthalmology” was used to identify top ophthalmology residency programs in the United States.<sup>15,16</sup> The top 30 ophthalmology residency programs were included in the analysis as this number marked the upper quartile or top 25%. Prior studies in other specialties also analyzed top programs.<sup>2,17</sup> All residents from the class of 2022 and the class of 2017 were either identified from the program Web sites or using the Internet Archive Wayback Machine (archive.org). If this information was not published or verified, it was omitted from the study. Overall, 1 program (3.3%) was omitted from the class of 2022 and 4 programs (13%) were omitted from the class of 2017. In total, we captured data on 161 matched applicants from the class of 2022 and 145 matched applicants from the class of 2017. Basic demographic information was collected for all matched applicants including gender, medical school, medical school rank, and PhD status.

### Data Collection

A literature search was then performed for each matched applicant to determine the total publication volume for the intern class of 2017 and the class of 2022. To determine the research output of each applicant prior to residency application submission, all research works prior to September 15th of the residents' fourth year of medical school was considered. Using both PubMed and Google Scholar, the applicant's first and last name were searched as “author.” If the article was an obvious match to the applicant, the applicant was credited with authorship. All indexed abstracts, presentations, and publications were included in our analysis. Potential article matches were evaluated under the following criteria: (1) if the article had a coauthor common to a publication, the article was considered a match, and (2) if the article had a corresponding or senior author at an institution that the intern was known to have been affiliated with, the article was considered a match. We recorded total number of publications (any authorship), first/second author publications, and ophthalmology-specific publications for each applicant.

### Statistical Analysis

Following data collection, overall publication volumes and applicant factors affecting research productivity such as MD/PhD status, attending a top 20 medical school, and geographic location were statistically compared against all others. The class of 2022 and the class of 2017 populations were compared with each other using a chi-squared test of independence with significance set at  $p < 0.05$  to assess for any differences. A student's heteroscedastic, two-tailed  $t$ -test

with a significance set at  $p < 0.05$  was used to compare the class of 2022 and class of 2017 for these analyzed categories. Geographic location of the medical school and the residency was also analyzed and statistically compared against all others. A one-way analysis of variance test was used for geographic analysis with a significance set at  $p < 0.05$ .

## Results

### Overall Research Productivity

Total publications (mean  $\pm$  standard deviation) for matched applicants were  $3.04 \pm 0.35$  for the class of 2022 and  $1.67 \pm 0.23$  for the class of 2017; mean publications in ophthalmology journals were  $1.07 \pm 0.20$  (2022) and  $0.58 \pm 0.13$  (2017); mean first author publications were  $1.00 \pm 0.13$  (2022) and  $0.64 \pm 0.11$  (2017); and mean second author publications were  $0.70 \pm 0.10$  (2022) and  $0.37 \pm 0.06$  (2017). Total publications, ophthalmology journal publications, first author publications, and second author publications were significantly higher for the class of

2022 than the class of 2017 ( $p = 0.001$ ;  $p = 0.03$ ;  $p = 0.03$ ;  $p = 0.02$ ). There were observed differences of 58.1, 58.8, 43.7, and 60.5%, respectively, supporting the trend of increased research among students.

### Ophthalmology Applicant Factors Affecting Research Productivity

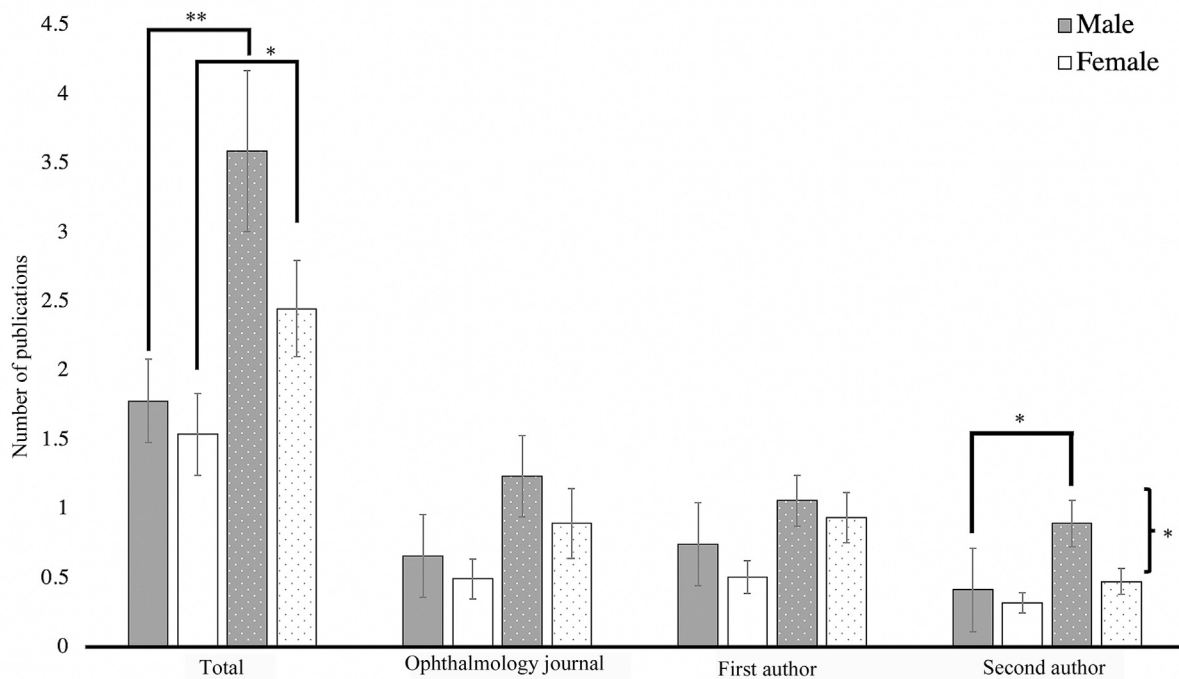
#### Gender

Out of the 161 total applicants identified from the class of 2022, 85 were male (52.8%) and 76 were female (47.2%). From the class of 2017, a total of 145 applicants were identified with 82 males (56.5%) and 63 females (43.5%). There was no significant difference in overall gender composition between the class of 2022 and the class of 2017 ( $p = 0.51$ ) (Table 1). However, there was an increase in the number of female residents from the class of 2017 to the class of 2022.

In the class of 2017, mean total publications of females were  $1.54 \pm 0.30$  and  $1.78 \pm 0.32$  for males; mean

**Table 1** Overall demographics of residents from the class of 2022 and the class of 2017

Demographics	n (%)		Statistical analysis	
	Class of 2022	Class of 2017	$\chi^2$	p-Value
Overall	161	145		
Sex			0.49	0.501
Male	85 (52.8)	82 (56.6)		
Female	76 (47.2)	63 (43.4)		
Medical school			2.30	0.102
Top 20	50 (31.1)	58 (40)		
Non-top 20	111 (68.9)	87 (60)		
MD/PhD status			0.19	0.799
MD/PhD	11 (6.8)	11 (7.6)		
Non-MD/PhD	150 (93.2)	134 (92.4)		
Location of medical school			9.43	0.185
Mid-Atlantic	32 (19.9)	24 (16.5)		
Midwest	25 (15.5)	26 (17.9)		
Northeast	38 (23.6)	45 (31.0)		
South	16 (11.2)	24 (16.5)		
Southwest	26 (16.2)	11 (7.6)		
West	14 (8.7)	11 (7.6)		
International	7 (4.3)	4 (2.8)		
Caribbean	1 (0.6)	0 (0)		
Location of residency			1.36	0.929
Mid-Atlantic	26 (16.2)	22 (15.2)		
Midwest	23 (14.3)	23 (15.9)		
Northeast	28 (17.4)	29 (20.0)		
South	24 (14.9)	23 (15.9)		
Southwest	20 (12.4)	13 (9.0)		
West	40 (24.8)	35 (24.1)		



**Fig. 1** Mean number of publications based on sex for the class of 2017 and the class of 2022. Error bars represent standard error of mean. Student's *t*-test, \* indicates significance level of  $p < 0.05$ . \*\* indicates significance level of  $p < 0.01$ .

publications in ophthalmology journals were  $0.49 \pm 0.14$  (female) and  $0.66 \pm 0.20$  (male); mean first author publications were  $0.51 \pm 0.12$  (female) and  $0.74 \pm 0.17$  (male); mean second author publications were  $0.32 \pm 0.07$  (female) and  $0.41 \pm 0.08$  (male). No significant differences were observed in any of the four publication volume metrics between males and females ( $p > 0.05$ ) (► **Fig. 1**).

On the other hand, in the class of 2022, mean total publications of females were  $2.45 \pm 0.35$  and  $3.59 \pm 0.58$  for males; mean publications in ophthalmology journals were  $0.89 \pm 0.25$  (female) and  $1.24 \pm 0.29$  (male); mean first author publications were  $0.93 \pm 0.18$  (female) and  $1.06 \pm 0.18$  (male); mean second author publications were  $0.47 \pm 0.09$  (female) and  $0.89 \pm 0.17$  (male). Males had significantly higher second author publications ( $p = 0.029$ ) than females, but there were no significant differences in the other three research output metrics. Importantly, when comparing males and females from the class of 2017 to the class of 2022, both males and females from the class of 2022 had significantly more total publications (2017 vs. 2022 male:  $1.78 \pm 0.32$  vs.  $3.59 \pm 0.58$ ,  $p = 0.008$ ; 2017 vs. 2022 female:  $1.54 \pm 0.30$  vs.  $2.45 \pm 0.35$ ,  $p = 0.049$ ) (► **Fig. 1**).

### Top 20 Medical School

Furthermore, the medical schools of all matched applicants from class of 2017 and class of 2022 were identified. Of the 145 matched applicants in the class of 2017, 58 (40.0%) attended a top 20 medical school in the US News and World Report "Best Research" ranking.<sup>18</sup> Of the 161 matched applicants in the class of 2022, 50 (31.06%) attended a top 20 medical school. Although there were fewer interns who

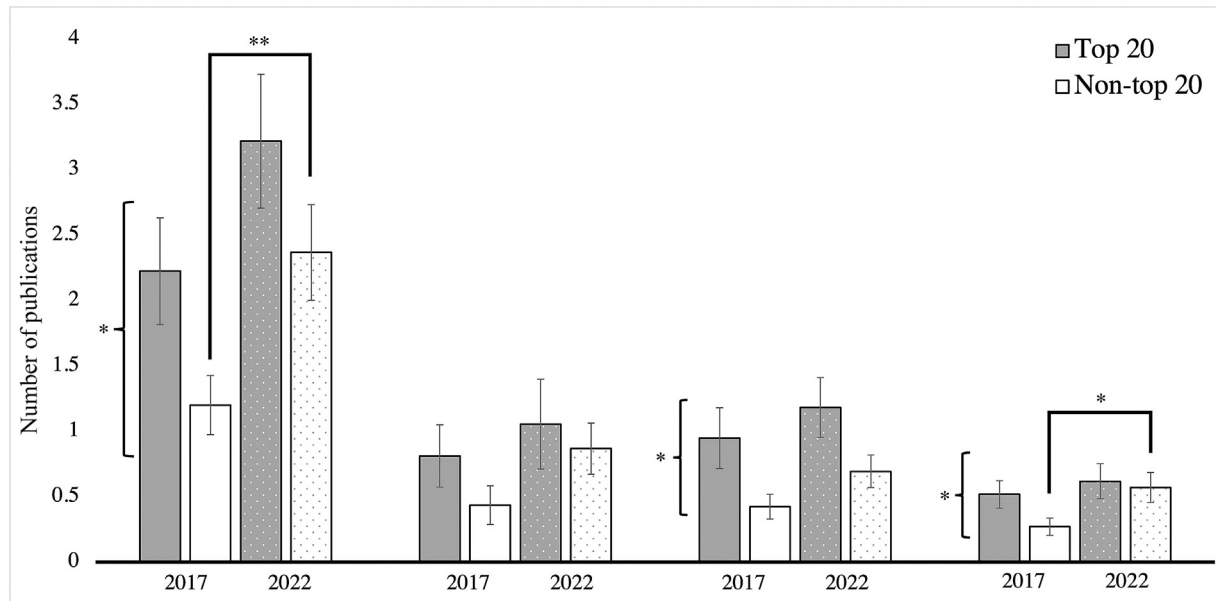
attended a top 20 medical school in the class of 2022, there was no significant difference in overall composition ( $p = 0.10$ ) (► **Table 1**).

There was no significant difference in any of the 4 metrics measured for residents that attended a top 20 medical school between class of 2022 and class of 2017 applicants. However, when looking at students that did not attend a top 20 medical school, the mean number of total publications and second author publications was higher for interns in the class of 2022 compared with the class of 2017 (total number of publications  $p = 0.007$ ; total second author publications  $p = 0.02$ ) (► **Fig. 2**).

Applicants that attended a top 20 medical school did not have significantly more research output than those that attended a non-top 20 medical school in the class of 2022. However, in the class of 2017, applicants that attended a top 20 medical school had significantly more overall publications ( $2.2 \pm 0.41$  vs.  $1.2 \pm 0.23$ ,  $p = 0.03$ ), first author publications ( $0.95 \pm 0.23$  vs.  $0.43 \pm 0.09$ ,  $p = 0.04$ ), and second author publications ( $0.52 \pm 0.11$  vs.  $0.27 \pm 0.07$ ,  $p = 0.049$ ) than those that attended a non-top 20 medical school, supporting the trend that those that attended a top 20 medical school had more research output than those that attended a non-top 20 (► **Fig. 2**).

### MD PhD

Similarly, matched applicants who obtained PhD degrees prior to residency were also identified. In the class of 2017, there were 11 (7.59%) applicants with PhD degrees whereas in the class of 2022, there were 11 (6.83%) applicants with PhD degrees (► **Table 1**). Compared with applicants without PhD degrees, applicants with PhD degrees had significantly



**Fig. 2** Mean number of publications based on top 20 medical school status for the class of 2017 and the class of 2022. Error bars represent standard error of mean. Student’s *t*-test, \* indicates significance level of  $p < 0.05$ . \*\* indicates significance level of  $p < 0.01$ .

more first author publications in both years (2022 PhD vs. non-PhD:  $2.91 \pm 0.68$  vs.  $0.86 \pm 0.12$ ,  $p = 0.01$ ; 2017:  $2.45 \pm 0.86$  vs.  $0.49 \pm 0.09$ ,  $p = 0.045$ ), but only PhD applicants from the class of 2017 had significantly more overall publications ( $5.36 \pm 1.32$  vs.  $1.37 \pm 0.20$ ,  $p = 0.01$ ) (→ Fig. 3).

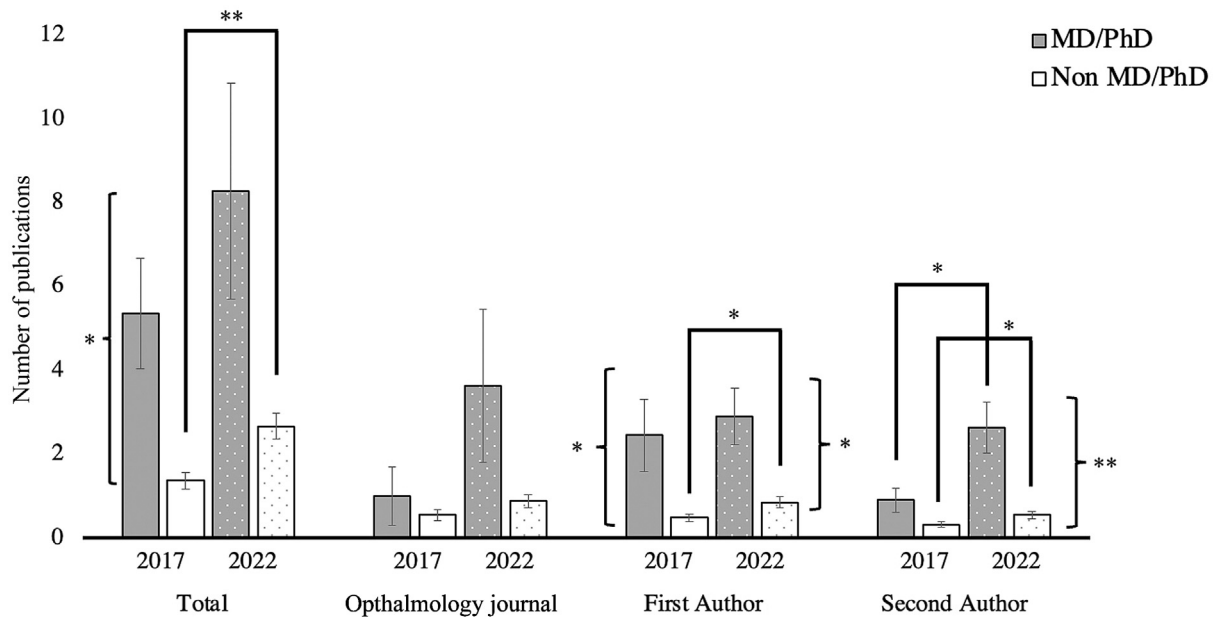
When comparing PhD applicants from the class of 2022 to 2017, there were no significant differences in total number of publications, ophthalmology journal publications, or first author publications, but PhD applicants from the class of 2022 had significantly more second author publications ( $2.64 \pm 0.61$  vs.  $0.91 \pm 0.28$ ,  $p = 0.02$ ). When PhD applicants were taken out of the two groups, applicants from the class of

2022 had significantly more total publications ( $2.67 \pm 0.31$  vs.  $1.37 \pm 0.20$ ,  $p < 0.001$ ), first author publications ( $0.86 \pm 0.12$  vs.  $0.49 \pm 0.09$ ,  $p = 0.01$ ), and second author publications ( $0.55 \pm 0.09$  vs.  $0.33 \pm 0.06$ ,  $p = 0.03$ ) than applicants from the class of 2017 (→ Fig. 3).

**Geography**

Moreover, matched applicants were also analyzed by the geographical location of the medical school as well as the residency.

In the class of 2022, 161 total applicants attended medical school in the following regions: Mid-Atlantic (32), Midwest (25), Northeast (38), South (18), Southwest (26), West (14),



**Fig. 3** Mean number of publications based on MD/PhD status for the class of 2017 and the class of 2022. Error bars represent standard error of mean. Student’s *t*-test, \* indicates significance level of  $p < 0.05$ . \*\* indicates significance level of  $p < 0.01$ .

International (7), and Caribbean (1) (►Table 1). The mean number of total publications per applicant was significantly higher among interns who attended medical school internationally ( $11.7 \pm 3.6$ ,  $p < 0.001$ ) than any other region (Mid-Atlantic  $3.77 \pm 0.87$ , Midwest  $1.6 \pm 0.32$ , Northeast  $3.13 \pm 0.67$ , South  $2.89 \pm 0.97$ , Southwest  $1.38 \pm 0.31$ , West  $3.29 \pm 1.05$ ). In the class of 2017, 145 total matched applicants came from the following regions: Mid-Atlantic (24), Midwest (26), Northeast (45), South (24), Southwest (11), West (11), and International (4) (►Table 1). When the same geographical analysis was performed on the class of 2017, there was no trend or significance observed between any of the regions.

The same analysis was applied for the geographical location of residencies. For the class of 2022, 161 total interns were residents in the following regions: Mid-Atlantic (26), Midwest (23), Northeast (28), South (24), Southwest (20), and West (40) (►Table 1). For the class of 2017, 145 total interns were residents in the following regions: Mid-Atlantic (22), Midwest (23), Northeast (29), South (23), Southwest (13), and West (35) (►Table 1). However, there were no geographical trends observed in either the class of 2022 or the class of 2017 with regard to total publication rates (►Fig. 4).

### Discussion

This report attempts to accurately capture matched ophthalmological applicant research productivity as reported on

their applications and analyze temporal trends of research productivity in ophthalmology residencies. We believe this topic is of value because ophthalmology residencies are becoming more competitive, reflected by increasing USMLE step 1 scores among matched applicants shown by SF Match data.<sup>1</sup> Currently, the USMLE step 1 is being phased out with recent changes of scoring to pass/fail. By removing step 1 scores, other factors, such as research, may become more important in assessing potential applicants. Unlike other residencies that are reported by Charting Outcomes of the Match, the SF Match has no data on research productivity of ophthalmology applicants. This study provides a realistic baseline on research productivity in the ophthalmology match and is likely of interest to prospective applicants as well as residency program directors. This is also especially relevant in the context of the COVID-19 pandemic. Mandatory quarantine and remote education may have profound effects on research output and productivity. Establishing a baseline number of publications by matched applicants pre-COVID-19 allows for future comparison on how research productivity has changed.

Most importantly, the mean total publication number was significantly greater for the class of 2022 compared with the class of 2017 ( $3.04 \pm 0.35$  vs.  $1.67 \pm 0.23$ ). A previous study on the number of indexed publications among matched ophthalmology applicants found a mean of  $1.23 \pm 0.81$  publications per applicant.<sup>5</sup> While this study was conducted for



**Fig. 4** Effect of geographical location on total publication volume. (A) Division of geographical location into 8 distinct regions (red = West; orange = Southwest; yellow = Midwest; green = South; blue = Mid-Atlantic; purple = Northeast; black = International; white = Caribbean). (B) Mean number of total publications based on medical school geographical location for the class of 2017 and the class of 2022. (C) Mean number of total publications based on residency program geographical location for the class of 2017 and the class of 2022. Error bars represent the standard error of mean. \*\* indicates significance of  $p < 0.01$ .

the class of 2019, it did not count abstracts or presentations as research publications, which would explain the lower number of publications compared with this study. We believe that our study more accurately captures the residency application because the SF application reports abstracts, presentations, and indexed publications as research output. Mean second author publications were also significantly greater for the class of 2022 than the class of 2017. While other measures of research productivity did not show significance, all metrics, regardless of significance, showed higher means for the class of 2022 than the class of 2017. This not only supports a temporal trend toward increased research publications but also highlights the growing competitiveness of ophthalmology, reflecting an increasing emphasis on research to be successful in the match.

Moreover, ophthalmology has historically been a male-dominated field. Indeed, in a 2014 American Society of Cataract and Refractive Surgery (ASCRS) Clinical Survey, ophthalmologists with 30 or more years of experience in the field were 92% male and 8% female.<sup>19</sup> Although not significantly different, the class of 2022 saw further increases in females going into ophthalmology from 43.5% for the class of 2017 to 47.2% for the class of 2022. This aligns with Xierali et al who assessed demographics of ophthalmologists from 2005 to 2015.<sup>20</sup> The study found an increase in the proportion of female ophthalmology residents, increasing from 35.6% to 44.7% from 2005 to 2015. Our study found a similar slow increase in female representation in ophthalmology, emphasizing the demographic shift across ophthalmology. Despite being underrepresented, for the class of 2022, females were equally competitive to their male counterparts with regard to publication volume.

Interestingly, in the class of 2017, applicants from a top 20 medical school had higher publication volume than applicants from a non-top 20 school. Generally, top 20 medical schools have more National Institutes of Health funding than non-top 20 medical schools so there are more opportunities available to conduct research.<sup>18</sup> Additionally, many of these top 20 institutions have capstone or research requirements built into their curriculum, which further increases opportunity to publish.<sup>9</sup> Nevertheless, this difference was not found in the class of 2022. As ophthalmology has become increasingly competitive, students from non-top 20 medical schools may have tried seeking research opportunities to distinguish themselves. This is reflected by higher mean research productivity in total research publications in applicants that did not attend a top 20 medical school for 2022 versus 2017. Other institutions may have also identified and sought out qualified students from smaller schools and provided research opportunities for these students to increase diversity in ophthalmology. Indeed, this may explain the decreased number of applicants that attended a top 20 school from 40% (2017) to 31.06% (2022).

As expected, applicants with a PhD prior to applying to residency had higher mean first author publications than non-PhD applicants, reflecting the primary research that PhD candidates perform. Interestingly, only PhD applicants from the class of 2017 had higher mean total publications

than non-PhD applicants. This may be due to a focus on basic sciences during the PhD portion of the MD-PhD education, where it is difficult to publish large quantities. Additionally, this could be attributed to the shift of increased research in general among applicants that would even out any research output difference between PhD applicants and non-PhD applicants. Geographically, applicants from international medical schools had higher total publications than from US medical schools, highlighting the difficulty for international medical students to match into ophthalmology.

This study has several limitations. First, we only analyzed the top 30 or top 25% of ophthalmology residency programs and not all ophthalmology programs. Prior studies analyzing matched applicants in urology and otolaryngology also analyzed applicants at top programs.<sup>2,17</sup> Our goal was to provide students, mentors, and program directors information about research productivity at these institutions. Second, due to the nature of a retrospective literature search, ophthalmology interns from the class of 2022 and the class of 2017 were based on different program Web sites listing matched applicants. As such, if this information was not published online or found anywhere else, it was excluded from the study. Even so, we were still able to capture 96.7% of the class of 2022 and 87% of the class of 2017. In addition, the SF Match, the governing body of the ophthalmology match does not release research output data on unmatched versus matched applicants so we could not include this analysis in our study. Furthermore, this study only used raw publication numbers to assess interns, which does not consider the impact of research or the individual value of abstracts, presentations, or publications on the application. There are multiple metrics that can be used to assess research impact including impact of respective journals, h-index of the applicant, and number of citations. Previous studies have evaluated the impact of these factors and so we opted instead to use raw publication numbers as it allows us to make direct comparisons temporally. Further studies are needed to assess the individual value of different subcategories of research on a successful match. Finally, no single ranking system is entirely objective. There is slight variability in the top 30 ophthalmology residencies based on which ranking system used. However, we believe by using two separate ranking programs, we enhance the accuracy and objectivity of encompassing the best residencies.

In conclusion, as the ophthalmology matching process continues to become more competitive, greater emphasis is placed on metrics like research. Overall, the authors found a temporal trend toward increased research publications at top 30 residencies in ophthalmology. In particular, increases in research from the class of 2017 to the class of 2022 seem to be related to medical school rank (non-top 20 medical school) as well as MD/PhD status (non-PhD). These two groups showed the largest increases in research output, reflecting an overall shift in attitude toward increasing research productivity. This study is useful for both medical students preparing for the ophthalmology application and for program directors as a baseline of research in future applicants. It is important to note that research alone does

not directly correlate with a successful match. Nevertheless, this analysis emphasizes the growing importance of research in matching into ophthalmology and can help future applicants navigate and prepare for their future application.

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#### Conflict of Interest

ASK is a consultant for Glaukos and on the speaker bureau for Allergan, Aerie, and Bausch & Lomb. None of the other authors report any disclosures.

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