

Globalization of *Plastic and Reconstructive Surgery*: A Continent, Country, and State-Level Analysis of Publications

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Background: Over the past decade, there has been a worldwide increase in plastic and reconstructive surgery research as well as increased interest in global collaboration. However, little is known about who is contributing to this global expansion or the trends of individual countries. The aim of our study was to analyze the output of *Plastic and Reconstructive Surgery (PRS)* over a decade to elucidate trends in the plastic surgery field.

Methods: The country of origin for all first authors of articles published by *PRS* from 2010 to 2019 were determined and date extracted using PubMed2XL. The change in frequency of publications over the decade by country, continental contributions, as well as state-level analysis within the United States were analyzed.

Results: From 2010 to 2019, there were a total number of 8680 publications with an increase in total articles from 747 to 1049 per year. 54 countries contributed over the decade, with the United States producing the most followed by Italy, China, Canada, and the UK. The top producing states were Texas, New York, California, Massachusetts, and Pennsylvania.

Conclusions: The last decade (2010–2019) saw a large international increase in research, not only with the total number of publications, but also in the diversity of originating country. Our work shows a shift away from a US-focused journal to incorporate more work from our international colleagues, as research is conducted in centers across the globe. (*Plast Reconstr Surg Glob Open* 2020;8:e3202; doi: 10.1097/GOX.0000000000003202; Published online 20 November 2020.)

INTRODUCTION

Plastic surgery is a rapidly growing field with demand for procedures increasing across the globe. The International Society of Aesthetic Plastic Surgery reported 6.7 million surgical procedures and 7.3 million non-surgical procedures in 2010,¹ which significantly increased to 10.6 million surgical procedures and 12.5 million nonsurgical procedures in 2018.² Historically, the United States of America (USA) and Brazil have dominated the field of plastic surgery. However, when analyzed by population, other countries have also established a large presence, with Venezuela having the largest number of procedures

per capita in 2013, followed by Brazil, Columbia, and then the USA.³ This data support the idea that there is tremendous globalization and proliferation of the plastic surgical field, with more procedures taking place in countries across the globe in recent years.

While there is significant data to show an increase in plastic surgery demand, very little is known about recent corresponding changes in the field's research production.⁴ Previous studies have allowed us to better understand patterns in publications within individual countries^{5–7} such as which city has the most prolific publisher in China (Taipei),⁸ or how Ireland has consistently increased their contribution to the field of plastic surgery over the past 2 decades.⁹ Other studies have utilized bibliometric analysis to examine trends in country-level production of surgical research, with some analyses focusing on plastic surgery.^{4–7,9–11} Bibliometric analyses may hold a significant role in revealing who the contributors are to the field of plastic surgery and how these change over time.

In the *Aesthetic Surgery Journal (ASJ)*, Moore et al used bibliometric analysis to show that the USA, Canada, China, and Brazil were the largest producers of research in terms

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of total publications within the journal.¹⁰ They demonstrated an increasing number of countries publishing, as well as an increase in total publications from all countries. However, *ASJ* is a newer and specialized journal and these findings may be difficult to translate to the field of plastic surgery as a whole.

In contrast, *Plastic and Reconstructive Surgery (PRS)* is one of the most prominent plastic surgery journals with a high impact factor in the field.^{11–13} *PRS* consistently publishes research from around the globe and the volume of articles published allows for trends elucidated from the journal to better reflect the field as a whole.¹²

In this study, we analyzed all documents published in *PRS* from 2010 through 2019. The aim of this work was to demonstrate how the publication outputs of individual countries, continents, states, and the journal itself have changed over the course of a decade. Based on the increase in the number of countries performing plastic surgery over this period, we hypothesized that there would be a growth in contributions from countries other than the USA as well as an expansion of the journal's total publications as the field is continually growing and expanding globally.

METHODS

All publications in *PRS* from 1/1/2010 through 12/31/2019 were extracted from PubMed in XML format using PubMed2XL¹⁴ with the exception of financial statements, nondisclosures, corrections, and duplicates. A country was assigned to each publication based on the primary author's correspondence address. In cases where the primary author's country of origin was not immediately available, either the original paper was retrieved or a PubMed search for the author was conducted and the most recent affiliation listed was used for country assignment. In rare cases where the location was not found using the previous techniques, decisions on country of affiliation was based upon where the author had the most previous publications. In instances of co-first author publications, the first listed author and the affiliated address were still used.

US state data were produced by identifying the primary author's correspondence address. Reprints from previous *PRS* articles outside the study date range were deleted from the data set as they did not contain the original address.

The data were also stratified by country income. Using World Bank country income level, they were divided into High Income (HI), Upper-Middle Income (UMI), Lower-Middle Income (LMI), and Low Income (LI).¹⁵ Analysis was performed comparing ratios of HI:UMI:LMI:LI as output from *PRS* and other journals. All data were entered into Excel, which was also utilized to make the graphs and tables. Visualizations were made using Tableau (Tableau Software, Seattle, Wash.).

RESULTS

Worldwide

A total number of 8680 publications were identified in *PRS* from 2010 to 2019 (Table 1). From 2010 to 2019, there was an increase in the number of total annual articles

from 747 to 1049, respectively. *PRS* published a low of 739 articles for the year in 2015, possibly due to the decline in Eurasian articles that year.

In total, there were 54 unique contributing countries over the decade. The number of countries publishing articles in a given year in *PRS* increased from 32 to 41 from 2010 to 2019 (Fig. 1). A maximum of 44 countries published in *PRS* in 2013, corresponding with an increase in the number of European countries publishing that year.

The United States consistently produced the majority of *PRS*'s publications (Figs. 2–3, Table 2). Over the decade the USA increased its publications from 56.7% of all articles in 2010 to 60.7% in 2019. Italy (4.5%), China (4.3%), and Canada (3.7%) were next most productive countries over the course of the decade (Fig. 4).

North America

Five individual countries published articles over the decade. Canada increased the number of publications from 25 up to 47 at the decade's end and was the world's 4th largest contributor the decade. Mexico made *PRS* contributions in 8 of 10 years, with an average of 2.3 articles per year. The USA produced an average of 521 publications per year.

The United States of America

We performed a sub-analysis of states within the USA from 5198 US articles identified in the original data set. In total, there were 5 reprint publications from outside the original date range of publication, which were removed. Analysis of states within the US found that the top producing states were Texas (779), New York (606), California (590), Massachusetts (418), and Pennsylvania (392) (Figs. 5 and 6, Table 3). Corresponding with the total decreased output of *PRS* from 2014 to 2016, there was a dip in all states contributing to *PRS* during that time period. Production from the states increased 1.5-fold over the course of the decade. Texas had an almost constant production during this time period, where some states such as New York had a 2.125-fold increase in total output.

Europe

European articles initially represented 21% of all *PRS* articles in 2010 but dropped to 13% by 2019. However, the number of individual articles published remained relatively constant with an average of 151.9 ± 21.6 European publications per year. The majority of European publications were from Italy (26.0%) and the United Kingdom (17.6%). No *PRS* publications were found from Russia.

Asia

Asia's representation in *PRS* increased from 13% (98 articles) to 17% (180 articles) over the last decade. China was the largest Asian producer, responsible for 30.8% of the 1235 Asian articles from the decade. They were followed by South Korea (19.5%) and Japan (18.3%). Singapore, China, and South Korea all notably increased their annual article count during the time of interest, while India decreased their count. 2019 was the first year that Asia produced more articles than Europe.

Table 1. Production of All Countries and Continents from 2010 to 2019

Continent/Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Grand Total	Average	SD	Country Income
Africa	6	2	1	5	2	1	2	4	2	4	29	2.9	1.73	
Egypt	1	1		3						1	6			LMI
Ghana				1							1			LMI
Morocco		1									1			LMI
Nigeria							1				1			LMI
South Africa	5		1	1	2	1	1	4	2	3	20			UMI
Asia	99	113	122	125	106	94	124	123	152	180	1238	123.8	25.59	
Afghanistan						1					1			LI
China	17	30	39	41	26	29	41	41	54	64	382			UMI
India	7	10	6	6	1		4	1	1	2	38			LMI
Indonesia				1							1			LMI
Iran	4	2	2	2	5	1	1			2	19			UMI
Israel	5	1	4	5	1	3	2	2	6	5	34			HI
Japan	22	25	29	27	18	12	15	28	25	27	228			HI
Lebanon				1			1	3	4	1	10			UMI
Pakistan										2	2			LMI
Qatar		1									1			LMI
Saudi Arabia							1				1			HI
Singapore	1	3	1		2	2	2	2	2	6	21			HI
South Korea	11	16	20	18	28	31	31	25	25	40	245			HI
Taiwan	20	16	12	13	18	8	14	15	19	18	153			HI
Thailand				1	2				5	4	12			UMI
Turkey	12	8	9	10	5	7	12	6	11	9	89			UMI
United Arab Emirates		1									1			HI
Europe	155	159	177	158	117	113	170	168	157	140	1514	151.4	21.63	
Austria	5	9	10	9	6	1	6	3	6	5	60			HI
Belgium	5	6	2	4	5	1	3	2	5	8	41			HI
Bulgaria		1									1			UMI
Croatia	1	1	1								3			HI
Czech Republic			3	1	1			1			6			HI
Denmark			1	1			1	2		2	7			HI
Finland		2	3	2	2	1	1		1	1	13			HI
France	11	10	12	8	7	17	35	35	22	17	174			HI
Germany	27	24	17	15	9	6	16	7	12	14	147			HI
Greece	3	3	2	3	1	2	5		6	3	28			HI
Hungary		1									1			HI
Ireland		2	2	1		2	1	1	1	1	11			HI
Italy	34	54	61	47	29	27	35	48	38	21	394			HI
Monaco				1							1			HI
Netherlands	8	9	11	15	14	13	24	22	24	26	166			HI
Norway	3	2	1		1		2	1	2	1	13			HI
Poland				2				1	1	1	5			HI
Portugal	2			3	1	1	1			1	9			HI
Romania				1	2				1	1	5			UMI
Serbia				1				1		1	3			UMI
Spain	7	3	4	7	6	9	3	14	7	3	63			HI
Sweden	5	4	5	3	3	2	2	6	3	5	38			HI
Switzerland	2	3	6	2	3	7	15	7	7	6	58			HI
UK	42	25	36	32	27	24	20	17	21	23	267			HI
North America	448	524	526	533	678	500	581	507	565	686	5548	554.8	76.11	
Canada	25	29	24	32	38	30	27	35	36	47	323			HI
Commonwealth of Dominica								3			3			UMI
Mexico		2	1	3		5	4	1	4	3	23			UMI
Puerto Rico		1		1		1					3			HI
USA	423	492	501	497	640	464	550	468	525	636	5196			HI
Oceania	18	17	18	22	16	13	9	16	18	20	167	16.7	3.62	
Australia	16	16	17	21	16	13	9	15	17	17	157			HI
New Zealand	2	1	1	1				1	1	3	10			HI
South America	21	12	26	13	12	18	22	14	27	19	184	18.4	5.60	
Argentina	2	2			1	1	3	4	3	1	17			UMI
Brazil	11	10	21	12	10	16	17	9	17	17	140			UMI
Chile	8		2	1	1		1		5	1	19			HI
Colombia			1						2		3			UMI
Peru			2			1	1	1			5			UMI
Grand Total	747	827	870	856	931	739	908	832	921	1049	8680	868	91.62	

Other

Five South American countries (Brazil, Chile, Argentina, Peru, and Colombia) contributed to *PRS* throughout the

decade. Brazil was the most prolific and published 79.9% of the 184 South American articles. Australia and New Zealand were the only Oceania contributors. Notably,

Unique number of countries publishing per continent per year

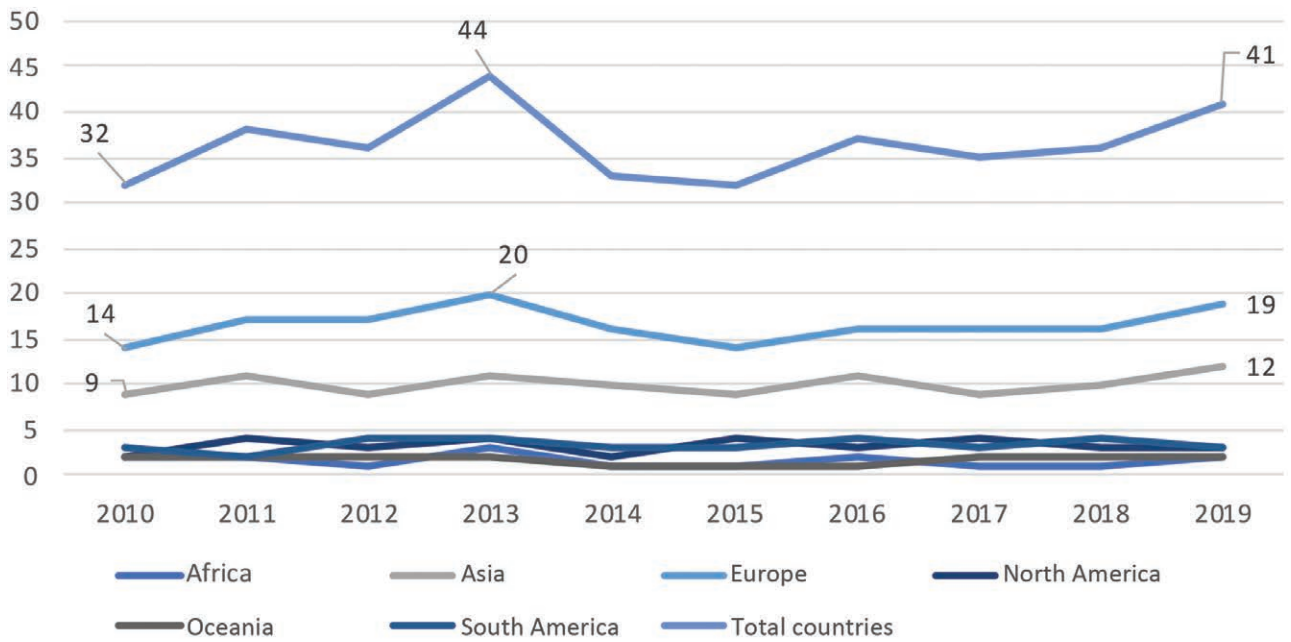


Fig. 1. Graph depicting number of countries publishing articles on plastic surgery, categorized by continent, from 2010 to 2019.

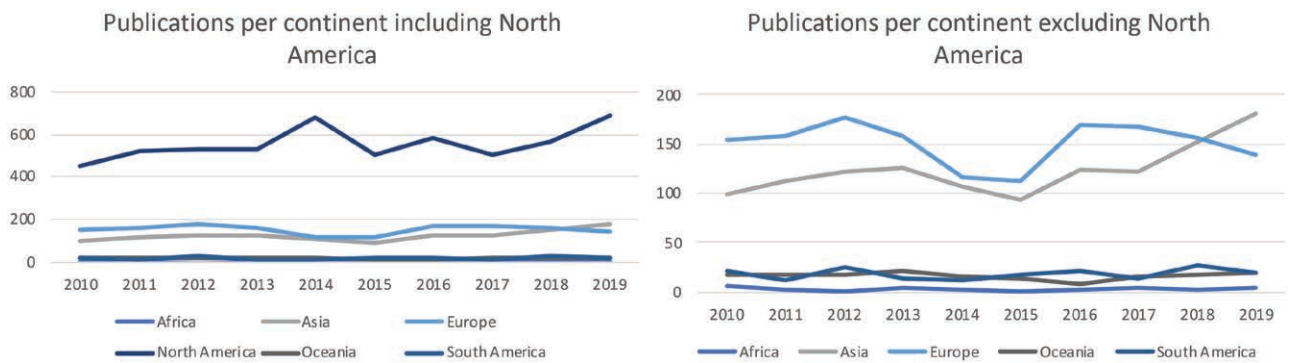


Fig. 2. Graphs representing publications per continent, including/excluding North America, from 2010 to 2019.

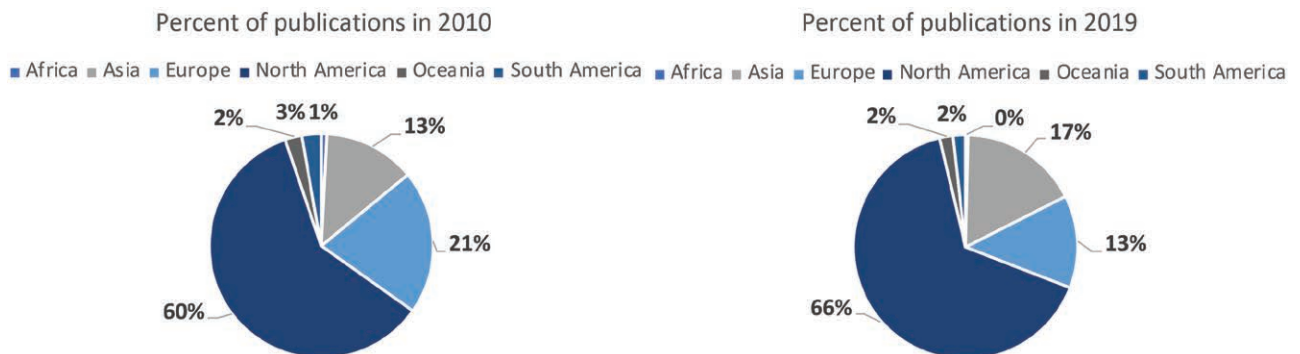


Fig. 3. Pie charts showing the percent of publications by continent in 2010 and 2019.

Table 2. Country Totals and Rank of Production from 2010 to 2019

Country	Totals	Rank
USA	5196	1
Italy	394	2
China	382	3
Canada	323	4
UK	267	5
South Korea	245	6
Japan	228	7
France	174	8
Netherlands	166	9
Australia	157	10
Taiwan	153	11
Germany	147	12
Brazil	140	13
Turkey	89	14
Spain	63	15
Austria	60	16
Switzerland	58	17
Belgium	41	18
Sweden	38	19
India	38	19

Australia was the 10th most productive country, with 156 *PRS* publications from 2010 to 2019. African countries published an average of 2.8 articles per year, with 5 contributing countries. South Africa published 19 of Africa’s 28 articles over these 10 years. The research production by country level income is represented in [Table 4](#).

DISCUSSION

Consistent with past plastic surgery-specific bibliometric works,^{4,10,11} we found the USA is responsible for the greatest proportion of articles produced. However, our analysis highlights important differences in many other trends compared with similar studies. The top producing countries in the current study differ markedly from these previous studies. For instance, Moore et al, found that, in order, the USA, Brazil, the UK, Turkey, and Canada were the top producing countries in *ASJ*.¹⁰ However, in *PRS*, we found this order to be the USA, Italy, China, Canada, and

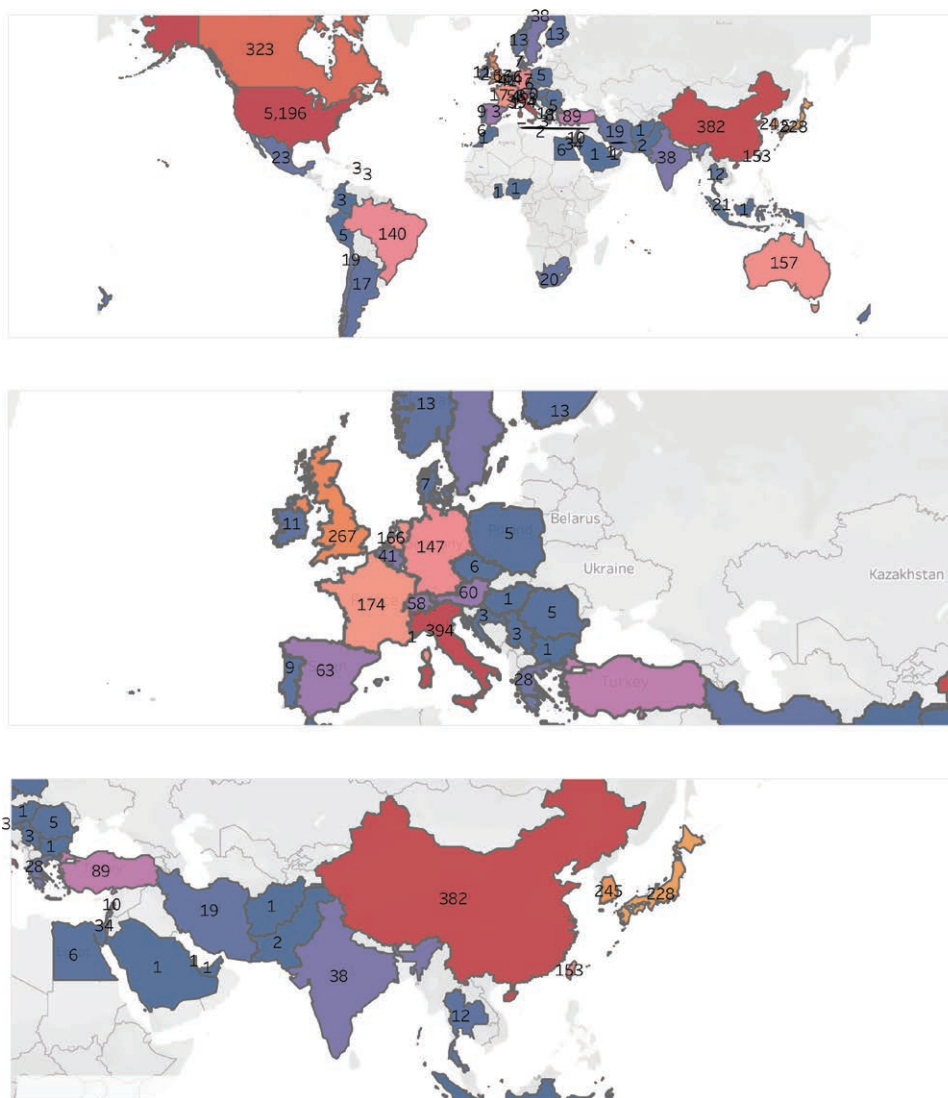


Fig. 4. Publications by country, as represented on a world map. Totals are from 2010 to 2019.

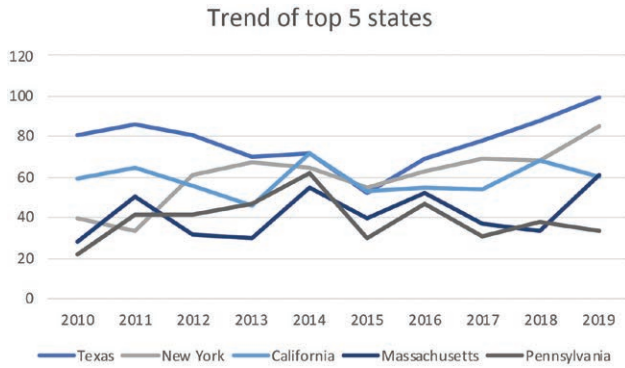


Fig. 5. Graph depicting the publication trend of top 5 states from 2010 to 2019.

the UK. It is striking that Brazil is the 13th most prolific in our study. This discrepancy may be due to subject matter difference between the two journals, with *ASJ* focusing specifically on aesthetic surgery. Moore et al posit that because Brazil is one of the top travel destinations for aesthetic surgery, its research and publishing output may be higher in an aesthetic-focused journal.¹⁰ Since *PRS* publishes articles in all aspects of plastic surgery (including breast, hand, reconstruction, cosmetic, pediatrics/craniofacial, and basic science research), this difference may reflect the different plastic surgery research interests of these countries.^{6,12}

In prior analyses, it was consistently seen that North America and Europe were the top two producers of articles

with a significant gap in production from the third leading producer, Asia.^{4,6,10,11} Our analysis is the first, to our knowledge, to show Asia outproducing Europe in terms of total articles contributed to a plastic surgery journal. Our figures show a strong upward trend from Asia, which may represent a shifting paradigm. Previous studies have documented the tremendous growth in plastic surgery research in several Asian countries and a desire for their work to be represented on an international stage.^{4,8} This growth may also reflect the increasing importance and societal value that is being placed upon aesthetic and reconstructive surgery in these countries.^{16,17} While our analysis does not extend to other journals, *PRS* may act as a weathervane as others follow suit.

Past bibliometric analyses have seen a dip in total output production between 2009 and 2013, which may have been explained by the global recession and a decrease in funding devoted to research.^{10,11} Our analysis showed that from 2009 to 2014, there was an almost linear uptrend in total number of publications, with 2014 being at the peak for several years. We do however see a dip between 2014 and 2016, which could be a result of another global recession. It may have been that *PRS* did not see decreased production because its high impact meant authors chose to contribute to *PRS* rather than to other journals. The delayed depression may reflect the decrease in production of research from all institutions due to decreased funding. Future bibliometric studies may provide a starting point to investigate trends in research production as correlated with changing research environments.

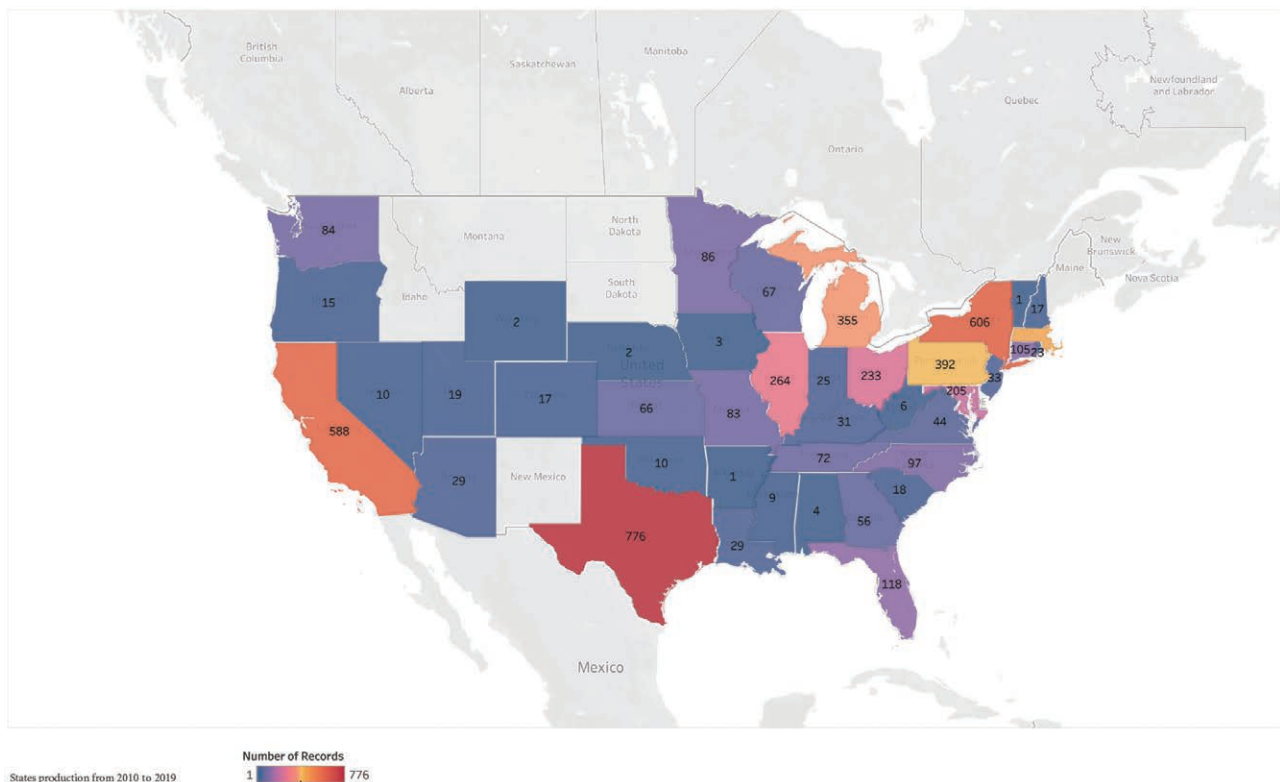


Fig. 6. Publications by state within the USA, as represented on a map. Totals are from 2010 to 2019.

Table 3. State Total Production from 2010 to 2019

States	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Grand Total	Rank
Texas	81	86	81	70	72	52	69	78	88	99	776	1
New York	40	33	61	67	65	55	63	69	68	85	606	2
California	59	65	56	46	72	53	55	54	68	60	588	3
Massachusetts	28	50	32	30	55	40	52	37	33	61	418	4
Pennsylvania	22	41	41	47	62	30	47	31	38	33	392	5
Michigan	28	35	42	36	49	36	37	28	29	35	355	6
Illinois	26	14	30	18	36	24	32	22	32	30	264	7
Ohio	19	20	21	25	39	21	26	18	16	28	233	8
Maryland	12	17	24	18	29	25	23	14	18	25	205	9
District of Columbia	11	21	17	24	22	14	14	14	14	19	170	10
Florida	11	18	14	7	9	12	12	6	6	23	118	11
Connecticut	5	11	11	12	12	17	6	5	11	15	105	12
North Carolina	6	6	5	6	17	2	14	15	11	15	97	13
Minnesota	5	2	2	8	10	5	14	8	14	18	86	14
Washington	5	6	6	3	8	8	7	8	14	19	84	15
Missouri	4	1	1	5	8	10	12	16	11	15	83	16
Tennessee	1	10	8	5	9	9	6	5	10	9	72	17
Wisconsin	6	6	3	8	10	4	7	8	8	7	67	18
Kansas	1	4	6	15	9	12	12	4		3	66	19
Georgia	10	6	10	5	6	6	3	8	2		56	20
Virginia	5	6	4	1	5	4	3	4	5	7	44	21
New Jersey	7	3	2	3	2	3	5	2	2	4	33	22
Kentucky	6	1	2	3	6		4	1	4	4	31	23
Louisiana	1	3	6	2	1	4	3	1	3	5	29	24
Arizona	1	6	3	1	3	5	5		1	4	29	24
Indiana	3	2	3	3	4	2	1	3	2	2	25	26
Rhode Island	2	1	1	1	7	2	4	2	3		23	27
Utah			1		1	3	4	3	4	3	19	28
South Carolina	3		1	1	3	1	2		4	3	18	29
Colorado	1	2	1	7	4		2				17	30
New Hampshire	2	2	1	7	1	2	1			1	17	30
Oregon	1	3	1	5			1	1	2	1	15	32
Nevada	2	2	1	1		3				1	10	33
Oklahoma	4	1						1	4		10	33
Mississippi				2	2		3	1		1	9	35
Hawaii	4	2	2	1							9	35
West Virginia		2		1	1			1		1	6	37
Alabama		1		1	1		1				4	38
Iowa				1			2				3	39
Nebraska		1		1							2	40
Wyoming	1	1									2	40
Arkansas		1									1	42
Vermont			1								1	42
Grand Total	423	492	501	497	640	464	552	468	525	636	5198	

Table 4. Production Per Country Income as Designated by the World Bank

Country Income	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Grand Total
HI	688	759	788	772	877	677	822	758	817	938	7896
UMI	51	55	76	73	53	61	81	73	103	106	732
LMI	8	13	6	11	1		5	1	1	5	51
LI						1					1

In contrast to Moore et al, we see that the USA actually increased its share of total production over the decade, from 56% to 60%.¹⁰ This is the first state-specific analysis of *PRIS* publications. Gast et al demonstrated that institutional-level bibliometric indices measuring production positively correlated with volume of plastic surgery trainees (Harvard, New York University, Pittsburgh, and Johns Hopkins).¹⁸ States containing larger numbers of academic plastic surgery programs correlate with our top 5 states: Texas, New York, California, Massachusetts, and Pennsylvania. Maryland (which encompasses Johns Hopkins) is the ninth in our analysis. The fact that California is one of our top producing states, but no specific school is recognized by Gast et al may reflect that the bulk of the research within the state comes from a multitude of academic institutions.

New York and Massachusetts had increases in research articles published over the decade from 40 to 85 and 28 to 61, respectively. This may reflect an increased focus on research at institutions in these states. Notably, the bottom 10 states in publication output do not have major academic plastic surgery programs.

We also analyzed country-level production of articles categorized by income level, as defined by the World Bank (Table 4).¹⁵ Similar to Moore et al, we see that high-income countries are responsible for the greatest number of publications.¹⁰ It is notable that we have more publications from each income category compared with Moore et al (8680 in *PRIS* to 1663 in *ASJ*). When analyzing production as ratios of HI:UMI:LMI, we see 154:14.4:1 for *PRIS*, and 151.7:21.6:1 for *ASJ*. Thus, *ASJ* produced a greater

percentage of publications from UMI countries, which may reflect Brazil and Turkey (both UMI) being in their top contributors but not in ours.

This study is limited in the fact that, using bibliometric analysis, we could not report the specific type of article produced from individual countries. This could certainly change the “output” of a country if the majority of their publications were letters to the editor rather than a randomized controlled trial studying a new technique. Previous studies have sought to use the impact factor as a measure of the “value” of the article; however the ability to artificially inflate the impact factor by self-citation within plastic surgery has been demonstrated by Miyamoto et al, and we did not believe this would be a reliable method.¹³ A future sub-analysis of our data set could explore subject material and article type. Another weakness is that by analyzing only one journal we are not able to make commentary on all areas of plastic surgery research that may be better represented in other journals. We believe that *PRs* accurately reflects the breadth of the field, but future studies should compare our results with other top plastic surgery journals. A third weakness of our paper was that analysis did not include second authors and onward. This would not change the overall article output but may reveal trends in international collaborations authorship other than first author, including senior authors. Our data should be interpreted in the light that previous studies have demonstrated that researchers from lower middle-income countries are under-represented as first (and last) authors on papers from research performed in their own countries.¹⁹ However, these results have not been confirmed in plastic surgery research and would be a field of study for future investigation.

Future bibliometric analysis should focus on Asia’s research output in other journals to see if it has outproduced Europe in recent years in other fields. Additionally, it would be important to investigate why Russia is not represented in our analysis nor others.^{4,6,10,11} Future analyses should examine the research priorities of these countries and other factors that affected research output, the research output of other top plastic surgery journals over the preceding decade, and how research production may affect the movement of surgeons across the globe (ie, brain drain).

Drs. Paul Farmer and Jim Kim remind us that there is no shortage of “surgical disease, which exists abundantly among the world’s poorest.”²⁰ The present study and past bibliometric works can be utilized to focus the efforts of the surgical community to increase research capacity in surgery internationally and in the United States.^{21–23} Our analysis highlights areas of the world where plastic surgeons with fewer resources are still producing significant research. By focusing our efforts on helping those surgeons, we can help train, expand their skill set, and gain lessons from their experience and research.

CONCLUSIONS

The last decade (2010–2019) saw a large international increase in research output as the world recovered from a recession. With this growth, we have seen more research

in plastic surgery, which is reflected not only in the total number of publications, but in the diversity of originating country as well. The United States has remained the top producer of total *PRs* articles annually, followed by Italy, China, Canada, and the UK. In 2019, Asian countries surpassed European countries in total publications for the first time. We show that Texas, New York, California, Massachusetts, and Pennsylvania are the most productive states within the U.S. Overall, from 2010 to 2019, there has been a global increase in both the quantity of *PRs* publications, and the number of unique contributing countries to the journal. We look forward to seeing what the next decade will bring for the Plastic and Reconstructive Surgery journal and the field of Plastic Surgery as a whole.

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