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The Research Trend of Soft Tissue Filler Injection from 2000 to 2022: A Bibliometric and Visualized Analysis

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Background: The demand for soft tissue filler injections has experienced a significant increase in recent years. Therefore, this study used bibliometric analysis to identify prominent research areas and emerging trends within the field.
Methods: Publications concerning research on soft tissue filler injections were collected from the Web of Science Core Collection database. Subsequently, VOSviewer 1.6.18 and CiteSpace 6.2.R4 software were used to analyze the co-authorship, co-occurrence, and citations of countries, institutions, authors, hotspot keywords, and journals associated with these studies.
Results: A total of 1370 records pertaining to filler injection research conducted between 2000 and 2022 were identified. The United States (524 publications) emerged as the country with the highest number of publications in this field, with Mayo Clinic (37 publications) making the most substantial contribution. *Dermatologic Surgery* emerged as the leading journal in this field, publishing the highest number of research articles (151 publications) and also being the most frequently co-cited. Cotofana proved to be the most prolific author with 51 publications, and Lemperle emerged as the most frequently co-cited author with 628 citations (including total link strength: 6587). The most popular keywords, in descending order of popularity, were "dermal filler," "injection," "soft-tissue augmentation," "complications," and "hyaluronic acid."
Conclusions: The findings of this study offer a comprehensive overview of the main directions in filler injection research. Furthermore, they underscore the imperative of intensifying efforts to prevent complications linked to filler injections. *(Plast Reconstr Surg Glob Open 2024; 12:e5579; doi: 10.1097/GOX.0000000000005579; Published online 2 February 2024.)*

INTRODUCTION

Soft tissue filler injections are widely acknowledged as a safe and straightforward treatment for aesthetic purposes. These fillers are derived from various materials, including hyaluronic acid, calcium hydroxyapatite, and poly-L-lactic acid. Notably, the Food and Drug Administration has approved more than 30 dermal fillers.[1–3] According to the American Society for Aesthetic Plastic Surgery, an estimated 3,410,730 soft tissue filler injections were performed in the United States in 2020, ranking it as the second most common minimally invasive cosmetic procedure.[4] However, the growing popularity of these procedures has resulted in an increase in associated adverse events.[5,6] To enhance their efficacy and minimize such complications, novel fillers, techniques, and fundamental research have been introduced.[7–11] Thus, it is crucial to summarize the present research status in this field and identify areas for further investigation to facilitate the implementation of soft tissue filler injections.

Bibliometric analysis, a mathematical modeling tool, is used to monitor research trends in specific fields.[12] Although bibliometrics has found extensive applications in medicine, including pneumonia,[13] arthritis,[14] hypertension,[15] and human immunodeficiency virus disease,[16] as well as in plastic surgery,[17–21] no previous bibliometric

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study has specifically focused on soft tissue filler injections. This research topic holds a significant value for enhancing clinical treatment. The rapid development of fillers and techniques has resulted in a substantial increase in the number of published articles. Consequently, both researchers and nonresearchers can use this information to efficiently accomplish specific objectives within their respective areas of interest by studying highly influential research.

The objective of this study was to perform a bibliometric and visualization analysis in the field of soft tissue filler injections. The aim was to offer a comprehensive overview of the present research status and identify potential future perspectives in the field.

Takeaways

Question: This study used bibliometric analysis to identify prominent research areas and emerging trends within the field of filler injection.

Findings: The study analyzed the co-authorship, co-occurrence, and citations of countries, institutions, authors, hotspot keywords, and journals associated with filler injection.

Meaning: The findings of this study offer a comprehensive overview of the main directions in filler injection research.

METHODS

Search Strategy

On March 7, 2023, we performed a search in the Web of Science Core Collection (WoSCC) database using the search terms "TS=((soft tissue filler injection) OR (dermal filler injection))" to identify studies published in English between January 1, 2000 and December 31, 2022. Two authors independently screened data and excluded documents irrelevant to the search strategies. We only considered original articles and reviews, resulting in 1384 retrieved records. To ensure data quality, we preprocessed the data to eliminate duplicates or inconsistencies related to the topic. After screening by three researchers, we acquired 1370 valid documents (Fig. 1).

Analysis Tool

The data retrieved from WoSCC consisted of articles and citations, h-index, keywords, publication years, journals, authors, countries/regions, and affiliations. The articles were analyzed, and visual representation was created using VOSviewer and CiteSpace software. The bibliographic data were exported as a txt file from the WoSCC database and subsequently imported into VOSviewer and CiteSpace software to generate visualization maps. The basic metrics and visualization maps of countries, institutions, authors, journals, and keywords were analyzed through VOSviewer and CiteSpace software. The basic metrics and visualization maps of countries, institutions, authors, journals, and keywords were analyzed through VOSviewer. A timeline view of co-cited reference was performed by CiteSpace. The size of the nodes and the thickness of the lines between the nodes represented

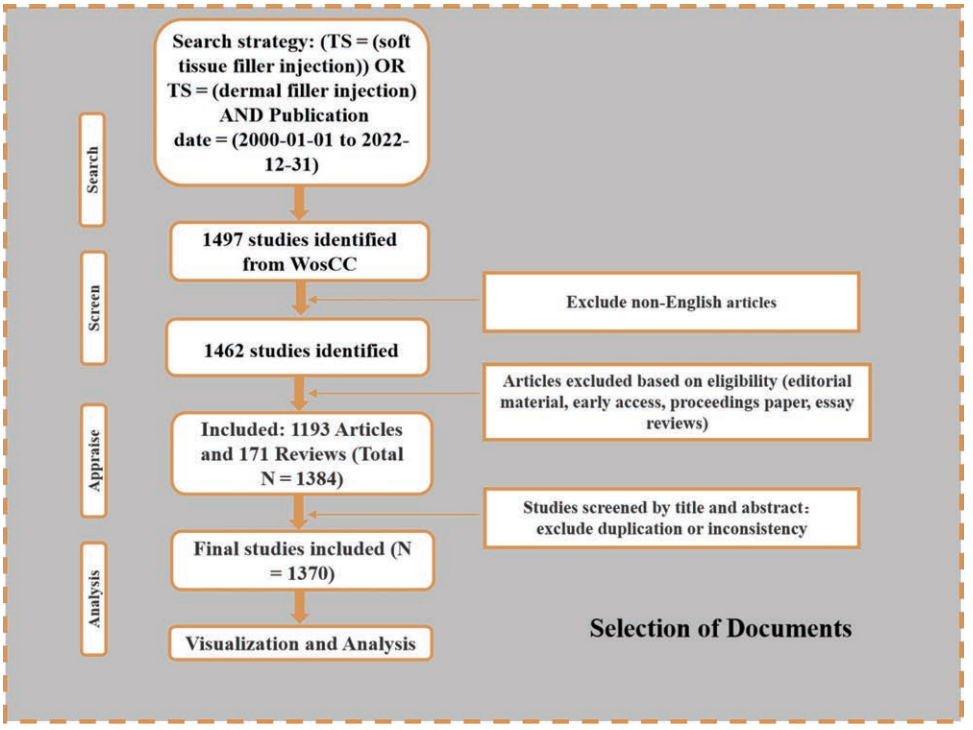

Fig. 1. Flowchart illustrating the article selection process for bibliometric mapping analysis and systematic review.

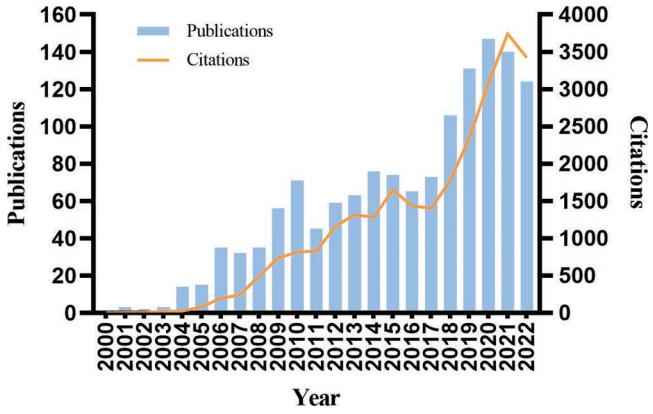

Fig. 2. Annual worldwide publication output.

the occurrence frequency and the degree of correlation of the relevant parameters, respectively. The nodes with the same color represented the same cluster in the visualization map.

RESULTS

The Number of Articles in the Field of Soft Tissue Filler Injection

After applying the predetermined exclusion criteria, the study included 1370 papers authored by 4557 individuals affiliated with 1870 organizations in 64 countries. These papers were published in 284 journals and were subsequently subjected to further bibliometric analyses. In total, the publications received 26,320 citations, of which 18,166 were non–self-citations. The average citations per document were 19.21, and the h-index of the publications was 69.

Distribution of Publications from 2000 to 2022

Figure 2 depicts the temporal distribution of publications in the field of soft tissue filler injection. Since 2017, the number of publications and citations in this field has shown a significant increase. It is noteworthy that there has been a substantial surge in publications and citations during this period, with the number of publications consistently surpassing 100, from 2018 to 2022. These findings indicate a growing interest among scholars in the research field of soft tissue filler injection, positioning it as a novel area of study within plastic and aesthetic research.

The National/Regional Distribution of Global Publication

Figure 3 illustrates the distribution of countries/regions with the highest number of global publications on soft tissue filler injection, whereas Table 1 provides a ranking of the top 10 most productive countries/regions. The top 10 countries accounted for 99.12% of the publications, with the United States leading in the number of published articles, followed by South Korea and Germany. Additionally, the United States, Germany, and South Korea had the highest numbers of citations, whereas France

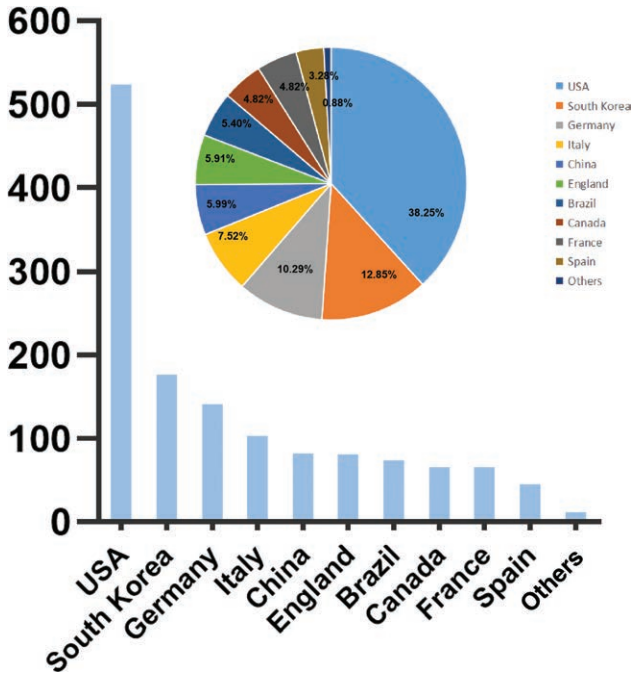

Fig. 3. Top 10 productive countries/regions.

had the highest h-index. Spain and the United States tied for second and third place in terms of h-index. The distribution of countries/regions was analyzed using the VOSviewer software, focusing on those with at least five documents. This analysis identified 41 countries that met the criteria, and their relationships were visualized in a network diagram and a density map, as depicted in Figure 4.

Distribution of Affiliations

Table 2 presents the top 10 most productive affiliations. These affiliations represent three countries: the United States, South Korea, and Germany, with six of them originating from the United States. The leading affiliations were the Mayo Clinic (2.70%, 37 publications), the University of California, San Diego (2.55%, 35 publications), and the University of Munich (2.19%, 30 publications). Among them, the University of California, San Diego (USA) achieved the highest h-index (20), while the University of California, Los Angeles (USA) had the highest citation/publication ratio (41.24). To analyze the collaboration among different affiliations, a minimum threshold of 10 documents per affiliation was set, resulting in 39 affiliations meeting the criteria.

Distribution of Journals and Co-cited Journals

Table 3 and Table 4 present the list of the top 10 productive and co-cited journals, respectively. *Dermatologic Surgery* ranked first with 151 publications, followed by the *Journal of Cosmetic Dermatology* (134 publications) and *Plastic and Reconstructive Surgery* (94 publications). Among the top 10 productive journals, *Plastic and Reconstructive Surgery* had the highest impact factor (IF; 5.169), h-index (36), and CPP (citations per publication; 42.50). Additionally, *Dermatologic Surgery* was the most frequently

Table 1. The Top 10 Productive Countries/Regions

Rank	Country/Region	Records	Percentage (%)	H-index	Citations	Citations per Publication
1	USA	524	38.25%	57	12,672	24.18
2	South Korea	176	12.85%	22	1923	10.93
3	Germany	141	10.29%	30	2809	19.92
4	Italy	103	7.52%	21	1564	15.18
5	China	82	5.99%	18	858	10.46
6	England	81	5.91%	23	1622	20.02
7	Brazil	74	5.40%	18	886	11.97
8	Canada	66	4.82%	22	1524	23.09
9	France	66	4.82%	25	1741	26.38
10	Spain	45	3.28%	20	1111	24.69

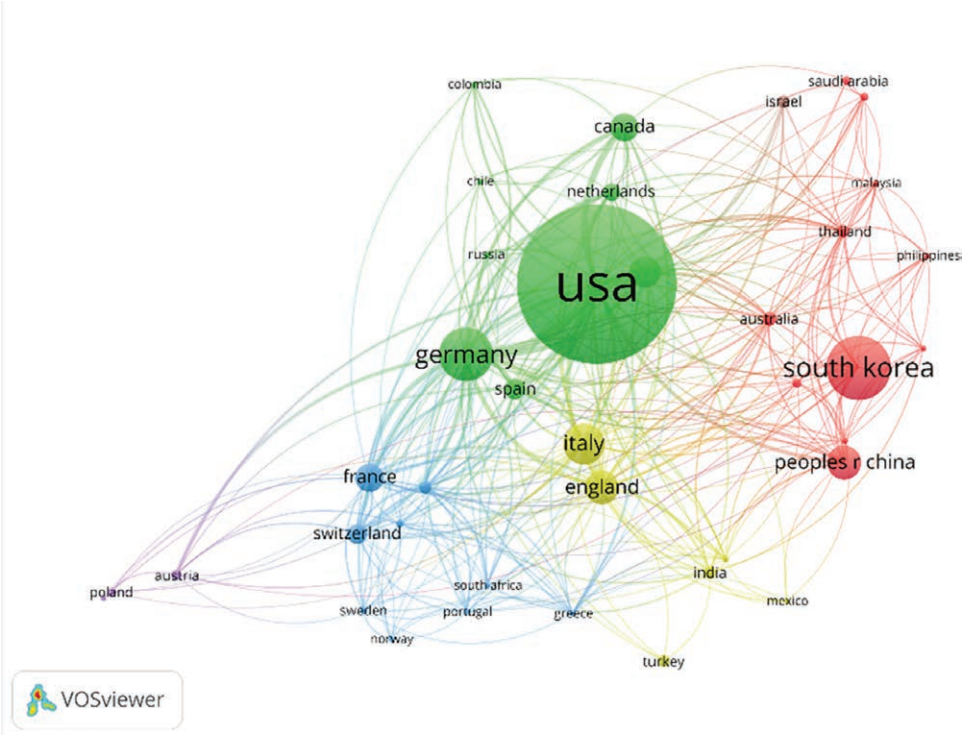

Fig. 4. Network visualization map of countries/regions.

Table 2. The Top 10 Productive Affiliations

Rank	Institution	Location	Records	Percentage	H-index	Citations	Citations Per Publication
1	Mayo Clinic	USA	37	2.70%	11	288	7.78
2	Univ Calif San Diego	USA	35	2.55%	20	1320	37.71
3	University of Munich	Germany	30	2.19%	17	433	14.43
4	Univ Calif Los Angeles	USA	29	2.12%	18	1196	41.24
5	Yonsei University	South Korea	26	1.90%	11	348	13.38
6	University of Miami	USA	23	1.68%	14	816	35.48
7	Chung-Ang University	South Korea	23	1.68%	8	137	5.96
8	University of British Columbia	England	21	1.53%	12	813	38.71
9	Albany Medical College	USA	20	1.46%	13	437	21.85
10	Northwestern University	USA	20	1.46%	14	496	24.80

co-cited journal, with 5689 citations [total link strength (TLS): 134,521]. A co-citation analysis using VOSviewer was conducted to reveal the complex relationships among the journals. The analysis included 49 journals meeting the criteria of a minimum of 100 citations per source (Fig. 5).

Table 3. The Top 10 Productive Journals

Rank	Journal	Records	Percentage	Citations	CPP	H-index	IF (2021)
1	*Dermatologic Surgery*	151	11.02%	4177	27.66	36	2.914
2	*Journal of Cosmetic Dermatology*	134	9.78%	1182	8.82	20	2.189
3	*Plastic and Reconstructive Surgery*	94	6.86%	3995	42.50	42	5.169
4	*Aesthetic Plastic Surgery*	91	6.64%	1684	18.51	23	2.708
5	*Journal of Drugs in Dermatology*	82	5.99%	1141	13.91	20	1.608
6	*Aesthetic Surgery Journal*	75	5.47%	1675	22.33	20	4.485
7	*Journal of Cosmetic and Laser Therapy*	43	3.14%	713	16.58	14	1.982
8	*Facial Plastic Surgery*	36	2.63%	475	13.19	13	1.286
9	*Clinical Cosmetic and Investigational Dermatology*	36	2.63%	323	8.97	9	2.765
10	*Dermatologic Therapy*	26	1.90%	298	11.46	8	3.858

Table 4. Top 10 Co-cited Journals

Rank	Journal	Citations	TLS	H-index	IF (2021)
1	*Dermatologic Surgery*	5689	134,521	36	2.91
2	*Plastic and Reconstructive Surgery*	4417	107,257	42	5.17
3	*Aesthetic Plastic Surgery*	1583	46,705	23	2.708
4	*Aesthetic Surgery Journal*	1502	41,293	20	4.485
5	*Journal of Drugs in Dermatology*	1078	29,899	20	1.608
6	*Journal of Cosmetic Dermatology*	873	22,284	20	2.189
7	*Journal of the American Academy of Dermatology*	773	28,630	10	15.49
8	*Facial Plastic Surgery*	648	18,524	13	1.286
9	*Journal of Cosmetic and Laser Therapy*	576	15,831	14	1.982
10	*Ophthalmic Plastic and Reconstructive Surgery*	474	14,738	9	2.01

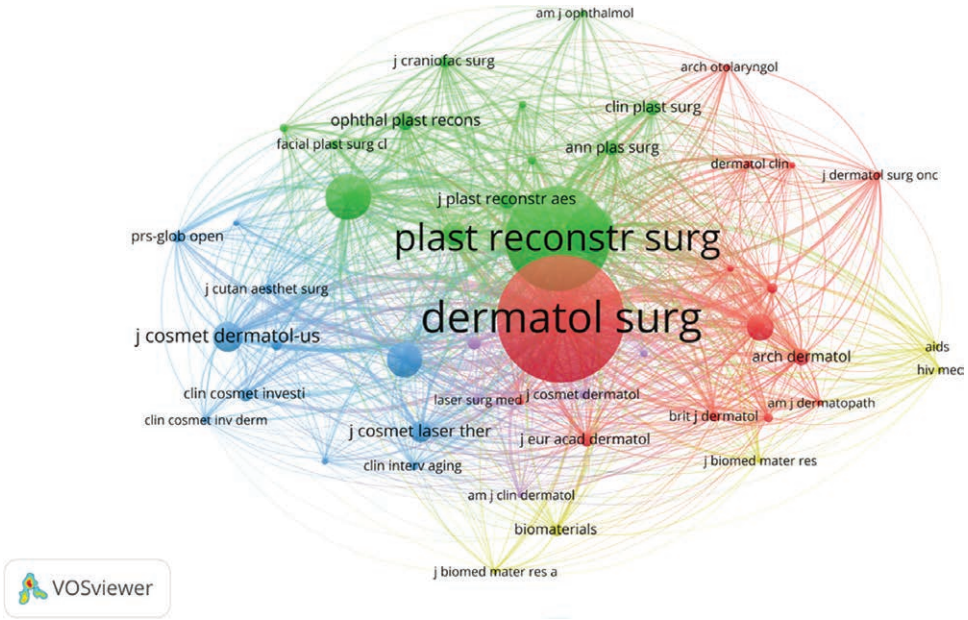

Fig. 5. Network visualization map of co-cited journals related to soft tissue filler injection.

Distribution of Authors and Co-cited Authors

Table 5 presents the top 10 authors who have made significant contributions to the field of soft tissue filler injection, with the majority of them affiliated with institutions in the USA and Germany. Collectively, their publications amount to 231 articles, representing 16.86% of all publications. Among them, Cotofana has the highest number of publications (51 articles), followed by Frank (44 articles), and Green (23 articles). Cotofana has the highest citation count and h-index, whereas Fagien leads in the CCP rankings (44.53), followed by Cohen (32.50), and Swift (21.27).

To examine the authors' cooperation, we conducted co-authorship analysis (Fig. 6) and co-citation analysis (Fig. 7). For co-authorship analysis, the minimum number of documents required for one affiliation was set at 5,

Table 5. The Top 10 Productive and Co-cited Authors

Rank	Author	Country	Records	Percentage	CCP	Co-cited Author	Citations	TLS	Country
1	Cotofana	USA	51	3.72%	13.14	Lemperle	628	6587	USA
2	Frank	Germany	44	3.21%	12.39	Narins	373	4420	USA
3	Green	USA	23	1.68%	11.91	Rohrich	276	3155	USA
4	Kim	South Korea	19	1.39%	6.11	Delorenzi	221	2462	Canada
5	Schenck	Germany	17	1.24%	20.35	Alijotas-Reig	214	3005	Spain
6	Pavicic	Germany	16	1.17%	16.81	Carruthers	207	2288	Canada
7	Cohen	USA	16	1.17%	32.50	Lowe	205	2502	USA
8	Swift	Canada	15	1.09%	21.27	Cotofana	199	1441	USA
9	Fagien	USA	15	1.09%	44.53	Alam	190	2475	USA
10	Sattler	Germany	15	1.09%	13.07	Carruthers	188	2378	Canada

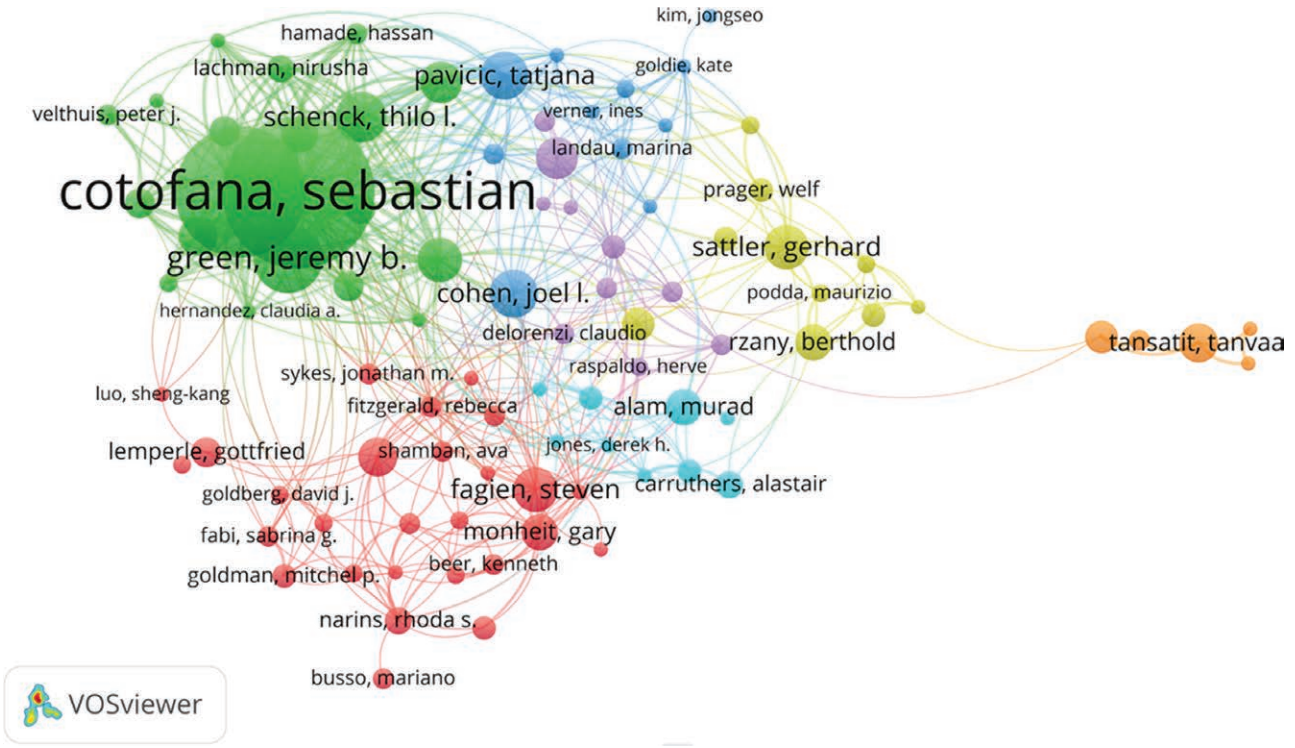

Fig. 6. Co-authorship network visualization of authors.

and 117 affiliations fulfilled this criterion. In the case of co-citation analysis, the minimum number of documents required for one affiliation was set at 50, and 91 authors satisfied this criterion.

Top 10 Highly Cited Articles

Table 6 presents a summary of the top 10 most-cited references, including the author, title, and year of publication. *Dermatologic Surgery* was the most prolific journal, with three publications, followed by *Aesthetic Surgery Journal* with two publications. The article titled "In vivo stimulation of de novo collagen production caused by cross-linked hyaluronic acid dermal filler injections in photodamaged human skin," authored by Wang and published in *Archives of Dermatology*, received the highest number of citations (298). Among the top 10 most-cited articles, seven focused on complications associated with filler injections.

Distribution of Research Hot Spots

To systematically identify the research hotspots and developmental direction of soft tissue filler injection, we performed a co-occurrence cluster analysis based on keywords using the VOSviewer software. After applying a threshold of 20, a total of 83 keywords were included for further visual analysis. A network map was created and is displayed in Figure 8A. The analysis of keyword citation counts revealed that the most frequently used keywords were "dermal filler," "injection," "soft-tissue augmentation," "complications," and "hyaluronic acid." The temporal diagram indicated that the research trends centered around "hyaluronic acid," "anatomy," "blindness," and "prevention" (Fig. 8B). Figure 9 displays the top 25 co-occurring keywords with the strongest citation bursts. The results revealed that the keyword "skin" had the highest burst intensity (5.79), followed by "soft tissue augmentation" (22.9) and "artecoll" (8.09). Subsequently, a keyword

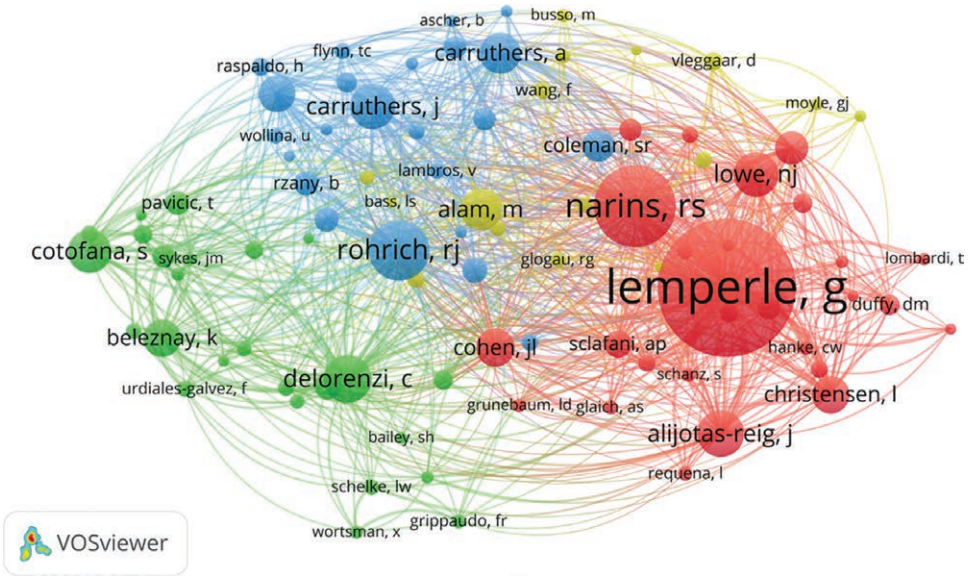

Fig. 7. Co-citation network visualization of authors.

Table 6. The Top 10 Articles with Most Total Citations

Rank	Title	First Author	Journal	Publication Time	Citation
1	In vivo stimulation of de novo collagen production caused by cross-linked hyaluronic acid dermal filler injections in photodamaged human skin	Wang	*Archives of Dermatology*	2007	298
2	Avoiding and treating blindness from fillers: a review of the world literature	Beleznay	*Dermatologic Surgery*	2015	286
3	The science of hyaluronic acid dermal fillers	Tezel	*Journal of Cosmetic and Laser Therapy*	2008	226
4	Adverse reactions to injectable soft tissue permanent fillers	Christensen	*Aesthetic Plastic Surgery*	2005	215
5	Adverse reactions to dermal fillers: review	Lowe	*Dermatologic Surgery*	2005	206
6	Complications of injectable fillers, part 2: vascular complications	DeLorenzi	*Aesthetic Surgery Journal*	2014	193
7	Adverse reactions to injectable soft tissue fillers	Requena	*Journal of The American Academy of Dermatology*	2011	189
8	Hyaluronic acid, a promising skin rejuvenating biomedicine: a review of recent updates and preclinical and clinical investigations on cosmetic and nutricosmetic effects	Bukhari	*International Journal of Biological Macromolecules*	2018	171
9	Understanding, avoiding, and managing dermal filler complications	Cohen	*Dermatologic Surgery*	2008	166
10	Complications after injection of soft-tissue fillers	Ozturk	*Aesthetic Surgery Journal*	2013	163

clustering analysis was conducted to categorize the co-occurrence network of keywords into six different clusters, namely "blindness," "double blind," "artecoll," "stem cells," "dermal fillers," and "hyaluronic acid" (Fig. 10).

DISCUSSION

Soft-tissue filler injection is a frequently performed aesthetic procedure and an effective treatment for facial aging and contour deformities. However, due to the steady global increase in the number of soft tissue filler treatments performed, providing a comprehensive assessment of the topic has become increasingly challenging. Bibliometric analysis, a tool that uses mathematical models to track the overall research trends in a specific field, has recently been widely applied in the field of plastic surgery.[14,18–20] To the best of our knowledge, this is the first bibliometric study conducted on the topic of soft tissue filler injection. This study identified 1370 research articles on soft tissue filler injection from the WoSCC database. The articles were published between January 1, 2000, and December 31, 2022.

Our analysis showed that before 2004, there were limited publications on soft tissue filler injection, with only a small number of articles being published each year. However, the citations for these articles started increasing after 2004, indicating a growing interest among researchers in this field as a potential research hotspot (Fig. 2). Among the 41 countries/regions that have published at least five articles in this field, the United States ranked first in terms of publications, accounting for 38.25%. The United States emerged as the primary contributor in the

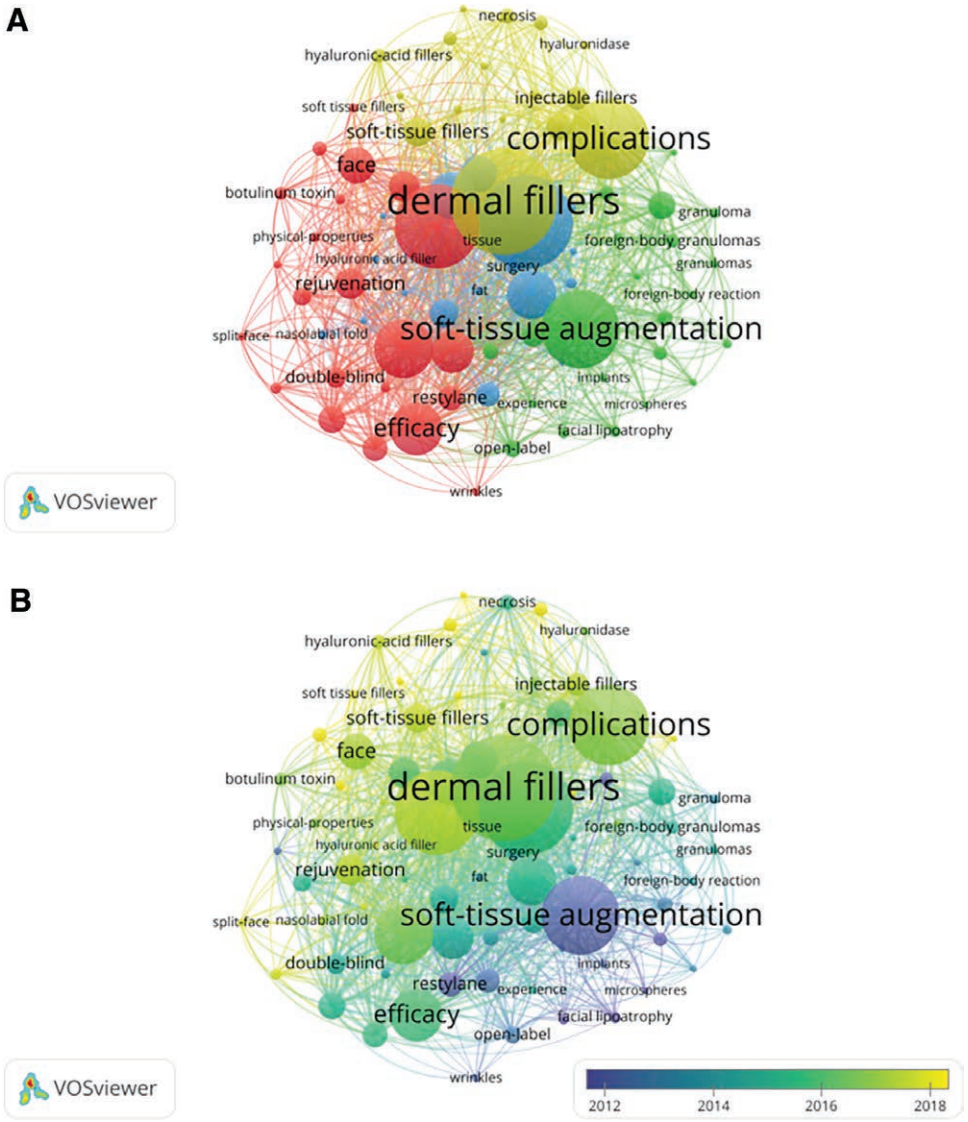

Fig. 8. Network visualization map of keyword co-occurrence. A, Cluster analysis. B, Timing analysis.

field, holding a significant academic reputation in filler injection research. This is supported by the number of publications, h-index values, and total number of citations (Table 1), which are closely linked to the country's scientific research capacity, social development, economic status, and other factors.

Additionally, the Mayo Clinic emerged as the top publishing institution with 2.70% of total publications (37 articles). Moreover, the University of California San Diego (USA) achieved the highest h-index of 20 and garnered 1320 citations, while the University of California Los Angeles (USA) attained the highest citation/publication ratio of 41.24. These findings underscore the significant contributions of the USA to the advancement of this field.

Among the top 10 most productive journals, *Dermatologic Surgery*, *Journal of Cosmetic Dermatology*, and *Plastic and Reconstructive Surgery* stood out for publishing the highest number of articles in this field. *Dermatologic Surgery* emerged as the leading journal, boasting the highest number of publications and citations. It claimed the top spot among the most co-cited journals, showcasing its significant influence in the field of research. *Plastic and Reconstructive Surgery* served as a reliable source of up-to-date knowledge, covering the latest techniques and notable advancements in all areas of plastic and reconstructive surgery. Specifically, within the field of filler injection, it boasted the highest IF (5.169), h-index (36), and CPP (42.50), signifying the presence of high-quality research within its pages.

Of the top 10 articles with the highest total citations, seven focused on filler complications,[22–28] which continue to pose significant safety concerns for both cosmetic patients and physicians, highlighting the importance of this research field. Blindness is a rare and devastating complication, and possessing comprehensive anatomical knowledge is crucial for its prevention.[29] These publications offered promising avenues that warrant further in-depth studies. Since 2016, there has been a surge in research interest regarding facial anatomy and vascular

Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2000 - 2022
skin	2000	5.79	**2000**	2007	
soft tissue augmentation	2001	22.9	**2001**	2009	
artecoll	2004	8.09	**2004**	2008	
collagen	2004	7.27	**2004**	2014	
hyaluronic acid gel	2004	6.84	**2004**	2010	
open label	2005	10.05	**2005**	2009	
restylane	2006	14.69	**2006**	2012	
facial lipoatrophy	2006	8.53	**2006**	2013	
history	2008	6.44	**2008**	2014	
l lactic acid	2009	5.55	**2009**	2015	
double blind	2004	6.31	**2010**	2011	
facial rejuvenation	2009	5.59	**2010**	2014	
gel	2001	5.18	**2010**	2012	
foreign body reaction	2010	4.78	**2010**	2013	
experience	2011	5.32	**2011**	2012	
injectable fillers	2014	8.75	**2014**	2019	
soft tissue fillers	2012	5.38	**2015**	2018	
blindness	2015	5.93	**2016**	2020	
artery	2018	4.91	**2018**	2019	
prevention	2014	5.4	**2019**	2022	
facial anatomy	2019	5.09	**2019**	2022	
soft tissue filler	2019	4.77	**2019**	2022	
anatomy	2017	8.85	**2020**	2022	
recommendations	2020	5.01	**2020**	2022	
skin necrosis	2017	4.94	**2020**	2022	

Fig. 9. The top 25 keywords with the strongest citation bursts based on CiteSpace.

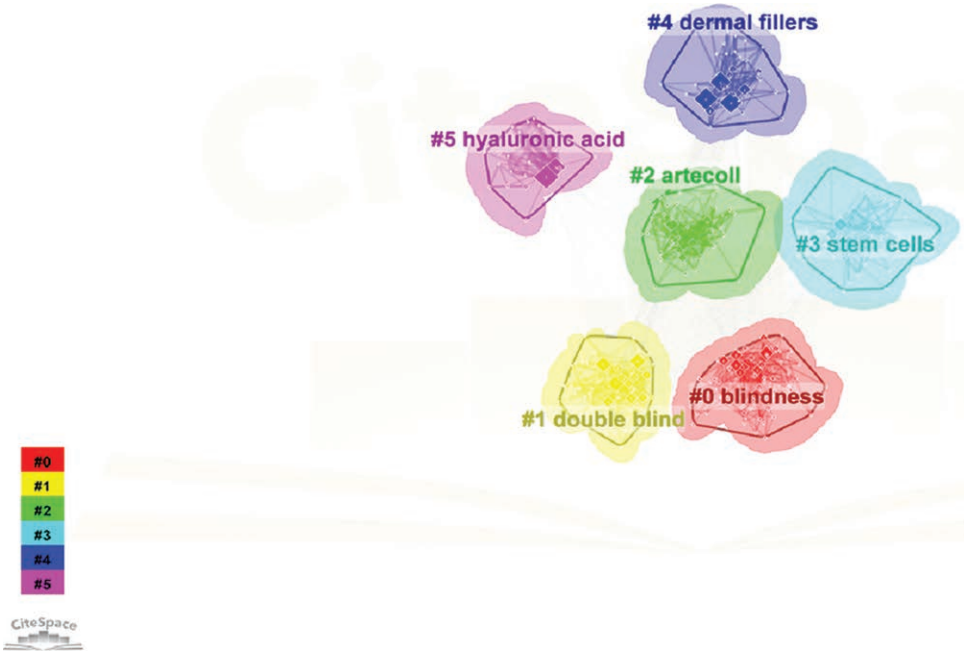

Fig. 10. Cluster analysis of keywords.

complications such as necrosis and blindness, making them the focal points of investigation (Figs. 9 and 11).

In this study, we conducted an analysis of articles pertaining to soft tissue filler injection by identifying them from the WoSCC database. We explored various aspects, including co-authorship, co-occurrence, and citation patterns among countries, institutions, authors, and hot spot keywords. Nevertheless, we restricted our analysis to English-language

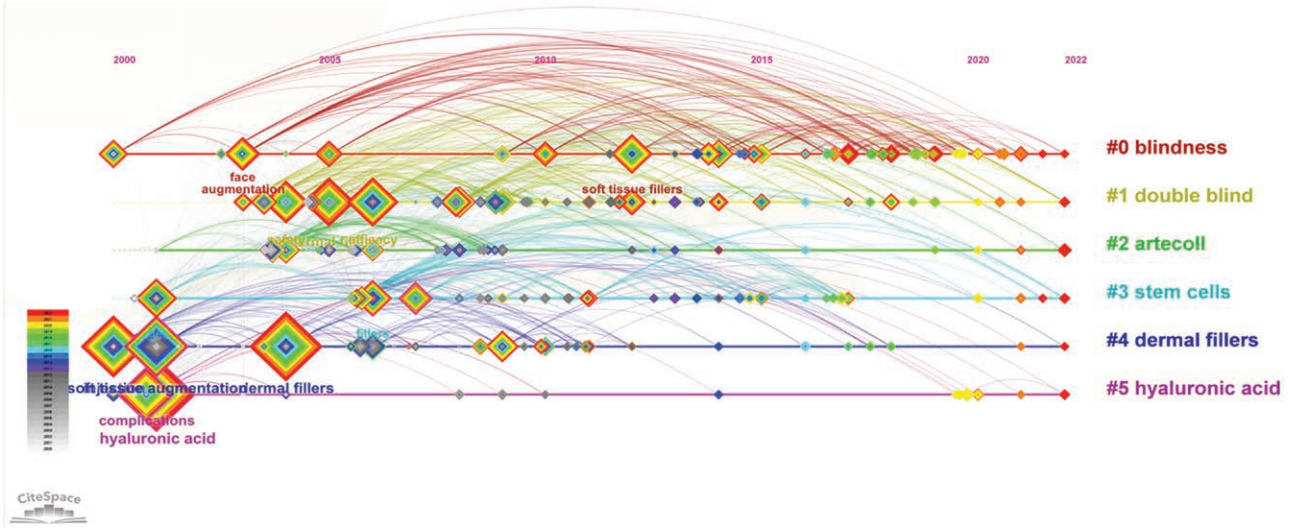

Fig. 11. Timeline visualization of keyword cluster analysis results from 2000 to 2022.

articles and solely relied on the WoSCC, which might not encompass all relevant databases. Consequently, the accuracy of our analysis may have been influenced.

CONCLUSIONS

Soft tissue filler injection has become a prominent subject in the realms of clinical and research domains within plastic and aesthetic surgery. Obtaining a comprehensive understanding of the trends and hotspots in this field is crucial to acquire valuable information. Our study offers a broad overview of the principal research directions in this field, emphasizing the contributions of the USA, as well as its affiliated institutions and authors. Prominent journals in this field include *Plastic and Reconstructive Surgery*, *Dermatologic Surgery*, and the *Journal of Cosmetic Dermatology*. Additionally, complications arising from filler injection and their prevention have garnered substantial attention and represent potential areas of future research focus. This study provides novel insights that can facilitate further research in this field.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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