DOI: 10.53660/CLM-4160-24T04

Facial rejuvenation: a bibliometric analysis

Received: 15-08-2024 | Accepted: 15-09-2024 | Published: 20-09-2024

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ABSTRACT

The escalating demand for facial rejuvenation (FR) procedures has paralleled a surge in scientific publications dedicated to this domain. This study aimed to carry out a bibliometric analysis of scientific articles concerning FR. To this effect, a search was carried out to identify all the articles on this topic in the Thomson Reuters Web of Science (WoS) database up to December 2023. Three researchers selected the scientific articles. The title, authors, country, year of publication, language, WoS category, title of scientific journals, topic of interest, and number of citations were extracted from each article. The search resulted in 2.214 published scientific articles. The articles found were published from 1979 onward, with the largest number published in 2020. The 100 most cited articles about FR were produced by groups of authors from the United States of America (56%). The scientific journal *Dermatologic Surgery* published 51 articles among the 100 most cited about FR. The analysis of citations revealed useful and interesting information about the scientific progress on this topic, with the last decade being the most productive, and articles related to techniques used in facial rejuvenation procedures having the highest citation rates.

Keywords: Facial rejuvenation, facial harmonization, facial fillers, bibliometric analysis.

INTRODUCTION

Advances in medicine and aesthetic requirements make treatments aimed at rejuvenating and beautifying the face constantly appear. Facial rejuvenation (FR) is based on aesthetic procedures that aim to promote a balance among the volume, shape, and angle of all parts of the face. Its main function is to highlight strong facial features and promote the correction of asymmetrical areas, in addition to improving the quality and support of facial tissues (Crowley et al. 2021).

Although FR has existed for 40 years, its practice has become one of the most prominent topics in the beauty industry in recent years (Carruthers A, 2003). According to the International Society of Aesthetic Plastic Surgery (ISAPS), Botulinum Toxin application and filling with Hyaluronic Acid are considered the most prevalent non-surgical procedures in the world. Besides that, other FR procedures aimed at the aesthetic and functional balance of the face, such as, collagen-inducing biomaterials, laser therapy, the application of enzymes, facial support wires, surgeries to remove facial fatty tissue and to correct the lips, orthognathic surgeries, and rhinoplasties (ISAPS, 2022).

Bibliometrics have been used in various fields of knowledge to obtain indicators to evaluate scientific production. In general, the principle of bibliometrics is to analyze scientific or technical activity through the quantitative study of publications (Kokol et al. 2021). The main goals of bibliometrics are to identify trends and the growth of knowledge in a given field of scientific research, to measure the degree of collaboration between authors, to analyze the processes of citation and co-citation, to evaluate the statistical aspects of language, words, and phrases, and to measure the growth of certain fields and the emergence of new topics (Tejasen, 2016). Besides, bibliometric studies can help explore scientific references over a subject, help researchers understand the trends on a given topic, and connect publications, authors, and journals while following scientific guidelines (Zupic & Cater, 2015). Additionally, the importance of bibliometric studies is supported by the need to know and evaluate the productivity and quality of the research of authors and researchers, allowing the detection of dispersion models and patterns of citation behavior in their scientific production (Mohadab et al. 2020). Therefore, it can be said that bibliometric studies have been increasingly requested and used to quantify production, as well as for purposes such as identifying groups and fields of academic excellence (Hawkins, 2001).

Based on the above, this study aimed to carry out a bibliometric analysis of scientific articles concerning FR, with a specific emphasis on elucidating characteristics in the knowledge of the production within this field.

MATERIALS AND METHODS

The study was carried out as previously described by Perazzo et al. 2019, with the aim of identifying all the articles mentioned in the "Core Collection" section of the Thomson Reuters Web of Science (WoS) database until December 2023. The search strategy was determined using specific keywords related to the field: TS = (facial rejuvenation OR facial harmonization OR face harmonization OR orofacial harmonization OR dermal fillers OR hyaluronic fillers and face OR facial fillers OR botulinum toxin AND face OR hyaluronic acid AND face OR polymethylmethacrylate AND face). The categories "Dermatology" and "Dentistry Oral Surgery Medicine" were selected to filter the articles.

The inclusion criteria were scientific articles or review articles focused on non-surgical procedures in FR, i.e., procedures performed under local anesthesia. The exclusion criteria adopted were scientific articles related to surgically invasive procedures performed under local or general anesthesia, such as lipoplasty of the face and neck, lip-lift surgery, orthognathic surgery, and rhinoplasty. Abstracts from scientific events and editorials were also excluded. No language or publication time restrictions were applied. Three researchers selected the scientific articles according to the selection criteria. Divergent opinions were resolved by consensus. The search results were organized in a list sorted by the number of citations in descending order. After the general search, the 100 most cited articles in the literature were filtered out. In the event of a tie, the article's position on the list was based on the highest average number of citations per year.

The title, authors, affiliation, country, year of publication, language, WoS category, title of scientific journals, topic of interest, position, number of citations, and the collaboration network between universities and authors were extracted from each article. The country was determined based on the corresponding author's affiliation.

VOSviewer software generated bibliometric networks (Van & Waltman, 2010). The authors were organized into clusters, each represented by a color. Authors with more citations had larger circles, and strongly related names were positioned close together.

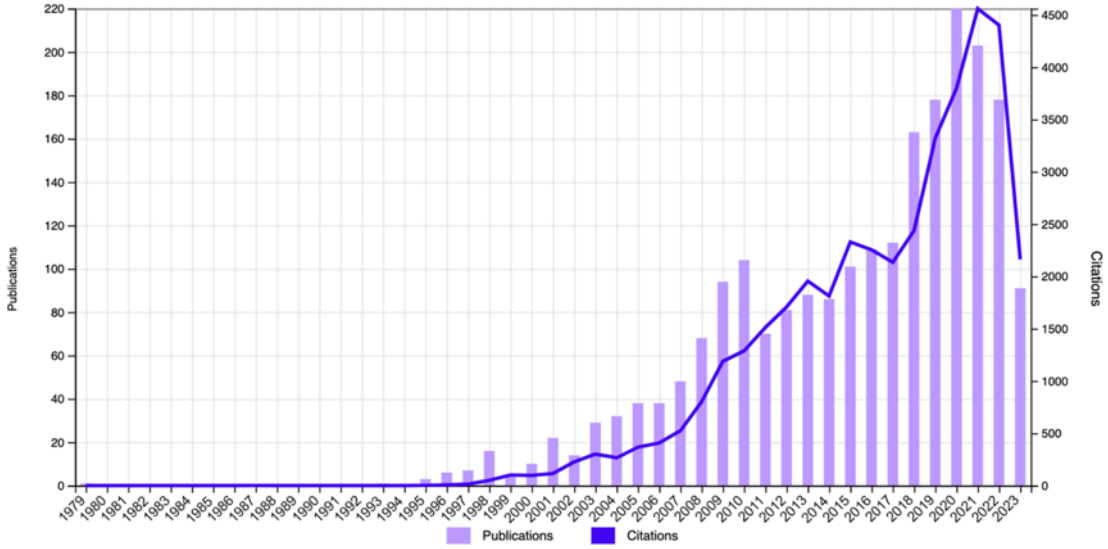
Lines were also drawn between items to indicate relationships, with thicker lines indicating a stronger link between two items (Van & Waltman, 2010; Van & Waltman, 2013).

RESULTS

General Bibliometric Analysis Of Scientific Articles Related To Fr

The search resulted in 2.214 published scientific articles. The articles found were published from 1979 onward, as shown in **Figure 1**.

Figure 1. Number of publications of scientific articles and citations over time (1979–2023) related to non-surgical facial rejuvenation procedures.



The largest number of published articles was found in 2020 (220 articles, 9.93% of the total), and the smallest number of published articles was found in 1979 (1 article, 0.04% of the total), as shown in **Table 1**.

Table 1. Quantification of scientific articles regarding non-surgical facial rejuvenation procedures over time (1979–2023).

YEAR OF PUBLICATION	NUMBER OF ARTICLES	% OF TOTAL (2.214)
2020	220	9.93
2021	203	9.16
2019	178	8.04
2022	178	8.04
2018	163	7.36
2017	112	5.05
2016	109	4.92

YEAR OF PUBLICATION	NUMBER OF ARTICLES	% OF TOTAL (2.214)
2010	104	4.69
2015	101	4.56
2009	94	4.24
2023	90	4.06
2013	88	3.97
2014	86	3.88
2012	81	3.65
2011	70	3.16
2008	68	3.07
2007	48	2.16
2005	38	1.71
2006	38	1.71
2004	32	1.44
2003	29	1.3
2001	22	0.99
1998	16	0.72
2002	14	0.63
2000	10	0.45
1997	7	0.31
1996	6	0.27
1999	4	0.18
1995	3	0.13
1993	1	0.04
1979	1	0.04

As for the type of publication found, 1.954 were categorized as full articles, and 260 were categorized as review articles. In addition, 2.154 (97.28%) were published in English, 24 (1.08%) in German, 23 (1.03%) in French, 11 (0.49%) in Spanish, 1 (0.045%) in Italian, and 1 (0.045%) in Portuguese.

As for the WoS category, 2.023 articles (91.37%) were found in the **"**Dermatology**"** category, 735 articles (33.19%) in the **"**Surgery**"** category, and 191 articles (8.62%) in the **"**Dentistry Oral Surgery Medicine**"** category, as shown in **Table 2**.

Table 2: Web of Science (WoS) category and the number of scientific articles published on the subject of non-surgical facial rejuvenation.

WoS CATEGORIES	QUANTITY	% of TOTAL (2.214)
Dermatology	2023	91.37
Surgery	735	33.19
Dentistry Oral Surgery Medicine	191	8.62
Chemistry Applied	12	0.54
Allergy	7	0.31
Biochemistry Molecular Biology	7	0.31
Geriatrics Gerontology	4	0.18
Engineering Biomedical	3	0.13
Critical Care Medicine	2	0.09
Pathology	2	0.09
Emergency Medicine	1	0.04
Materials Science Biomaterials	1	0.04
Pediatrics	1	0.04
Pharmacology Pharmacy	1	0.04
Radiology Nuclear Medicine Medical Imaging	1	0.04

Several countries published articles related to FR, including the United States of America (961 articles, 43.40%), Germany (230 articles, 10.38%), South Korea (196 articles, 8.85%), Brazil (151 articles, 6.82%), and Italy (151 articles, 6.82%), as shown in **Table 3**.

Table 3. Countries and the number of scientific articles related to non-surgical facial rejuvenation procedures.

COUNTRY	QUANTITY	% OF TOTAL (2.214)
United States of America	961	43.40
Germany	230	10.38
South Korea	196	8.85
Brazil	151	6.82
Italy	151	6.82
France	132	5.96
Canada	129	5.82
United Kingdom	126	5.69
China	124	5.60
Spain	80	3.61
Egypt	55	2.48
India	54	2.43
Switzerland	51	2.30
Israel	45	2.03
Thailand	45	2.03
Netherlands	44	1.98

COUNTRY	QUANTITY	% OF TOTAL (2.214)
Turkey	35	1.58
Iran	34	1.53
Australia	32	1.44
Belgium	30	1.35
Japan	30	1.35
Russia	30	1.35
Poland	28	1.26
Sweden	27	1.20
Taiwan	27	1.22

In terms of the number of articles published in scientific journals, the *Surgery Dermatology* journal published 479 articles (21.63%), the *Journal of Cosmetic Dermatology* published 438 articles (19.78%), the *Journal of Drugs in Dermatology* published 216 articles (9.75%), and the *Journal of Cosmetic and Laser Therapy* published 111 articles (5.01%), as shown in **Table 4**.

Table 4. Scientific journals and the number of articles related to the subject of non-surgical facial rejuvenation.

SCIENTIFIC JOURNALS	QUANTITY	% OF TOTAL (2.214)	IMPACT FACTOR*
DERMATOLOGIC SURGERY	479	21.63	2.40
JOURNAL OF COSMETIC DERMATOLOGY	438	19.78	2.30
JOURNAL OF DRUGS IN DERMATOLOGY	216	9.75	1.52
JOURNAL OF COSMETIC AND LASER THERAPY	111	5.01	1.20
CLINICAL COSMETIC AND INVESTIGATIONAL DERMATOLOGY	91	4.11	2.30
DERMATOLOGIC THERAPY	80	3.61	3.60
LASERS IN SURGERY AND MEDICINE	65	2.93	2.40
JOURNAL OF THE AMERICAN ACADEMY OF DERMATOLOGY	43	1.94	13.80
DERMATOLOGIC CLINICS	39	1.76	2.40
CLINICS IN DERMATOLOGY	30	1.35	2.70
SEMINARS IN CUTANEOUS MEDICINE AND SURGERY	29	1.31	0.57
JOURNAL OF DERMATOLOGICAL TREATMENT	26	1.17	2.90
JOURNAL OF ORAL AND MAXILLOFACIAL SURGERY	26	1.17	1.90
JOURNAL OF THE EUROPEAN ACADEMY OF DERMATOLOGY AND VENEREOLOGY	23	1.03	9.20
SKIN RESEARCH AND TECHNOLOGY	23	1.03	2.20
INTERNATIONAL JOURNAL OF DERMATOLOGY	22	0.99	3.60

SCIENTIFIC JOURNALS	QUANTITY	% OF TOTAL (2.214)	IMPACT FACTOR*
JOURNAL OF CRANIO MAXILLOFACIAL SURGERY	22	0.99	3.10
HAUTARZT	19	0.85	0.75
ANNALES DE DERMATOLOGIE ET DE VENEREOLOGIE	18	0.81	0.90
ANNALS OF DERMATOLOGY	18	0.81	1.60
ARCHIVES OF DERMATOLOGICAL RESEARCH	16	0.72	3.00
CUTIS	16	0.72	1.67
BRITISH JOURNAL OF DERMATOLOGY	14	0.63	11.11
DERMATOLOGY	14	0.63	3.40
AMERICAN JOURNAL OF CLINICAL DERMATOLOGY	11	0.49	7.30

* According to *Journal Citation Reports* (Clarivate Analytics, 2023).

Bibliometric analysis of the 100 most cited scientific articles on FR

The 100 most cited articles on FR were listed in descending order of the number of citations found in the **"**Core collection**"** section of WoS, as shown in **Table 5**. The most cited article was **"**Manstein D, Herron GS, Sink RK, Tanner H, Anderson RR. Fractional photothermolysis: a new concept for cutaneous remodeling using microscopic patterns of thermal injury. *Lasers Surg Med*;34(5):426-38, 2004," which was cited 1.115 times.

Table 5: The 100 most cited articles on FR listed in descending order of number of citations.

Position	Title of the scientific article	Year of publication	Number of citations (All Databases)
1	Fractional photothermolysis: A new concept for cutaneous remodeling using microscopic patterns of thermal injury	2004	1.115
2	A randomized, double-blind, multicenter comparison of the efficacy and tolerability of Restylane versus Zyplast for the correction of nasolabial folds	2003	393
3	The spectrum of laser skin resurfacing: Nonablative, fractional, and ablative laser resurfacing	2008	341
4	InjecTable hyaluronic acid gel for soft tissue augmentation - A clinical and histological study	1998	346
5	Successful and safe use of 2 min cold atmospheric argon plasma in chronic wounds: results of a randomized controlled trial	2012	326

Position	Title of the scientific article	Year of publication	Number of citations (All Databases)
6	In vivo stimulation of de novo collagen production caused by cross-linked hyaluronic acid dermal filler injections in photodamaged human skin	2007	345
7	Comparative Physical Properties of Hyaluronic Acid Dermal Fillers	2009	364
8	Avoiding and Treating Blindness From Fillers: A Review of the World Literature	2015	317
9	The science of hyaluronic acid dermal fillers	2008	307
10	Fractional photothermolysis: Current and future applications	2006	243
11	Non-invasive rejuvenation of photodamaged skin using serial, full-face intense pulsed light treatments	2000	270
12	Adverse reactions to dermal fillers: Review	2005	211
13	Adverse reactions to injecTable soft tissue fillers	2011	199
14	Understanding, avoiding, and managing dermal filler complications	2008	178
15	Physiochemical properties and application of hyaluronic acid: a systematic review	2016	171
16	Intense Pulsed Light (IPL): A Review	2010	174
17	Hyaluronic acid skin fillers: Adverse reactions and skin testing	2001	169
18	Comparison of the Rheological Properties of Viscosity and Elasticity in Two Categories of Soft Tissue Fillers: Calcium Hydroxylapatite and Hyaluronic Acid	2010	164
19	Soft tissue augmentation with Artecoll: 10-year history, Indications, techniques, and complications	2003	175
20	Ultrasound tightening of facial and neck skin: A rater-blinded prospective cohort study	2010	173
21	A Review of the Metabolism of 1,4-Butanediol Diglycidyl Ether-Crosslinked Hyaluronic Acid Dermal Fillers	2013	162
22	Injection necrosis of the glabella: Protocol for prevention and treatment after use of dermal fillers	2006	147
23	Treatment of InjecTable Soft Tissue Filler Complications	2009	144
24	Cosmetic denervation of the muscles of facial expression with botulinum toxin - A dose-response study	1996	146
25	Enhancing Structural Support of the Dermal Microenvironment Activates Fibroblasts, Endothelial Cells, and Keratinocytes in Aged Human Skin In Vivo	2013	146
26	Hyaluronic acid fillers	2006	140

Position	Title of the scientific article	Year of publication	Number of citations (All Databases)
27	Hypertrophic Scarring of the Neck Following Ablative Fractional Carbon Dioxide Laser Resurfacing	2009	128
28	Comparison of smooth-gel hyaluronic acid dermal fillers with cross-linked bovine collagen: A multicenter, double-masked, randomized, within-subject study	2007	164
29	Assessment of the safety and efficacy of poly-L-lactic acid for the treatment of HIV-associated facial lipoatrophy	2005	117
30	Basics of Dermal Filler Rheology	2015	124
31	Pain associated with injection of botulinum A exotoxin reconstituted using isotonic sodium chloride with and without preservative - A double-blind, randomized controlled trial	2002	115
32	Calcium hydroxylapatite filler for facial rejuvenation: A histologic and immunohistochemical analysis	2008	112
33	Radiofrequency in Cosmetic Dermatology: A Review	2012	112
34	Gel Properties of Hyaluronic Acid Dermal Fillers	2012	111
35	Radiofrequency facial rejuvenation: Evidence-based effect	2011	110
36	Botulinum toxin type A (Botox) for the neuromuscular correction of excessive gingival display on smiling (gummy smile)	2008	121
37	Botulinum toxin type A treatment for contouring of the lower face	2003	107
38	Human anti-hyaluronic acid antibodies: Is it possible?	2001	102
39	The Risk of Alar Necrosis Associated with Dermal Filler Injection	2009	104
40	The Asian Dermatologic Patient Review of Common Pigmentary Disorders and Cutaneous Diseases	2009	105
41	Host Tissue Interaction, Fate, and Risks of Degradable and Nondegradable Gel Fillers	2009	100
42	3D in-vivo optical skin imaging for topographical quantitative assessment of non-ablative laser technology	2002	108
43	Evaluation of plasma skin regeneration technology in low-energy full-facial rejuvenation	2007	104
44	Comparative Histology of Intradermal Implantation of Mono and Biphasic Hyaluronic Acid Fillers	2011	99
45	Validated Assessment Scales for the Upper Face	2012	97
46	Effects of CO_2 laser pulse duration in ablation and residual thermal damage: Implications for skin resurfacing	1996	96

Position	Title of the scientific article	Year of publication	Number of citations (All Databases)
47	A Case Series of Facial Depigmentation Associated With Low Fluence Q-Switched 1,064 nm Nd/YAG Laser for Skin Rejuvenation and Melasma	2010	93
48	Delayed immune-mediated adverse effects related to hyaluronic acid and acrylic hydrogel dermal fillers: clinical findings, long-term follow-up and review of the literature	2008	94
49	Validated Assessment Scales for the Lower Face	2012	97
50	Effect of injection techniques on the rate of local adverse events in patients implanted with nonanimal hyaluronic acid gel dermal fillers	2008	92
51	Delayed-Onset Nodules Secondary to a Smooth Cohesive 20 mg/mL Hyaluronic Acid Filler: Cause and Management	2015	91
52	Nonablative laser skin resurfacing using a 1540 nm erbium glass laser: A clinical and histologic analysis	2002	92
53	Facial rejuvenation with a nonablative 1320 nm Nd : YAG laser: A preliminary clinical and histologic evaluation	2001	93
54	Double-blind, half-face study comparing topical vitamin C and vehicle for rejuvenation of photodamage	2002	93
55	ASDS guidelines of care: InjecTable fillers	2008	88
56	Botulinum toxin type A in the treatment of excessive gingival display	2005	90
57	Phagocytosis of different particulate dermal filler substances by human macrophages and skin cells	2002	92
58	Volumizing Hyaluronic Acid Filler for Midface Volume Deficit: 2-Year Results from a Pivotal Single-Blind Randomized Controlled Study	2013	83
59	Multicenter, Randomized, Parallel-Group Study of the Safety and Effectiveness of OnabotulinumtoxinA and Hyaluronic Acid Dermal Fillers (24-mg/mL Smooth, Cohesive Gel) Alone and in Combination for Lower Facial Rejuvenation	2010	82
60	Rheological Evaluation of the Physical Properties of Hyaluronic Acid Dermal Fillers	2011	89
61	Repeated botulinum toxin A injections for the treatment of lines in the upper face: A retrospective study of 4,103 treatments in 945 patients	2007	84
62	In vivo Bio-Integration of Three Hyaluronic Acid Fillers in Human Skin: A Histological Study	2014	80
63	Cosmetic use of botulinum A exotoxin for the aging neck	1998	82
64	Gummy smile and botulinum toxin: A new approach based on the gingival exposure area	2010	86

Position	Title of the scientific article	Year of publication	Number of citations (All Databases)
65	Dermal fillers: pathophysiology, prevention and treatment of complications	2017	79
66	Effects of intense pulsed light on sun-damaged human skin, routine, and ultrastructural analysis	2002	86
67	Transarterial Degradation of Hyaluronic Acid Filler by Hyaluronidase	2014	78
68	Novel cosmetic patches for wrinkle improvement: retinyl retinoate- and ascorbic acid-loaded dissolving microneedles	2014	82
69	Aesthetic botulinum A toxin in the mid and lower face and neck	2003	78
70	Adverse effects when injecting facial fillers	2007	76
71	Botulinum toxin type A: History and current cosmetic use in the upper face	2001	80
72	Systematic review of the use of platelet-rich plasma in aesthetic dermatology	2015	79
73	A Randomized, Split-Face, Histomorphologic Study Comparing a Volumetric Calcium Hydroxylapatite and a Hyaluronic Acid-Based Dermal Filler	2014	78
74	Combination 532-nm and 1064-nm lasers for noninvasive skin rejuvenation and toning	2003	75
75	Outcomes of Polydioxanone Knotless Thread Lifting for Facial Rejuvenation	2015	77
76	Validated Assessment Scales for the Mid Face	2012	74
77	Surgery for foreign body reactions due to injecTable fillers	2006	75
78	COVID-19/SARS-CoV-2 virus spike protein-related delayed inflammatory reaction to hyaluronic acid dermal fillers: a challenging clinical conundrum in diagnosis and treatment	2022	72
79	The evolution of soft tissue fillers in clinical practice	2005	74
80	Multiple Pass Ultrasound Tightening of Skin Laxity of the Lower Face and Neck	2012	71
81	Botulinum toxin type A treatment of multiple upper facial sites: Patient-reported outcomes	2007	71
82	Cutaneous granulomatous reaction to injecTable hyaluronic acid gel	2006	72
83	Complications of injecTable synthetic polymers in facial augmentation	1997	71
84	Glycolic acid peels in the treatment of melasma among Asian women	1997	71
85	Lasers for facial rejuvenation: a review	2003	71

Position	Title of the scientific article	Year of publication	Number of citations (All Databases)
86	Facial Allergic Granulomatous Reaction and Systemic Hypersensitivity Associated With Microneedle Therapy for Skin Rejuvenation	2014	68
87	Ultrasound detection and identification of cosmetic fillers in the skin	2012	69
88	International consensus recommendations on the aesthetic usage of botulinum toxin type A (Speywood Unit) - part I: upper facial wrinkles	2010	75
89	A randomized study of the efficacy and safety of injecTable poly-L-lactic acid versus human-based collagen implant in the treatment of nasolabial fold wrinkles	2010	68
90	Platelet-rich fibrin matrix for improvement of deep nasolabial folds	2010	74
91	Surface Anatomy of the Lip Elevator Muscles for the Treatment of Gummy Smile Using Botulinum Toxin	2009	74
92	Late-onset granulomatous reaction to artecoll	2003	68
93	Resistant and Recurrent Late Reaction to Hyaluronic Acid-Based Gel	2016	69
94	Safety Study of Transcutaneous Focused Ultrasound for Non-Invasive Skin Tightening in Asians	2011	96
95	Facial volume restoration of the aging face with poly-l-lactic acid	2011	66
96	Persistence and improvement of nasolabial fold correction with nonanimal-stabilized hyaluronic acid 100,000 gel particles/mL filler on two retreatment schedules: Results up to 18 months on two retreatment schedules	2008	72
97	Retro or PeriBulbar Injection Techniques to Reverse Visual Loss After Filler Injections	2015	65
98	Anatomy of the Facial Fat Compartments and their Relevance in Aesthetic Surgery	2019	67
99	Systematic Review of Clinical Trials of Small- and Large-Gel-Particle Hyaluronic Acid InjecTable Fillers for Aesthetic Soft Tissue Augmentation	2013	64
100	Adverse cutaneous reactions to soft tissue fillers - a review of the histological features	2008	65

As for the scientific journals that published the 100 most cited articles on FR, the *Dermatologic Surgery* journal published 51 articles, followed by the *Journal of the American Academy of Dermatology***,** and *Lasers in Surgery and Medicine*, which published eight articles each, as shown in **Table 6**.

Table 6. Scientific journals and the number of articles published among the 100 most cited articles on non-surgical facial rejuvenation.

SCIENTIFIC JOURNAL	% OF ARTICLES	IMPACT FACTOR*
DERMATOLOGIC SURGERY	51	2.40
JOURNAL OF THE AMERICAN ACADEMY OF DERMATOLOGY	8	13.80
LASERS IN SURGERY AND MEDICINE	8	2.40
ARCHIVES OF DERMATOLOGY	4	3.07
JOURNAL OF THE EUROPEAN ACADEMY OF DERMATOLOGY AND VENEREOLOGY	4	9.20
JOURNAL OF COSMETIC DERMATOLOGY	3	2.30
AMERICAN JOURNAL OF ORTHODONTICS AND DENTOFACIAL ORTHOPEDICS	2	3.00
BRITISH JOURNAL OF DERMATOLOGY	2	11.11
DERMATOLOGIC THERAPY	2	3.60
JOURNAL OF DRUGS IN DERMATOLOGY	2	1.52
SEMINARS IN CUTANEOUS MEDICINE AND SURGERY	2	0.57
AMERICAN JOURNAL OF CLINICAL DERMATOLOGY	1	7.30
THE ANGLE ORTHODONTIST	1	3.40
ARCHIVES OF DERMATOLOGICAL RESEARCH	1	3.00
DERMATOLOGIC CLINICS	1	2.40
DERMATOLOGY	1	3.40
INTERNATIONAL JOURNAL OF COSMETIC SCIENCE	1	2.30
INTERNATIONAL JOURNAL OF DERMATOLOGY	1	3.60
JAMA DERMATOLOGY	1	10.09
JOURNAL DER DEUTSCHEN DERMATOLOGISCHEN GESELLSCHAFT	1	3.60
JOURNAL OF COSMETIC AND LASER THERAPY	1	1.20
JOURNAL OF CUTANEOUS PATHOLOGY	1	1.70
JOURNAL OF INVESTIGATIVE DERMATOLOGY	1	6.50

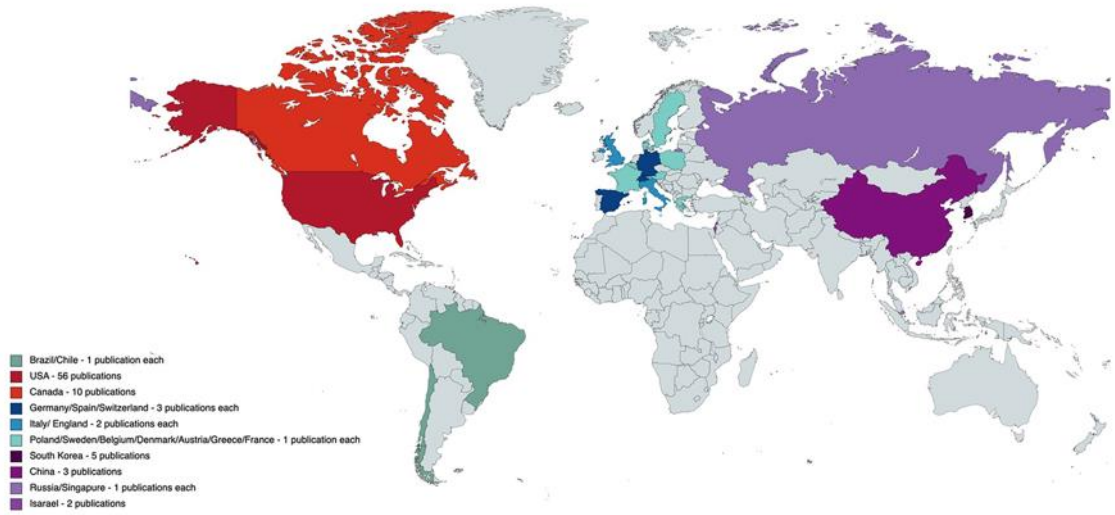
* According to *Journal Citation Reports* (Clarivate Analytics, 2023).

The oldest scientific article among the 100 most cited on FR was published in 1996, with the majority published between 2008 and 2012 (40%). English was the most used language (99%), followed by German (1%). The most published document type was **"**original article**"** (86%), followed by review articles (14%). The most frequently covered topics were facial rejuvenation/aesthetics (51%), followed by complications (26%) and biomaterial analysis (23%).

In general, the 100 most cited articles in FR were produced by groups of authors from the United States of America (56%), Canada (10%), and South Korea (5%). Articles

produced by groups of authors from countries such as Germany, Spain, Switzerland, and China were also cited (3% each). It is worth noting that only 1 group of authors from Brazil (1%) was included in the list of the 100 most cited articles in FR. Countries from Central America, Africa, and Oceania did not produce articles included in the 100 most cited in FR, as shown in **Figure 2**.

Figure 2. Worldwide distribution of the 100 most cited scientific articles on non-surgical facial rejuvenation according to country of origin.



The countries that received the highest number of citations were the United States of America (56 articles, 8.474 citations), followed by Canada (10 articles, 1.010 citations). The sole article produced by a group of authors from Brazil received 86 citations.

As for the authors' affiliations in the 100 most cited scientific articles on FR, authors from the University of California were present in 38 publications. Authors from Harvard University were present in 16 publications. Authors from the University of British Columbia were present in 10 publications. Authors from the Pontifical Catholic University of Rio Grande do Sul were present in 2 publications.

As for scientific relations between universities, it was possible to identify collaborations between the various campuses of the University of California with Harvard University, New York University, and the University of Miami (**Figures 3** and **4**). Although some American universities, such as the University of California, stand out for their large number of citations, there is only a clear collaborative network between universities in the United States.

Figure 3. A network of scientific collaboration between the University of California campuses and other institutions is present in the 100 most cited articles on facial rejuvenation.

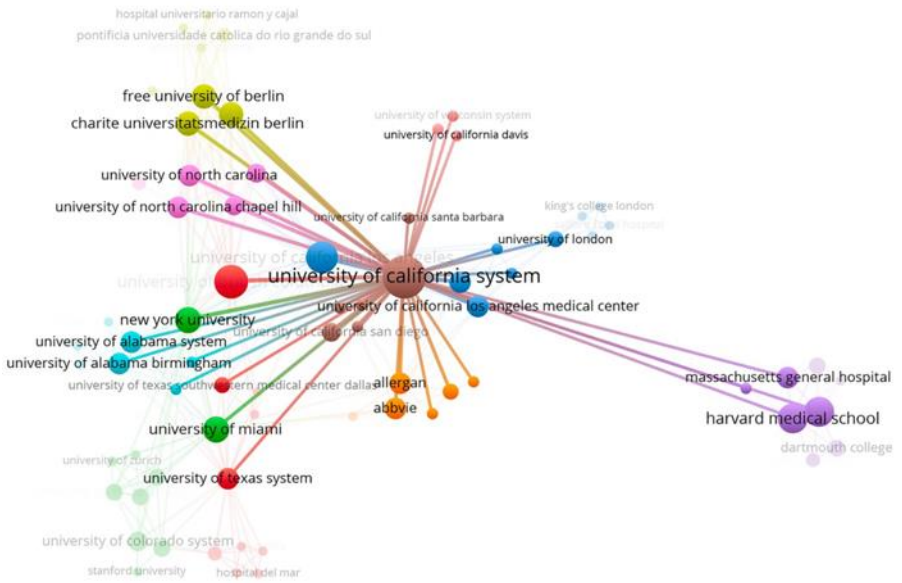
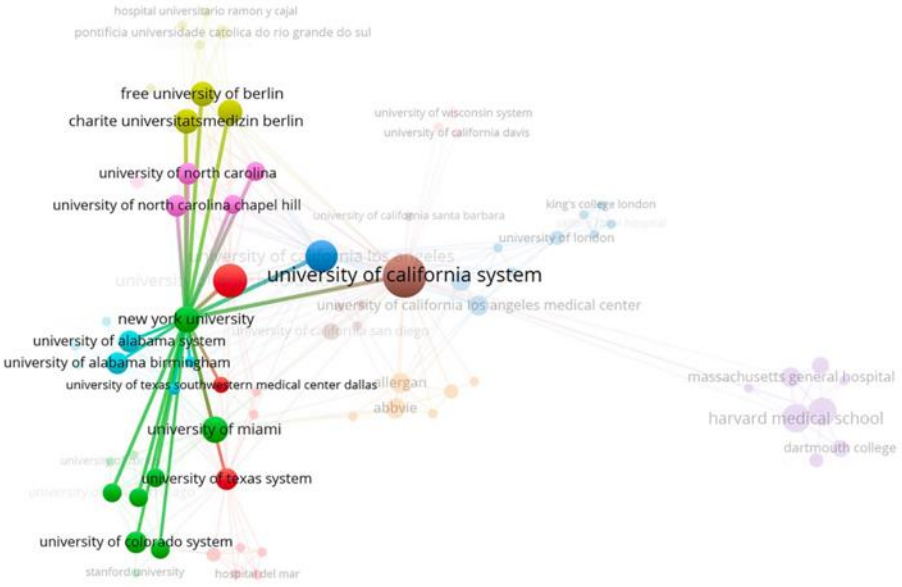
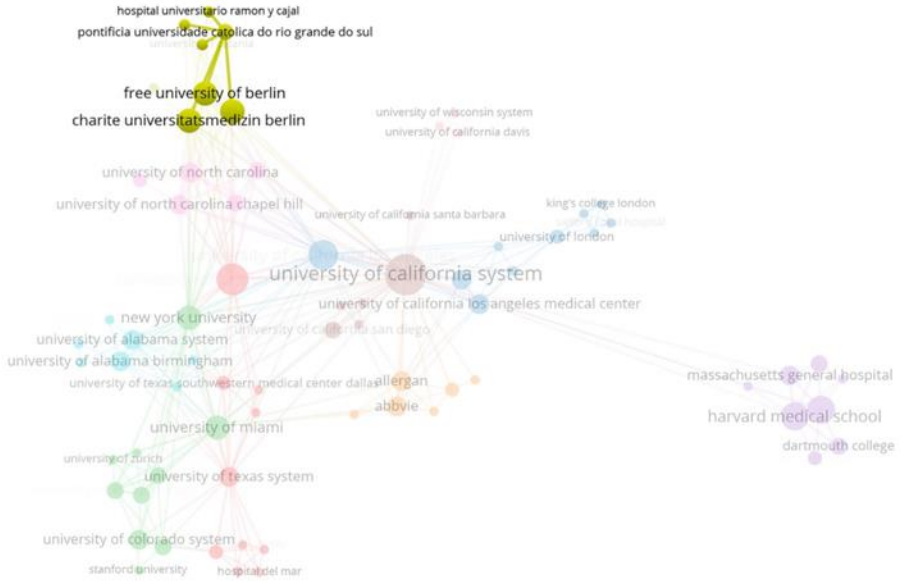


Figure 4. Network of scientific collaboration between New York University and other institutions present in the 100 most cited articles on facial rejuvenation.



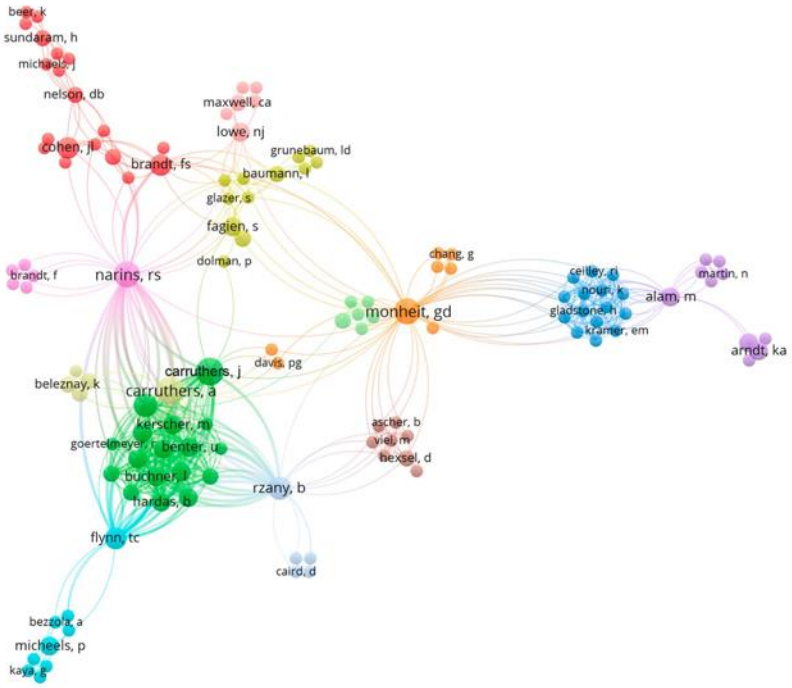
As for the collaborative network of Brazilian researchers came about through collaborations of the Pontifical Catholic University of Rio Grande do Sul with the Free University of Berlin (Germany) and the Ramón y Cajal University Hospital (Spain), as shown in **Figure 5**.

Figure 5. Network of scientific collaboration between the Pontifical Catholic University of Rio Grande do Sul and other institutions present in the 100 most cited articles on facial rejuvenation.



As for the authors with the most publications among the 100 most cited scientific articles in FR, Carruthers, JDA (University of British Columbia, Canada) participated in 10 publications; Carruthers, A (University of British Columbia, Canada) participated in 8 publications; Narins, RS (New York University School of Medicine, USA) participated in 7 publications; Monheit, GD (University of Alabama at Birmingham, USA) participated in 7 publications; Jones, D (University of California at Los Angeles, USA) participated in 5 publications; and Rzany, B (Charité University Hospital, Berlin, Germany) participated in five publications. It is worth noting that these authors are also co-authors, which increases their participation in bibliographic production, as shown in **Figure 6**.

Figure 6. Network of scientific collaboration between the authors of the 100 most cited articles on non-surgical facial rejuvenation.



Discussion

FR is a set of facial aesthetic procedures whose demand from patients and healthcare professionals has grown in recent years. Based on this subject, the present study aimed to carry out a bibliometric analysis of scientific articles on the topic of FR, focusing on understanding the production of knowledge worldwide. Firstly, all the articles found in the area of FR were analyzed globally using the predetermined keywords. Subsequently, the 100 most cited articles on this topic were analyzed.

As for the overall analysis of the articles, publications were found between 1979 (1 article, 0.04%) and 2023 (90 articles, 4.06%). However, the year with the most articles published was 2020 (220 articles, 9.93%). The direct relationship between the worldwide demand for FR procedures and knowledge production can explain this finding. This increase in demand was related to the rise in the use of facial filters on social media, which directly influenced the search for aesthetic procedures (Heydenrych et al. 2021; Hermans et al. 2022). Conversely, after 2020, there was a downward trend in the number of publications (203 publications in 2021 vs. 178 publications in 2022). This finding can be explained, at least in part, by the special attention paid by the scientific community to the COVID-19 pandemic, focusing mainly on new findings related to that problem (Nane

et al. 2023) and by the decrease in scientific activities in the initial phase of the pandemic (Myers et al. 2020).

Approximately 97% of the articles found were written in English, which was to be expected given that the search was carried out using keywords in this language. In addition, the English language is the standard commonly chosen by most researchers to reach the largest number of international readers and, consequently the largest number of citations (Di Bitetti & Ferreras, 2017). The countries that have published the most are the United States of America (961 articles), followed by Germany (230 articles), South Korea (196 articles), Brazil and Italy (151 articles each). This finding can be explained by the direct relationship between the search for aesthetic procedures and the amount of knowledge generated in this field since these countries perform the most procedures for aesthetic purposes in the world, both invasive and non-invasive (Heidekrueger et al. 2017). Additionally, when analyzing the scientific journals that published most articles on FR, *Surgery Dermatology* published 479 articles (21.63%), the *Journal of Cosmetic Dermatology* published 438 articles (19.78%), the *Journal of Drugs in Dermatology* published 216 articles (9.75%), and the *Journal of Cosmetic and Laser Therapy* published 111 articles (5.01%). These journals have an affinity with the field of dermatology, specifically in the sub-field of cosmetic procedures, and together, they published more than 56% of the articles.

When analyzing the 100 most cited articles on FR, the article with the largest number of citations was published in 2004 and was cited 1.115 times, with an average of 58.68 citations/year (Manstein et al. 2004). The article with the smallest number of citations was published in 2008 and was cited 65 times, averaging 4.33 citations/year Dadzie et al. 2008). It is worth noting that 43% of the 100 most cited articles on FR received more than 100 citations (104 to 1.115 citations). In addition, the majority of the 100 most cited articles in FR (51 articles) were on the subject of procedures related to facial/aesthetic rejuvenation techniques.

Regarding the journals that published the 100 most cited articles in FR, the journal *Dermatologic Surgery* (51 articles), which caters for the dermatology field, has an impact factor of 2.40. The second journal that published the 100 most cited articles in FR was the *Journal of the American Academy of Dermatology* (8 articles), also in the field of dermatology, with an impact factor of 13.80. Analyzing the impact factors together, the journals that published the 100 most cited articles have a mean impact factor of 3.51.

As for the country of origin of the 100 most cited articles in FR, the United States of America produced 56 articles (38 produced by the University of California alone), followed by Canada with ten articles (all produced by the University of British Columbia). These findings can be explained by the fact that these countries have important research centers and receive large amounts of funding for research (Shadgan et al. 2010). Additionally, it is possible to observe the fact that some countries, such as Germany, Italy, and Brazil, produced a large number of scientific articles according to the global analysis (230, 151, and 151 articles, respectively); however, only three articles produced by authors from Germany, two articles by authors from Italy, and 1 article with authors from Brazil appeared on the list of the 100 most cited articles on FR. Contrarily, the scientific articles produced by Canada (129 publications in the global analysis and ten publications among the 100 most cited) contradict this finding, with those articles being cited 1.010 times.

It is important to note that the number of citations an article receives is not necessarily a measure of the quality of the research; rather, it reflects its recognition by the scientific community and its influence in generating changes in practice, controversies, discussion, or future research (Fardi et al. 2010). Furthermore, one limitation of using the total number of citations an article has accumulated as a measure of impact is that older publications and journals are favored. Time can have various effects on an article's citation ranking. Over time, each article has a greater chance of being cited. In this context, an article's true impact and eminence cannot be accurately assessed for at least two decades (Fardi et al. 2010; Baltussen &Kindler, 2004).

Although the United States of America published the largest number of scientific articles (961 articles) and had the largest number of these in the category of the 100 most cited articles on FR (56 articles), when evaluating the main authors involved in the publications, Carruthers JDA and Carruthers A, both affiliated to the University of British Columbia (Canada), participated in 10 and 8 publications respectively, regardless of the order of authorship.

Finally, this study has some limitations inherent to the research methodology; for example, self-citations were not assessed. Therefore, future studies could consider more in-depth analyses of the impact of different types of self-citation (direct, co-authored, or collaborative).

CONCLUSION

The analysis of the number of citations revealed valuable and interesting information about scientific progress in the area, with the last decade being the most productive. Articles related to techniques used in facial rejuvenation procedures had the highest citation rates.

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