CLINICAL ORAL IMPLANTS RESEARCH

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Bibliometric analysis of the scientific production in implantology (2009–2013)

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Abstract

Objectives: To quantify, using bibliometric indicators, the scientific productivity of researchers, organizations, and countries, publishing articles on implantology in dental journals indexed in Journal Citation Reports between 2009 and 2013.

Materials and methods: Published texts were identified by applying the truncated search term "implant*." Document type was limited to "Article." Records were manually refined and normalized to unify terms and to remove typographical, transcription, and/or indexing errors.

Results: A total of 6088 articles were located. A progressive increase in the rate of publication was observed, especially between 2010 and 2012. This increase was clearly linked to increased collaboration between authors, institutions, and countries. Keywords appeared at a frequency of 3.1 per document. The journals *Clinical Oral Implants Research* and *International Journal of Oral & Maxillofacial Implants* published the highest numbers of articles.

Conclusions: This study revealed a significant growth in implant dentistry literature in terms of the total number of journals, number of authors, organizations, and author collaborations. Most key bibliometric indicators demonstrated upward trends.

Recent decades have seen major technological and biological advances in implant dentistry and increasing numbers of patients treated with dental implants (Jayaratne & Zwahlen 2015). Like any other dental specialty, implant dentistry is constantly evolving, particularly since the advent of modern implant techniques in the 1960s (Brånemark et al. 1977). As a result, implant dentistry now enjoys high levels of accuracy, functionality, comfort, esthetics, and quality assurance.

In tandem with technological developments in the field of dentistry, and especially in implant dentistry, scientific publication has grown progressively in terms of both the number of journals in existence and their content, doubling production in recent years. This is a common phenomenon across all biomedical disciplines where, in addition to the increased production of scientific papers, the number of co-authorships and organizational collaborations is also growing (Gazni et al. 2012). Several different theories explain this phenomenon, including the difficulty of researching individually and the growing need for multidisciplinary collaboration (Pulgar et al. 2013).

This growth in the rate of scientific publication requires analysis to allow the scientific community to quantify both outcomes and the impact of research. In this context, bibliometric indicators are useful and objective tools for evaluating the results of scientific activity (Bordons & Zulueta 1999; Geminiani et al. 2014), identifying the most productive authors, research centers, impact factors, and impact on subsequent work, as well as patterns of collaboration between published authors (López-Piñero & Terrada 1992a,b; Aleixandre-Benavent & Porcel-Torrens 2001; Moppett & Hardman 2011).

In recent years, several bibliometric studies of dental research have been published, including Kaur & Gupta (2011) about production in India, Gracio et al. (2013) who assessed the impact of research in Brazil, and Cartes-Velásquez & Manterola (2014) who analyzed publications dated between 2007 and 2011 cited in the category "dentistry" in the Web of Science database. Although several reviews have been published that deal with various topics related to dental implants, they provide only a limited and partial view of scientific production within implantology.

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To address the lack of bibliometric studies in this field, this study provides an overview of implantology during the 5-year period 2008–2013. Bibliometric indicators were used to quantify the scientific productivity of researchers, organizations, and countries publishing articles on implant dentistry in dental journals indexed in Journal Citation Reports; the study also analyzes the publishing rates of dental journals and authors' use of keywords.

Materials and methods

Search strategy

A search was conducted among the core collection of Thomson Reuters' Web of Science database, selected on the basis of its broad thematic and geographic coverage of health sciences. The documents identified were all original articles – the main vehicle for the dissemination of research results.

The search took place in July 2014, applying the truncated search term "implant*" to locate original articles on implant dentistry and its derivate forms. The search was conducted within the topic field (title, keywords, and abstract), and three inclusion criteria were applied: articles published during the 5-year period 2009–2013; only documents denominated as articles were included; and lastly, articles categorized as Web of Science Medicine Dentistry and Oral Surgery. Articles about orthodontics were excluded after a manual revision of title and abstract. The search identified a total of 6088 records.

All text files related to the 6088 records were entered in a Microsoft Access database, using self-developed software *Bibliometrics*.

Data normalization

Records were manually refined and normalized to unify terms and to remove typographical, transcription, and/or indexing errors; normalization was completed in the fields "Author," "Organization," and "Country of Origin."

Normalization was complicated by the numbers of different entries for a single author. In these cases, the institutional affiliations of the authors were consulted to check whether different entries belonged to the same author. If this information was not available, an Internet search was carried out to eliminate potential error.

Normalization of organizations followed the same procedure. Only macro-organizations (i.e., universities, and research centers) were included, discarding micro-organizations,

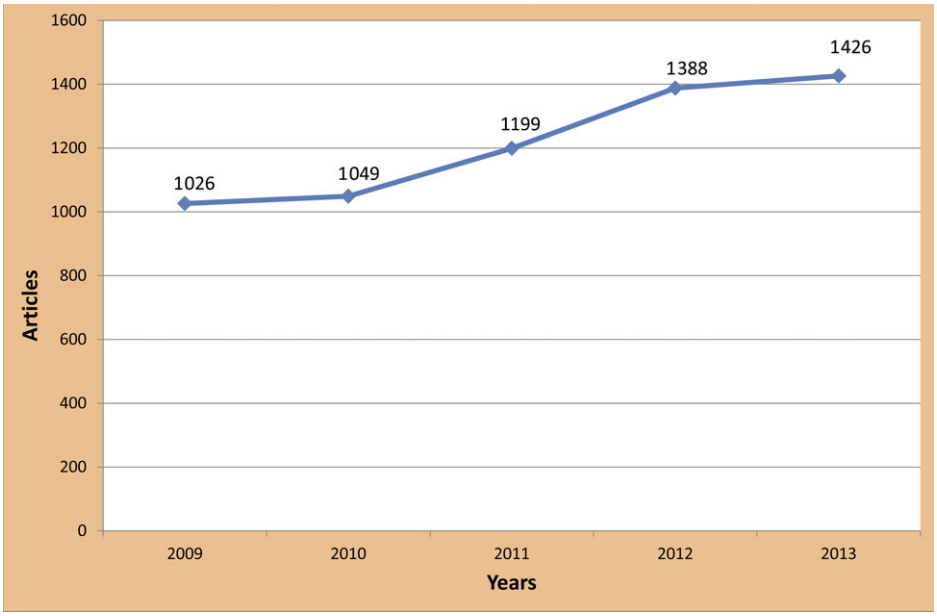

Fig. 1. Annual evolution of the scientific production.

Table 1. **The most productive authors (more than 30 published documents)**

Author	Organization	Country	Total docs	% Docs
Piattelli. Adriano	Università degli Studi G. d'Annunzio Chieti e Pescara	Italy	94	1.54
Lang. Niklaus Peter	University of Hong Kong	China	79	1.30
Wang. Hom-Lay	University of Michigan	United States	72	1.18
Coelho. Paulo Guilherme	New York University	United States	66	1.08
De Bruyn. Hugo	Ghent University	Belgium	51	0.84
Iezzi. Giovanna	University of Chieti-Pescara	Italy	50	0.82
Degidi. Marco	Private practice	Italy	42	0.69
Felice. Pietro	Università di Bologna	Italy	42	0.69
Jung. Ronald Ernst	University of Zurich	Switzerland	42	0.69
Penarrocha-Diago. Maria A.	University of Valencia	Spain	42	0.69
Esposito. Marco	University of Gothenburg	Sweden	41	0.67
Kim. Su-Gwan	Chosun University	South Korea	41	0.67
Haemmerle. Christoph Hans Franz	University of Zurich	Switzerland	39	0.64
Raghoebar. Gerry M.	University of Groningen	the Netherlands	38	0.62
Sennerby. Lars	University of Gothenburg	Sweden	38	0.62
Bonfante. Estevam Augusto	Unigranrio University	Brazil	37	0.61
Buser. Daniel	University of Bern	Switzerland	37	0.61
Kim. Young-Kyun	Seoul National University	South Korea	36	0.59
Perrotti. Vittoria	University of Chieti-Pescara	Italy	36	0.59
Shibli. Jamil Awad	Guarulhos University	Brazil	36	0.59
Jansen. John A.	Radboud University Nijmegen	the Netherlands	35	0.57
Schlegel. Karl Andreas	University of Erlangen-Nuremberg	Germany	35	0.57
Botticelli. Daniele	Ardec Rimini	Italy	34	0.56
Meijer. Henny J. A.	University of Groningen	the Netherlands	33	0.54
Penarrocha-Diago. Miguel	University of Valencia	Spain	33	0.54
Suzuki. Marcelo	Tufts University	United States	33	0.54
Schwarz. Frank	Düsseldorf University	Germany	32	0.53
Vissink. Arjan	University of Groningen	the Netherlands	32	0.53
Bornstein. Michael M.	University of Bern	Switzerland	31	0.51

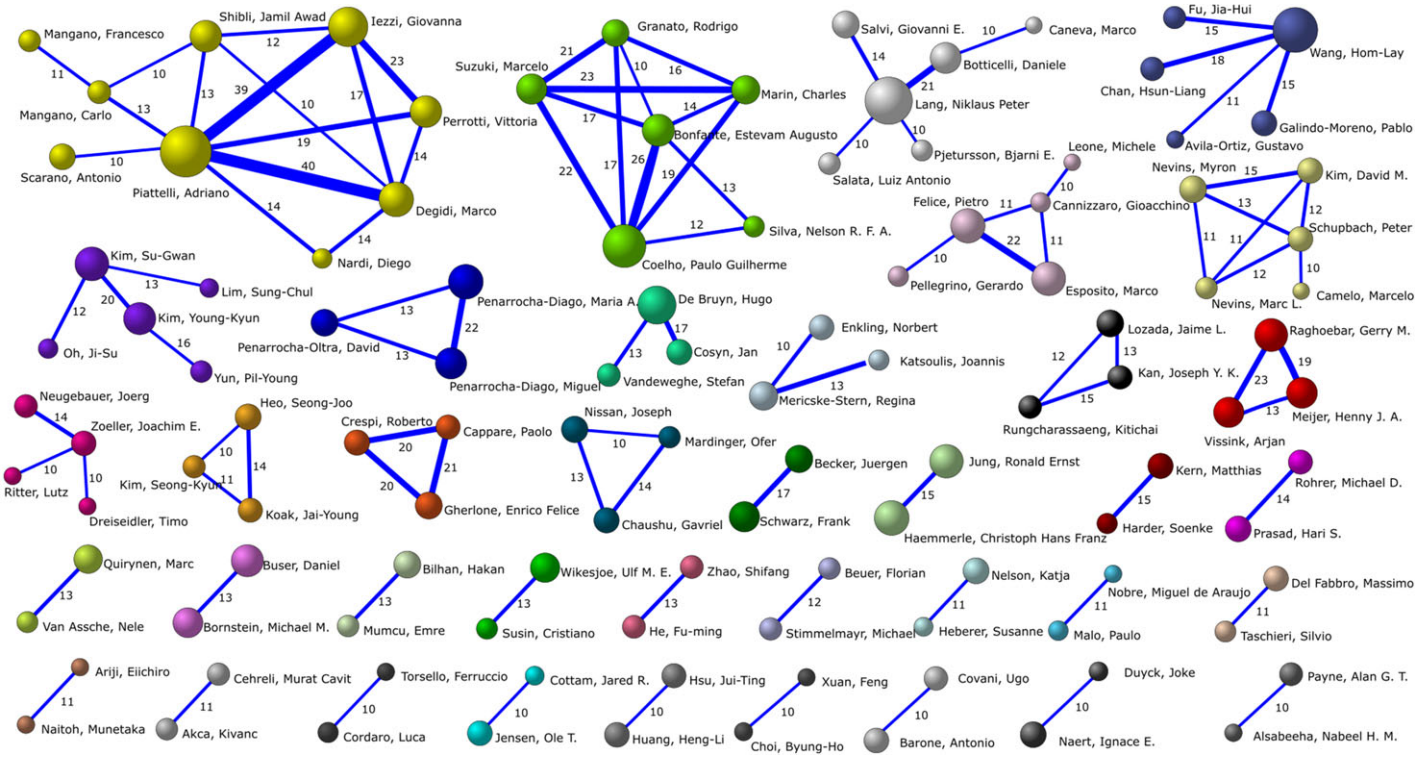

Fig. 2. Authors' social network (10 or more collaborations).

such as individual departments or research units. When the same organization signed the same work more than once, it was only counted once. The "Country" field was also normalized.

Due to the heterogeneity of keywords entered, the research team decided to categorize key terms for data normalization.

Data analysis

Descriptive analysis of variables and crosstables was performed using Microsoft Access and Excel software. The evolution of scientific productivity by authors, organizations, countries, and journals was assessed, as well as the frequency of appearance of keyword categories. Analysis and visualization of large networks were performed using Pajek software (http://vlado.fmf.uni-lj.si/pub/networks/pajek/).

Results

The 5-year period 2009–2013 saw the publication of 6088 original articles. A progressive increase in the number of publications took place, with a growth rate of 39% (Fig. 1), although this increase occurred mainly between 2010 and 2012 (31%).

Author production

The 6088 documents were authored by 14,050 different authors with a total of 28,419 signatures, making an average of 4.66 authors per document.

Table 1 shows the 29 most productive authors. The most productive was Piatelli, Adriano ($n = 94$) from the Università degli Studi G. d'Annunzio Chieti e Pescara (Italy), followed by Lang, Peter Niklaus ($n = 79$) from the University of Hong Kong, and Wang, Hom-Lay from the University of Michigan ($n = 72$).

Analysis of author distribution in relation to productivity found that the highest (>10 articles published) producers ($n = 255$; 1.8%) made up 17.5% of signatures, whereas the lowest (with a single article published) producers ($n = 9609$; 68.4%) represented 33.8% of signatures.

Fig. 2 shows 38 research networks including 113 authors, in which the network led by Adriano Piattelli (involving up to 10 authors) stands out. The size of nodes (balls) marking vertices is proportional to the number of articles published by each author, with Piattelli in first place (94 documents), followed by Lang (79), Wang (72), and Coelho (66). These nodes/vertices (authors) represent the lead authors of the 4 most significant research networks. A total of 26 of the 29 most productive authors were integrated in collaborative networks.

Organization production

All of the 39 most productive organizations (with 50 or more published documents) were universities (Table 2). Two universities published more than 200 works: the University of Gothenburg ($n = 232$) and Sao Paulo State University ($n = 202$). But generally speaking, the most productive organizations were located in Europe ($n = 20$).

Fig. 3 illustrates networks of inter-organizational collaboration (applying a threshold of 10 or more collaborations). The varying thickness of the links shows the intensity of collaboration.

Country productivity

Table 3 shows that the United States participated in 1418 articles, followed by Germany ($n = 702$), Italy ($n = 673$), and Brazil ($n = 641$).

Networks of international collaboration were formed applying a threshold of 10 or more collaborations. Fig. 4 shows that the United States and Germany were the most collaborative countries and entered into the highest numbers of international collaborations.

Keywords

A total of 4813 (79.1%) of the 6088 records were indexed using some type of keyword (Table 4), with an average frequency of 3.1 keywords per document of 2.45 over the total. "Implant" (2944) was the most commonly used keyword, followed by "bone" (2218) and "prosthesis" (1400).

Table 2. **The most productive institutions (50 or more published documents)**

Institution	Country	Total docs	% Docs
University of Gothenburg	Sweden	232	3.81
Sao Paulo State University	Brazil	202	3.32
University of Sao Paulo	Brazil	186	3.06
University of Bern	Switzerland	175	2.87
New York University	United States	145	2.38
Università degli Studi Gabriele D'Annunzio	Italy	137	2.25
Seoul National University	South Korea	125	2.05
University of Michigan	United States	114	1.87
University of Hong Kong	China	110	1.81
Harvard University	United States	100	1.64
Università degli Studi di Milano	Italy	98	1.61
Malmo University	Sweden	88	1.45
University of Zurich	Switzerland	87	1.43
Universidad Complutense de Madrid	Spain	81	1.33
Yonsei University	South Korea	81	1.33
Tufts University	United States	78	1.28
University of Texas San Antonio	United States	77	1.26
State University of Campinas	Brazil	75	1.23
Università di Bologna	Italy	74	1.22
Catholic University of Leuven	Belgium	68	1.12
Istanbul University	Turkey	65	1.07
Tel Aviv University	Israel	65	1.07
Ghent University	Belgium	64	1.05
University of Washington	United States	63	1.03
Ohio State University	United States	58	0.95
Università degli Studi di Napoli Federico II	Italy	58	0.95
University of Groningen	the Netherlands	58	0.95
University of Southern California	United States	58	0.95
Johannes Gutenberg University of Mainz	Germany	57	0.94
Radboud University Nijmegen	the Netherlands	57	0.94
Medical University of Vienna	Austria	56	0.92
Universidad de Valencia	Spain	56	0.92
Loma Linda University	United States	55	0.90
University of Erlangen-Nuremberg	Germany	55	0.90
University of Pennsylvania	United States	53	0.87
University of California Los Angeles	United States	52	0.85
University of Freiburg	Germany	52	0.85
University of Geneva	Switzerland	51	0.84
Academic Centre for Dentistry Amsterdam (ACTA)	the Netherlands	50	0.82

Journals

Table 5 shows the 13 most productive journals, which published more than 150 papers each. Among them, four are located in the first quartile, 6 in the second quartile, and three in the third quartile; 10 of them are edited in the United States, and three are European (two from Denmark and one from Scotland). *Clinical Oral Implants Research* (n = 847) and *International Journal of Oral & Maxillofacial Implants* (n = 746) have the highest production. The remaining 11 journals published between 374 and 154 papers.

Discussion

This study evaluated scientific production and collaboration within the field of implant dentistry in recent years. The 5-year period analyzed (2009–2013) saw an increase in the number of published articles on implant dentistry, an increase also seen within other dental disciplines (Jayaratne & Zwahlen 2015).

As expected, the most productive authors are renowned specialists in dentistry and most of them are linked to health institutions or universities. The most productive author was Adriano Piatelli from the University of Chieti-Pescara in Italy; paradoxically, this organization is not one of the most productive.

The average number of authors per paper was 4.66, which is a figure close to other medical fields, for example, 5.3 in Virology (5.3) (Ruiz-Saenz & Martinez-Gutierrez 2015) and 6.23 in Cardiology (Valderrama-Zurián et al. 2007). Other studies in biomedicine reveal that the average number of authors per article increased from 4.5 in 1980 to 6.9 in 2000 (Weeks et al. 2004). This increase in co-authorship can be explained by the growing complexity of medical practice and a growing need for interdisciplinary research (Bhopal et al. 1997; Scott 1997), which has even become a condition imposed by some funding sources (Relman 1984; Fenning 2004; Valderrama-Zurián et al. 2007).

The study showed that increased scientific production is obviously linked to increased collaboration. Co-authorship networks offer several advantages including the sharing of valuable information, the possibility of incorporating new researchers into well-established networks, and allowing established researchers to multiply their contacts within the field and participate more actively in discussion forums.

The co-authorship networks identified in the present study show that authors collaborate more frequently with authors belonging to the same organization and/or country. The most productive authors enjoy higher than the average rates of collaboration. Recent bibliometric data reveal that dental literature, including specialty publications, is now of higher quality and greater complexity – a reflection of the growing collaboration between researchers and research teams (Barão et al. 2011; Gutiérrez-Vela et al. 2012; Kanavakis et al. 2016). The two main organizational collaboration networks identified were a European network and an American network, and the two networks interlinked via collaboration between Malmo University and New York University.

The United States was seen to be the largest contributor, a finding that agrees with similar bibliometric studies (Rahman & Fukui 2003; Zyoud et al. 2015). However, analyzing the most productive organizations, the University of Gothenburg in Sweden was the most prolific producer. Although Sweden is a small country, it has one of the longest traditions of implant dentistry, mainly due to Dr. Branemark, the father of modern implantology and the inventor of osseointegrated implants (1977). The second most productive organizations are two universities in Sao Paulo (Brazil).

The present study found that the most productive institutions are Universities, a situation that differs from other medical specialties such as Pediatrics, in which hospitals play a major role in scientific production (Alonso-Arroyo et al. 2013). Countries in the same collaborative network were usually

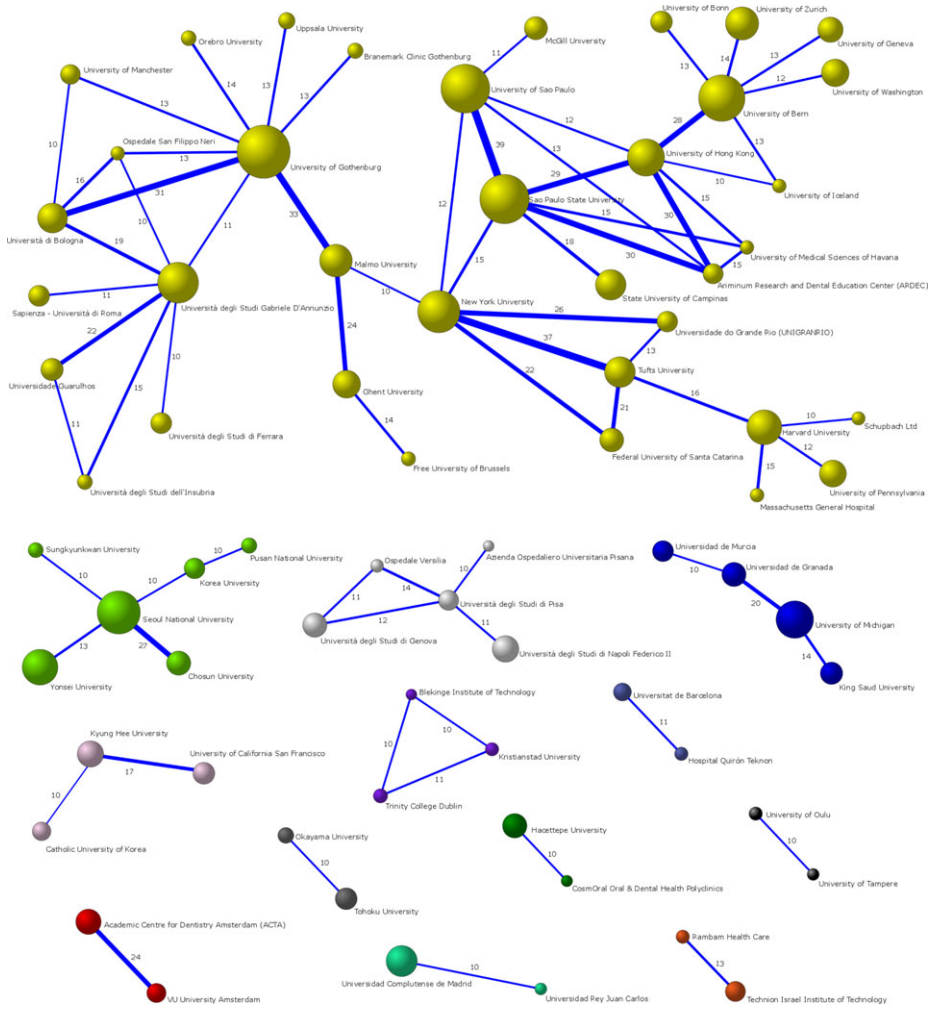

Fig. 3. Organizations' social network (10 or more collaborations).

found to be located on one continent, although the study identified a trend toward increasing collaboration between European and American countries.

Obviously, the most commonly used keyword used was "implant," followed by "bone" and "prosthesis." Authors often used very general keywords such as "Diagnostic," "Pathology," or "Factors," which are difficult to group. Interestingly, a frequently used term is "implant failure." Another focus of interest was survival and complication rates; the attention paid to complications is closely related to initiatives to improve treatment outcomes, reduce treatment costs, and increase patient satisfaction (Pjetursson et al. 2014).

The articles identified in the present study were published in 79 journals. Ten of the 13 most productive journals are based in the United States, a finding that matches other related disciplines such as orthodontics (Kanavakis et al. 2016). English is the most usual language of publication, the *lingua franca* of the scientific community (Vasconcelos et al. 2007; Gutiérrez-Vela et al. 2012). The 13 most productive

Table 4. **List of the most frequent Keywords (more than 100 appearances)**

Keywords	*N*	% (over articles with keywords)
Implant	2944	61.17
Bone	2218	46.08
Prosthesis	1400	29.09
Anatomy	1277	26.53
Surgery	972	20.20
Material	915	19.01
Diagnosis	847	17.60
Pathology	783	16.27
Success factors	624	12.96
Type of analysis	601	12.49
Risk factors	322	6.69
Patients	257	5.34
Histology	245	5.09
Properties	173	3.59
Treatment	164	3.41
Drugs	156	3.24
Implant failure	127	2.64

Table 3. **The most productive countries (more than 100 published documents)**

Country	Total docs	% Docs
United States	1418	23.29
Germany	702	11.53
Italy	673	11.05
Brazil	641	10.53
Switzerland	388	6.37
Sweden	377	6.19
South Korea	371	6.09
Spain	350	5.75
Japan	349	5.73
China	339	5.57
Turkey	292	4.80
United Kingdom	235	3.86
the Netherlands	182	2.99
Belgium	153	2.51
Israel	136	2.23
Canada	127	2.09
France	118	1.94
Australia	108	1.77
Austria	103	1.69

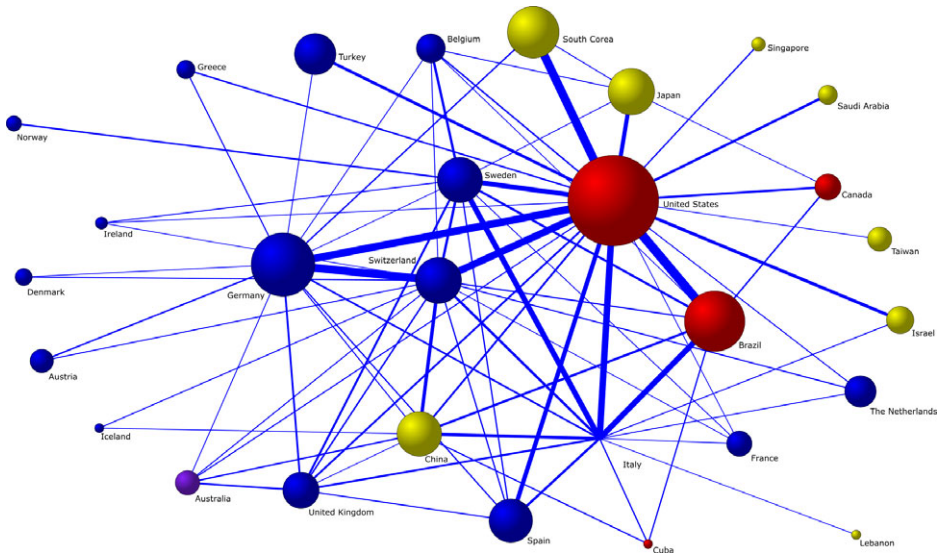

Fig. 4. Countries' social network (10 or more collaborations).

Table 5. **The most productive journals (more than 150 published papers)**

Journal	ISSN	Total Docs	Country	IF 2014	Quartile	Position
Clinical Oral Implants Research	0905-7161	847	Denmark	3.889	1	3
International Journal of Oral & Maxillofacial Implants	0882-2786	746	United States	1.451	2	37
Implant Dentistry	1056-6163	374	United States	1.175	3	48
Journal of Oral and Maxillofacial Surgery	0278-2391	337	United States	1.425	2	38
Clinical Implant Dentistry and Related Research	1523-0899	311	United States	3.589	1	7
Journal of Oral Implantology	0160-6972	308	United States	1.016	3	61
Journal of Periodontology	0022-3492	229	United States	2.706	1	14
International Journal of Periodontics & Restorative Dentistry	0198-7569	212	United States	1.415	2	39
Journal of Clinical Periodontology	0303-6979	185	Denmark	4.010	1	2
Journal of Prosthetic Dentistry	0022-3913	179	United States	1.753	2	24
Oral Surgery Oral Medicine Oral Pathology Oral Radiology	2212-4403	172	United States	1.261	3	88
International Journal of Oral and Maxillofacial Surgery	0901-5027	154	Scotland	1.565	2	31
International Journal of Prosthodontics	0893-2174	154	United States	1.464	2	36

journals cover the fields of implant dentistry, periodontology, or prosthetics.

In conclusion, recent years have seen a significant growth in implantology literature in terms of the number of journals, number of authors, research organizations, and author collaborations. Most bibliometric indicators demonstrated upward trends. While providing a self-evaluation for the dental community, these findings could be valuable to editors and publishers of dental journals, as well as dental and implantology professionals.

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