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The Growth of Dental Implant Literature from 1966 to 2016: A Bibliometric Analysis

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Abstract

This bibliometric book chapter overviewed the dental implant literature from 1966 to 2016 via the Web of Science database. Articles and reviews published by 2016 on the topic of dental implants were identified and analyzed in terms of their authors, affiliations, countries/territories of the affiliations, journal title and journal category. The performance indices of the 10 journals with the highest numbers of dental implant publications were extracted from Journal Citation Reports. A total of 14,335 articles or reviews were published in 1081 academic journals, with majority (10,487; 73.2%) in dental journals. With 317,263 total citations, each publication was cited 22.1 times on average. About 10 journals accounted for 47.0% of total publications, five dedicated to dental implants. Performance indices of journals publishing dental implant manuscripts have been stable over the last decade. *Clinical Oral Implants Research* was the best performing journal among them in 2016.

Keywords: dental implants, bibliometric, impact factor, literature, publication

1. Introduction

Dental implantation is a treatment option for replacement of teeth missing due to disease or trauma. It has gained substantial support from oral healthcare providers and patients over the last two to three decades [1–3]. The popularity of this treatment modality has sparked numerous related research activities. Dental implant researches have assisted the evidence-based clinical practice of implant dentistry to a great extent. Multiple papers have critically and systematically reviewed the importance and relevancy of how such research results inform clinical practice [4–7]. These publications assessed the outcomes of researches that aimed at answering specific, important

questions regarding dental implants and thus were expected to be read by a large audience. On the other hand, related bibliometrics could also be important to educators, researchers and healthcare workers in the dental field via analyzing the statistics of academic literature related to dental implantology. Such analyses have identified the most cited implant articles [8–10], popular implant research topics [11–13], highly cited topics [14], publication bias of implant journals [15, 16], and the distribution of evidence, which informs disease etiology, diagnosis, therapy and prognostic aspects relevant to dental implants [17]. They also can reveal the sources of past and recent research funding supporting the corresponding intellectual development [18, 19] and the quality assessment of implant case series [20] and systematic reviews/meta-analyses [21].

As more patients have become aware of dental implants as an option to replace missing teeth, the research fields of dental implantology have diversified and are receiving more attention. Usually the latest advancements in technology or treatment guidelines are published and distributed by academic journals. Since 94% of dental practitioners would place implants or refer patients with such treatment need to a colleague for the procedure, they benefit from keeping up to date on information on various aspects of dental implantation [3]. With the expansion of dental implant literature, it is crucial for practitioners and educators to quickly identify the leading literature from dental implant journals or other resources which would best potentially inform their practice and fulfill their continuous education needs. Past studies have tracked the time trends in journal performance indices, such as the Impact Factor, for selected journals in dentistry [22], public health [23], radiology [24] and medicine [25]. However, to the best knowledge of the authors, no published studies have investigated specifically the academic performance of journals dedicated to dental implants or which include many dental implant publications which inform the academic development concerning the field of implant dentistry.

Hence, this chapter aimed to track the dental implant publication counts over the last 50 years with considerations of annual trend and background publishing information, and then to identify the most productive journals and analyze their performance over the last decade. The implications of the findings were also discussed.

2. Study on dental implant literature

2.1. Literature search

The Thomson Reuters Web of Science database indexes academic publications and was the source of data for the study. The Web of Science database has been considered the golden standard to be used to extract and analyze bibliometric data of the existing scientific literature [26–30]. To identify appropriate keywords to perform a literature search, we searched the Medical Subject Headings (MeSH) library developed by the United States National Library of Medicine (NLM). The term “dental implantation” was used from 1966 to 1989 and was replaced by “dental implants” in 1990. In the Web of Science Core Collection database, we employed the term “dent* implant*” to search the “topic” of each record in the database. This would search for “dental implant” and its variants such as “dental implants” and “dental implantation” within the title, abstract and keywords of each indexed publication.

Publications from 2018 were excluded since the annual record was incomplete at the time of this study. Only articles and reviews were included.

The remaining records were described in terms of their annual trend of publications and citations. The publications were sorted by journal categories, journal titles, languages, countries/territories, organizations and authors. We analyzed the top 10 journals with the highest numbers of dental implant publications by examining their shares of the total publication counts. Further, we accessed the online version of Thomson Reuters Journal Citation Reports (JCR) to extract data of their bibliometric metrics, namely Impact Factor, Immediacy Index and Eigenfactor Score over the last decade from 2007 to 2016. The Impact Factor is a renowned metric, whereas the Immediacy Index indicates how fast articles in that journal are cited, and Eigenfactor Score is similar to Impact Factor but gives weighting to the citing journals and excludes the influence of self-citations. The bibliometric metrics of the top 10 dental journals with highest numbers of dental implant publications were tracked and examined.

The distributions of these dental implant publications among authors and journals were evaluated regarding whether they followed Price's law or Bradford's law, respectively. Price's law [31] states that half of the publications are written by a number of authors that equals to the square root of all authors. Meanwhile, Bradford's law [32] states that if journals are ranked according to their publication count and divided into three groups, with each group publishing one third of all papers, then the number of journals in each group should be in the ratio of $1/n/n^2$. In brief, a few core journals accounted for one third of all dental implant papers published, whereas many other journals each published a few only.

2.2. Survey outcome

The Web of Science Core Collection database was accessed on 6 March 2018. A search for the topic of "dent* implant*" in all years returned 17,954 records. After excluding records from 2017 and 2018, 16,002 records remained. Year 2017 was excluded because Impact Factor data was not yet available. After selecting only articles and reviews, 14,809 records remained. Publications within this pool were double-checked by the "Analyze Results" function to examine their document types, and subsequently 469 proceedings papers, 4 book chapters and one retracted publication were excluded. Finally, the search returned 14,335 documents, of which 13,283 were articles and 1052 were reviews.

2.2.1. Overview of the dental implant literature from 1966 to 2016

The first dental implant publication indexed in the Web of Science Core Collection was published in 1966. For the following two decades, the annual publication count was consistently below 15. The annual count reached 30 in 1990, and the dental implant literature has been steadily growing ever since, exceeding 100 publications in 1996 and 1000 in 2012. During the study period of 1966–2016, there were totally 14,335 dental implant publications that received 317,263 citations. On average, each publication was cited 22.1 times.

From 1966 to 2016, the 14,335 dental implant publications were recorded in 1081 academic journals distributed in 143 journal categories. There were 10,487 (73.2%) publications in

“Dentistry, Oral Surgery & Medicine” journals, 2765 (19.3%) in “Engineering, Biomedical”, 1056 (7.4%) in “Materials Science, Biomaterials” and 901 (6.3%) in “Surgery”. Note that these categories were not mutually exclusive since a journal could be assigned to multiple categories. For example, *Clinical Oral Implants Research* was indexed in the “Dentistry, Oral Surgery & Medicine” and “Engineering, Biomedical” categories and accounted for 57.3% (1584/2765) records of the latter category.

The 10 journals with the highest numbers of dental implant publications accounted for 47.0% of total publication count. Five of them were dedicated to dental implants, namely *International Journal of Oral & Maxillofacial Implants* (1621 publications; 11.3%), *Clinical Oral Implants Research* (1584; 11.1%), *Clinical Implant Dentistry and Related Research* (574; 4.0%) and *Implant Dentistry* (528; 3.7%) and *Journal of Oral Implantology* (418; 2.9%). The other five journals were not dedicated to dental implants but also belonged to the “Dentistry, Oral Surgery & Medicine” category (**Figure 1**). They were *Journal of Periodontology* (712; 5.0%), *Journal of Prosthetic Dentistry* (392; 2.7%), *Journal of Oral and Maxillofacial Surgery* (378; 2.6%) and *International Journal of Periodontics and Restorative Dentistry* (285; 2.0%) and *International Journal of Oral and Maxillofacial Surgery* (242; 1.7%). Three of these 10 journals each had 10% share of the total citation count (**Figure 1**). The first, second and last one-third of the articles and reviews were published by five, 32 and 1044 journals respectively (**Table 1**). If $n = 32$, the predicted distribution would be 1:32:1024. The actual distribution had more journals publishing the first one-third of all papers than predicted.

It is worth mentioning that some journals from the “Materials Science, Biomaterials” category represented a considerable share of the dental implant literature. *Biomaterials* had 148 (1.0%) publications. *Journal of Biomedical Materials Research* (published until 2002) had 95 (0.7%) publications, *Journal of Biomedical Materials Research Part A* (published since 2003) had 118 (0.8%) publications, and *Journal of Biomedical Materials Research Part B Applied Biomaterials* (published since 2003) had 103 (0.7%) publications, so in total 316 articles were published in the *Journal of Biomedical Materials* series. However, none of the biomaterials journals, when considered individually, had a larger total publication count than the tenth most prolific journal mentioned above (*International Journal of Oral and Maxillofacial Surgery*).

Most of the publications were in English (13,903; 97.0%), followed by German (166; 1.2%), French (58; 0.4%), Korean (57; 0.4%) and Spanish (37; 0.3%). All other languages had less than 30 indexed publications. Among the 109 countries/territories that the authors represented, the 10 countries with which the most institutions affiliated were the United States (3266; 22.8%), Italy (1633; 11.4%), Germany (1444; 10.1%), Brazil (1330; 9.3%), Sweden (876; 6.1%), Japan (817; 5.7%), Switzerland (813; 5.7%), South Korea (811; 5.7%), China (792; 5.5%), and Spain (775; 5.4%).

More than 5600 organizations have published on dental implants. The 10 most productive organizations were University of Gothenburg (510; 3.5%), University of Bern (357; 2.5%), São Paulo State University (356; 2.5%), University of Chieti-Pescara (351; 2.4%), University of São Paulo (343; 2.4%), University of Texas (280, 2.0%), University of Milan (262; 1.8%), New York University (261; 1.8%), University of Michigan (260; 1.8%), and Harvard University (228; 1.6%).

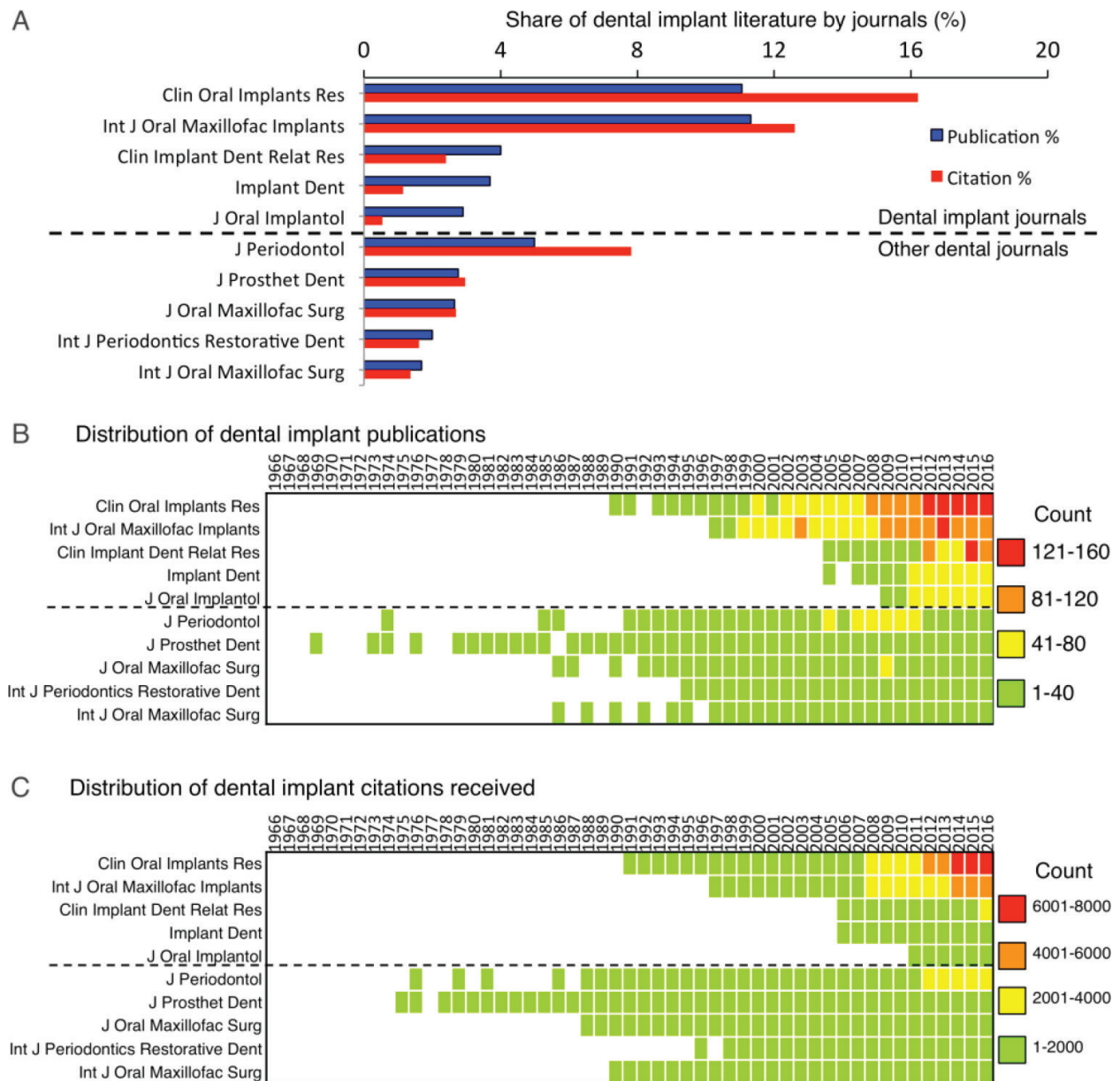


Figure 1. Time trend of annual publication counts for dental implant articles and reviews from 1966 to 2016 by the 10 most prolific journals which publish dental implant articles. (A) Publication and citation share of dental implant literature by journals; (B) distribution of dental implant publications over the survey period; (C) distribution of dental implant citation received over the survey period.

Over 28,800 authors have published on dental implants. Each author has published an averaged number of 2.3 papers (SD, 4.7). Over 80% of authors published either 1 (18,806; 65.2%) or 2 (4519; 15.7%) papers. The most prolific 164 authors have written 7641 articles or reviews, which roughly followed Price's law (170 authors should have written 7168 papers). The 10 most productive authors were Adriano Piattelli (251; 1.8%), Hom-Lay Wang (167; 1.2%), Marco Esposito (137; 1.0%), Niklaus P. Lang (121; 0.8%), Gerry M. Raghoobar (116; 0.8%), Paulo G. Coelho (104; 0.7%), Giovanna Iezzi (103; 0.7%), Daniel Buser (100; 0.7%), Antonio Scarano (96; 0.7%) and Henry J.A. Meijer (95; 0.6%).

	Journal	Pub count
Zone 1	International Journal of Oral Maxillofacial Implants	1621
	Clinical Oral Implants Research	1584
	Journal of Periodontology	712
	Clinical Implant Dentistry and Related Research	574
	Implant Dentistry	528
Zone 2	Journal of Oral Implantology	418
	Journal of Prosthetic Dentistry	392
	Journal of Oral and Maxillofacial Surgery	378
	International Journal of Periodontics Restorative Dentistry	285
	International Journal of Oral and Maxillofacial Surgery	242
	Journal of Clinical Periodontology	225
	Journal of Craniofacial Surgery	184
	European Journal of Oral Implantology	170
	International Journal of Prosthodontics	159
	Biomaterials	148
	Journal of Oral Rehabilitation	136
	Journal of Dental Research	129
	Journal of Prosthodontics Implant Esthetic and Reconstructive Dentistry	124
	Implantologie	122
	Journal of Biomedical Materials Research Part A	118
	Quintessence International	112
	Journal of Cranio Maxillofacial Surgery	110
	Medicina Oral Patologia Oral Y Cirugia Bucal	110
	Journal of Biomedical Materials Research Part B Applied Biomaterials	103
	Clinical Oral Investigations	98
	Journal of Materials Science Materials in Medicine	97
	Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology	97
	Journal of Biomedical Materials Research	95
	Dental Materials	87
	Journal of The American Dental Association	86
	Dentomaxillofacial Radiology	85
	British Journal of Oral Maxillofacial Surgery	83
	Materials Science Engineering C Materials for Biological Applications	82
	Journal of Periodontal and Implant Science	80

Journal	Pub count
Clinical Advances in Periodontics	79
Journal of the Korean Association of Oral and Maxillofacial Surgeons	75
Journal of Advanced Prosthodontics	67

They are listed in descending order of implant original articles or reviews published from 1996 to 2016.

Table 1. Journals that published the first (zone 1, also known as core journals, as defined by Bradford’s law) and second (zone 2) one-thirds of the publications.

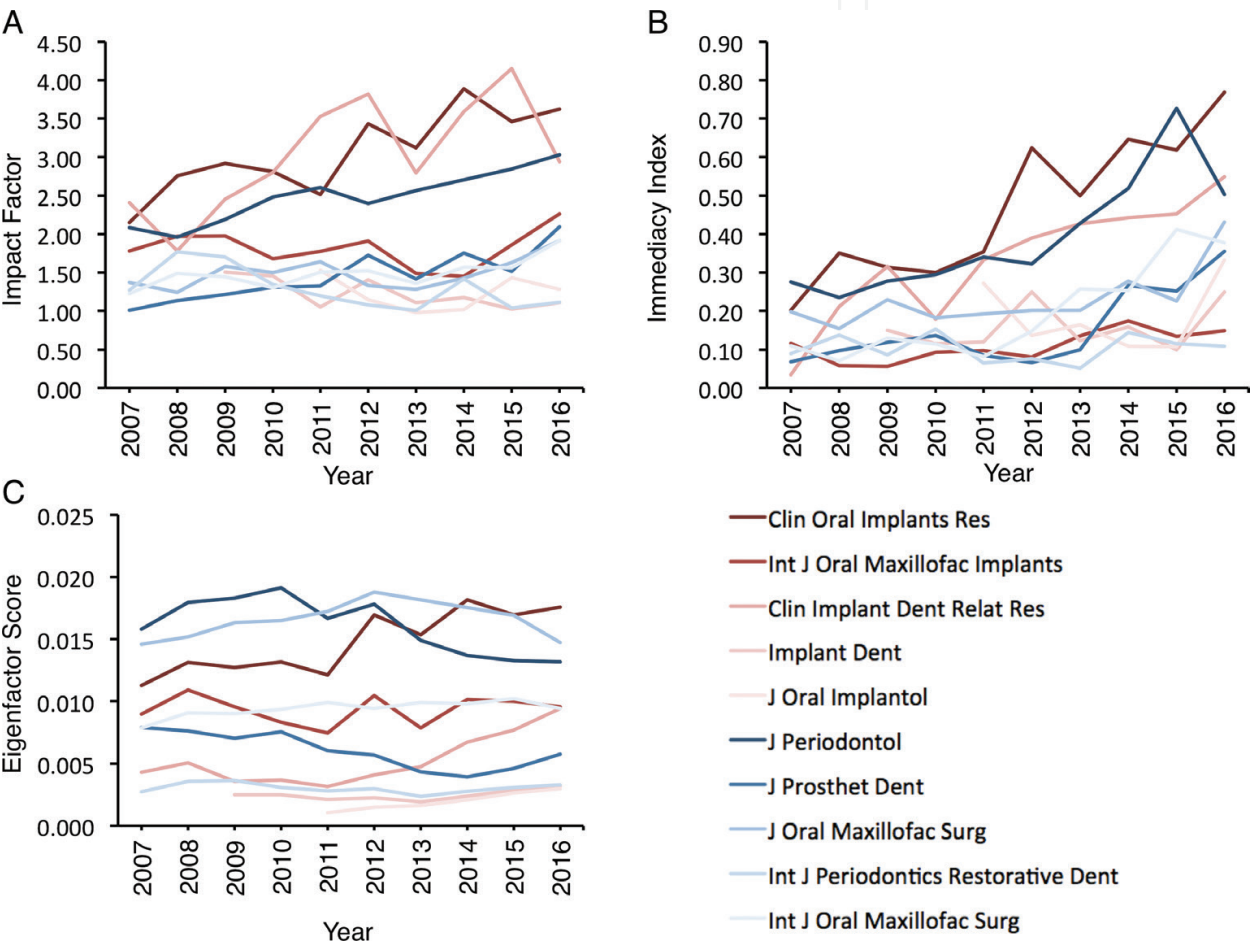


Figure 2. Performances of the 10 most prolific journals which published dental implant articles over the last decade (2007–2016) in terms of (A) impact factor, (B) immediacy index and (C) Eigenfactor score. The data lines for dental implant journals are in red, while those for other dental journals are in blue.

2.2.2. Performances of 10 selected journals in the last decade of 2007–2016

The top 10 journals with the highest numbers of dental implant publications were compared. The latest data published by JCR (bibliometric metrics in the year 2016) showed that *Clinical Oral Implants Research* had the highest Impact Factor (3.624; **Figure 2**), highest Immediacy Index (0.769; **Figure 2**) and highest Eigenfactor Score (0.0176; **Figure 2**) among the 10 journals

with the highest numbers of dental implant publications. Over the entire period of 2007–2016, the Impact Factor of the journals stayed approximately within the range of 1–4. For an exploratory analysis, linear regressions have shown a significant linear increasing trend of the Impact Factor for most of these journals (except *International Journal of Oral and Maxillofacial Implants*, *Journal of Oral Implantology* and *International Journal of Periodontics Restorative Dentistry*) over the survey period. Similarly, most of these journals had a significant linear increasing trend of the Immediacy Index (except *Implant Dentistry*, *Journal of Oral Implantology* and *International Journal of Periodontics Restorative Dentistry*).

3. Discussion

Reported here is the first account that reviewed trends in the dental implant literature all the way from the 1960s to the present while simultaneously examining the bibliometric metrics of representative journals over the last decade. Since the early studies of dental implants were published half a century ago, nearly three quarters of the successive publications have been within dental journals. It has been suggested that the increase in dental implant publications in recent years can be attributed to the increased collaboration between authors, institutions and countries [12]. Given the substantial increase observed in the annual publication count of dental implant articles and reviews, it was demonstrated that dental implantology has emerged as an important research field in dentistry. The distribution of publications followed Price's law, implying that there are dominant authors who have strong contributions to the field. However, the distribution of publications showed more journals publishing the first one-third of all papers than predicted by Bradford's law, implying that readers should look for multiple journals instead of a single journal when they want to search for implant publications. Another implication is that no single journal is dominating the publishing market of dental implant papers as predicted by Bradford's law.

European scientists and clinicians were key players in dental implant research who were responsible for three fifths of the total publications from 1966 to 2016, and 5 of the 10 most productive organizations were in Europe. North America came in second, as it was responsible for one quarter of the publications and had three organizations in the top 10. Asia and South America were responsible for one fifth and one tenth of the publications respectively. Unlike Barão et al.'s [19] work, which classified the geographic origin of articles by the location of corresponding authors, the counts of geographic origin in this study were not mutually exclusive, and thus we could not directly compare the figures reported in the two studies. However, Barão et al. [19] reported that Europe accounted for nearly half of the articles published in five selected implant-related journals from 2005 to 2009, while North America and Asia accounted for one fifth each. These findings implied that the bulk of the dental implant researches were based in Europe, and they were consistent with the fact that major implant brands were based in Europe, such as Nobel Biocare (Zurich, Switzerland) and Straumann (Basel, Switzerland).

Russo et al. [17] reported that *Clinical Oral Implants Research*, *International Journal of Oral & Maxillofacial Implants*, *Journal of Prosthetic Dentistry* and *Journal of Oral & Maxillofacial Surgery* were the four most productive journals, accounting for nearly 50% of the dental implant papers

published from 1994 to 1999. Our results confirmed that they were among the top 10 journals with the highest numbers of dental implant publications over the last 50 years. However, these four journals only accounted for 28% of the all-time implant publications included in our study. This difference may be considered in several aspects. First, there was a difference in search criteria. While Russo et al. [17] searched for English articles on human dental implants on MEDLINE database, we searched for all dental implant articles and reviews on the Web of Science database. Another important consideration was that recently introduced implant-specific journals might have taken a share, such as *Clinical Implant Dentistry and Related Research*, which started in 1999, and *European Journal of Oral Implantology*, which started in 2008. Meanwhile, Tarazona et al. [13] has evaluated implant literature contributed by Spanish researchers and concluded that the *Clinical Oral Implants Research* and *Medicina Oral Patologia Oral y Cirugia Bucal* were the most prolific journals. This has implied that certain journals may have a regional preference. In fact, the research topics or types of studies are also geographic dependent. A previous survey [19] has reported that clinical studies were mostly conducted by North American and European research teams supported by industrial funding, whereas the Asian and South American research teams were more focused on *in vitro* or animal studies supported by governmental funding.

Besides implant journals, periodontology and oral and maxillofacial surgery journals have also been major publishing grounds for implant manuscripts, as demonstrated previously by the H-classics method [9]. Consistent to our results, it was reported that *Journal of Clinical Periodontology* and *Journal of Periodontology* have been publishing many highly cited implant articles [10], and that implantology was the most frequent field of publication in *Journal of Oral and Maxillofacial Surgery* and *International Journal of Oral and Maxillofacial Surgery* [33]. Despite the changes in the dental implant research field, *Clinical Oral Implants Research* has stayed in the mainstream. Regardless of whether the time frame was across the entire half-century period or limited to the last decade, *Clinical Oral Implants Research* was responsible for around one tenth of publications. In 2016, it had the highest Impact Factor, Immediacy Index and Eigenfactor Score. The performances of the dental journals publishing dental implant literature have been relatively consistent over the last decade in terms of Impact Factor, Immediacy Index and Eigenfactor Score. In particular, *Clinical Oral Implants Research*, *Clinical Implant Dentistry and Related Research* and *Journal of Periodontology* had the best and generally increasing Impact Factor and Immediacy Index, whereas *Clinical Oral Implants Research*, *Journal of Periodontology* and *Journal of Oral and Maxillofacial Surgery* had the best Eigenfactor Score. These findings are comparable to a previous study that reported the relative consistency of performance indices of the top five and bottom five dental journals [22]. From a recent citation analysis of the implant literature [14], papers dealing with peri-implantitis and implant survival / success / failure had higher averaged citation count than papers dealing with other topics. As implant dentistry is becoming more popular and readily available to patients, we expect these journals would publish more papers related to these hot topics and continue to have an increasing Impact Factor in the near future.

The scientific value or academic impact of the research findings or ideas reported from an article or review will eventually depend on its usage. With regards to dental implant research, findings should ultimately inform or transform clinical practice instead of staying merely as a piece of scientific publication. However, most of the key bibliometric indices are based on citation analysis of the journals instead of the individual articles or reviews. Moreover, citations

themselves may not accurately reflect the academic merit earned by the cited publications. For instance, a paper could be cited to highlight its flaws [34]. Researchers may read an article or review, discuss it with colleagues, cite it, teach students based on its findings, or incorporate the findings into their evidence-based practice of dentistry. However, the current performance indices of the journals are unable to determine which actions readers have taken after reading the articles or reviews.

There are so-called altmetrics that track and evaluate the impact of articles apart from citation count; for instance, by recording the number of mentions in Twitter, Facebook, Wikipedia, news blogs, etc. [35–38] Similar to citation count, these altmetrics are also tracked by different companies, such as Altmeter and PlumX, which have different counts and give different weights to the individual components to be tracked. Several studies have concluded that the altmetrics data cannot correlate well with the citation count data and are concentrated on recent publications, meaning that the publications published before the introduction of the altmetrics often receive zero or very low score of altmetrics count [35–38].

It should be noted that this study was limited to analyses of publication trend as well as bibliometric data of dental implant articles and reviews without investigating the publication contents. The results from this study should be interpreted together with those from other studies that investigated the types of clinical information contained in dental implant publications [17], publication bias of implant journals [15, 16], the source of funding and internationalization of dental implant journals [19], and the trend of surgical and prosthetic topics concerning dental implantology [11]. From previous studies it seems that the research topics gaining popularity in recent years have been immediate loading, platform switching, lateral sinus grafting, flapless implant surgery and guided implant surgery [11]. Meanwhile, the all-time most cited dental implant articles were mainly dealing with implant success/survival, peri-implant tissue healing and health, guided bone regeneration and biomechanical topics [10, 39]. Implant outcome and peri-implantitis were keywords with increased citations since 2014 [14]. All these findings have suggested that the clinical research of dental implant has been popular and may readily be translated to clinical practice.

As for future perspectives, previous studies have suggested that most of the dental implant publications reported positive significant results [15, 16]; future studies can also consider evaluating if the dental implant journals are willing to publish replication studies or not. As in the fields of neuroscience [40] and psychology [41] journals usually do not explicitly welcome replication studies in their aims and scope and instructions to authors, this may be explored in dental implant field to help understand the publication bias issue. Together, these findings should be able to give the readers a better understanding and more comprehensive picture of the dental implant literature.

4. Conclusion

The current book chapter has summarized the results from a bibliometric study on dental implant literature over the last 50 years. Precisely, the publication data extracted from Web of

Science online database was broken down and analyzed according to the background of the articles and reviews in terms of authors, countries/territories, affiliations and journals. The number of dental implant publications has grown steadily since the 1990s, with the United States being the most productive country and Europe being the predominant continent in terms of publishing. Four of the five journals with the highest numbers of dental implant publications were dedicated to dental implant researches. *Clinical Oral Implants Research* accounted for 11% of total publications. It was also the best performing journal within this research field in 2014, topping the most productive journals with dental implant publications in terms of Impact Factor, Immediacy Index and Eigenfactor Score. The distribution of publications followed Price's law among the authors but had more journals publishing the first one-third of all papers than predicted by Bradford's law.

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Conflict of interest

The authors declare no conflict of interest.

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