

A bibliometric analysis of top 100 most-cited articles in dentistry with author(s) affiliated with Taiwan institutes

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Abstract

Background: Citation analysis can provide a historical perspective in the advancement of research, evolution, and areas of research. Taiwan exhibits rigorous academic and scientific activities in dentistry; however, based on its empirical contribution in research, there is no report in the literature analyzing the top-cited articles published by authors affiliated with Taiwan institutes. The purpose of this study was to analyze the citation characteristics of the top 100 most-cited articles published in dentistry with author(s) affiliated with Taiwan institutes.

Methods: The Scopus database was used to search the qualified articles with authors from Taiwan published in journals. The bibliometric parameters, including year of publication, study design, research fields, citation half-life, self-citation, institute of origin, and international collaboration were analyzed. Multivariable linear regression in generalized linear model was used to find associated factors related to trends of citation counts.

Results: The top 100 most-cited articles were determined by analyzing 7667 articles from the Scopus database. The steadily increasing trends were observed in the number and percentage of articles of author(s) affiliated with Taiwan institutes to the world. The most common study design was the in vitro research (55 %). The majority citation half-life is 3-5 and 6-8 years, and self-citation counts were between one to five times ($n = 26$). The percentage of international collaboration of these most-cited articles was 32%, and the main collaboration country was the United States. By using multivariable linear regression in the generalized linear model, the associated factors, study design, and self-citation were significantly associated with the escalating trends of citation counts.

Conclusion: This is the first study that provides valuable information in the dentistry regarding the academic activity, and empirical contribution of author(s) affiliated with Taiwan institutes in the world. The trends of citation characteristics were significantly correlated with study design and self-citation of these articles.

Keywords: Bibliometric analysis; Dentistry; Half-life; Publications; Research design; Taiwan

1. INTRODUCTION

Bibliometric analysis is a useful and objective tool, which has been extensively employed to evaluate the impacts of scientific activity by appraising performance of journal, publication,

author, institute, country association, a given disease, and technique, etc.¹⁻⁷ Bibliometric analysis building on citation analysis aids in providing valuable information on the research field, describing impact characteristics on subsequent work, and projecting future development in the specific subject category.^{1-4,8}

Series studies use citation analysis to evaluate the citation characteristics, such as top-cited articles in specific subject categories from InCites Journal Citation Reports (JCR).^{4,9-11} Moreover, citation analysis of the published articles in peer-reviewed journals can provide a historical perspective in the advancement of research, evolution, and areas of intensive research.^{1-6,9-11} However, to our knowledge, citation analysis focusing on the scientific performance and contribution of published articles in specific dental peer-reviewed journals by authors affiliated with institutes from a specific country is still limited.¹²

The convergence of basic and clinical dental researches has resulted in a substantially increased in the number of publications over the last decade.^{1-6,11} This growth in the rate of publication requires scientific metrics to quantify both outcomes and the impact of research in scientific community.^{1-7,9-11} In recent

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years, several countries had investigated the recent scientific performance and progress in specific disciplinary to highlight significant advances, underline research funding, and clarify future research direction and cooperation.^{12,13} In this context, over the years, Taiwan exhibits much higher academic and scientific activity by investing more budget and investments in dentistry, such as certain specific endemic diseases (ie, complex oral sensitivity disorder, oral cancers, and oral submucous fibrosis related to betel nut chewing habit) in particular regions are focused as well.^{14–16} However, based on its empirical contribution in research, there is no similar report in the literature analyzing the top-cited articles published by authors affiliated with Taiwan institutes.

While citation is one of the useful bibliometric tools to assess the scholarly effect of researchers or clinicians in a particular discipline, which could provide a structured objective and reliable analysis to handle a large body of information to a specific journal or article in its respective field.^{1–6,8,11,14–18} Citation analysis could aid in drawing the current panorama of dentistry in the society of Taiwan with regard to the most cited dental articles, as well as areas and topics that attract international attention. To clarify the empirical contribution and research performance by author(s) affiliated with Taiwan institutes, the purpose of the present study was to analyze the citation characteristics and associated factors of the top 100 most-cited articles in dentistry published by authors affiliated with Taiwan institutes by conducting a bibliometric analysis.

2. METHODS

2.1. Database selection

To acquire the top 100 most-cited articles produced by institutes from Taiwan Science Citation Index (SCI) journals across time, the Scopus database (<https://www.scopus.com>, Elsevier, Amsterdam, Netherlands) was used in this study. The Scopus database is one of the largest abstracts and citation database of peer-reviewed literature in the world, which provides the most comprehensive overview of published articles in the field of health science.¹⁹ It is designed to enable researchers not only to access the scientific information electronically, but to study the literature for different analyses purposes, such as citation tracking and bibliometric parameters (eg, author's details, source details, citation counts, and self-citation, etc). The Scopus database provides a quick and superior support of the literature research process and has been used in many published bibliometric studies.^{3,4,19} Hence, in this study, Scopus database was used to analyze the bibliometric characteristics of the identified articles.

2.2. Searching strategy and eligibility criteria

The electronic literature searching strategy and eligibility criteria was illustrated as Supplemental Fig. 1, <http://links.lww.com/JCMA/A82>. Briefly, in April 2021, a search in Scopus database was performed by setting all fields as “Dentistry,” the affiliation country as “Taiwan.” The acquired 8425 articles were further limited to the document type as “Article” and “Review,” source type as “Journal,” language as “English,” and the publication stage was “Final” and had undergone a full peer-review process as SCI journals and articles.

The resulting list of articles, out of 7667 results, articles were then compiled and sorted by option “total citation counts” in the descending order from the highest cited article to the lowest one and when more than one article had the same number of citations, the most recent article was ranked higher.^{4,20} The top 100 most-cited articles were then identified for analysis based on the total citation counts with at least one author affiliated with institute(s) from Taiwan.

2.3. Bibliometric parameters

All selected articles were then independently identified and categorized. The following variables were recorded for each article included in the analysis:

1. Title and year of publication;
2. Citation characteristics (eg, total citation counts, annual citation averages, citing half-life, self-citation counts, current citation index, etc);
3. Study design;
4. Author's information (eg, number of authors, first author, corresponding author);
5. Country and institute of origin (first author and co-author(s));
6. International collaboration.

2.4. Study design

With regard to the study design of the selected articles, the following seven univocal outcomes were determined by Oxford Centre for Evidence-Based Medicine (<https://www.cebm.net/2009/06/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/>):¹⁸

1. Review;
2. Cross-sectional study;
3. Epidemiology (case-control and cohort study);
4. *In vitro* research;
5. Animal experiment;
6. Diagnostic/randomized clinical trials;
7. Case report/case series/case analysis.

The study was defined as a review if the article focused on summarizing and discussing basic and clinical findings related to dentistry. The study was defined as a type of cross-sectional research that analyzes data of variables collected at one given point in time across a sample population or a predefined subset in nature. Studies regarding case-control and cohort study were used to investigate the causes and to establish links between associated factors and outcomes. Studies not involving human subjects were defined as *in vitro* research/animal experiment. The study design was defined as clinical trial if the study involved human participants and the design was either a clinical trial or a randomized clinical trial, which included both a control and a test group. Case reports, case series, and case analysis were also categorized for analysis.

2.5. Citation characteristic analysis

The annual citation averages was the average number of citations received by an article each year since it was published until 2019.¹²

The citation half-life of each selected article was defined as a median age of the article that was cited in the InCites JCR year. The citation half-life of each article was calculated by how far back in time when the number of citations earned by an article was half of the number.²¹ For example, if one article received a total of 500 citations in 10 years—calculated from the date of publication to the current year—and 250 citations of total citations were received 3 years from the current year, the citation half-life of this article is 3 years.

2.6. Self-citation analysis

Several types of citation linkage of self-citation could be found in bibliometric research, such as author self-citation, institutional self-citation, and journal self-citation.^{7,22,23} The author self-citation is defined as a citation received from its own scientists. The “total citations” and “exclude self-citations of all authors” were

search options available in Scopus database. Thus, author self-citation was calculated accordingly.

Author self-citation = total citations – exclude self-citations of all authors.

2.7. Institute of origin

The institutes of origin were designated by the affiliation provided by the authors, which were divided into two groups: first author and co-author(s).

2.8. International collaboration

The “international collaboration” of the study was defined as authors’ affiliated institute of origin from any country other than Taiwan.⁴ On the contrary, “domestic” was defined when the authors’ affiliated institute of origin were solely from Taiwan.

The citation counts of international collaboration are the accumulation of citation counts produced by international collaborations for an article. The annual citation averages are an indication of a country/institution or author’s ability to attract international collaboration.

2.9. Eligibility and validity

All articles retrieved from Scopus database were manually reviewed by two researchers (first and second authors) by reading all titles and abstracts and independently identifying all variables of the selected articles. In cases of any disagreement in the interpretation and characterization of selected articles, a final decision was made by consulting a third definitive evaluation, an experienced researcher (corresponding author), who read the full text of the selected article to reach a final consensus.^{3,4}

2.10. Statistical analysis

Eligible articles and bibliometric parameters were collected, analyzed, and exported into a spreadsheet software (Excel 2010, Microsoft 2016; Microsoft Corporation, Seattle, MA) for descriptive analysis. Statistical and scientific graphing software (GraphPad PRISM, version 8.0, San Diego, CA) was used for generating descriptive and statistical graphs. Multivariable linear regression in generalized linear model was used to find the factors related to trends of citation counts. In this model, independent factors were year of publication, study design, research fields, citation half-life, self-citation, number of authors, and international collaboration. Statistical analysis was performed using a statistical package SPSS for Windows (Version 22.0; SPSS, Inc, Chicago, IL). Significance was accepted when the *p* value was less than 0.05.

3. RESULTS

A total of 8425 articles were initially acquired from the Scopus database, and 7667 published articles were screened. Finally, top 100 most-cited articles were enrolled by total citation counts in descending order as eligible articles for analysis (Supplemental Fig. 1, <http://links.lww.com/JCMA/A82>). The ranking of the top 100 most-cited articles was listed (Supplemental Table 1, <http://links.lww.com/JCMA/A82>), which received a total of 18 864 citations, and the citation range was from 890 to 112 times (mean = 188.64 and median = 152), and the annual citation averages 74.17 to 3.73. These 100 most cited articles were published in 59 different journals (21 dental journals and 38 non-dental journals), and none of them was issued in Taiwan. Among these top 100 most-cited articles, 56 articles were acquired from 38 non-dental journals, which obtained 11 200 total citation counts. On the other hand, 44 articles from these 21 dental journals were acquired with 7664 total citation counts (Supplemental Fig. 1 <http://links.lww.com/JCMA/A82>).

To illustrate the performance of author(s) affiliated with Taiwan institutes to the world’s academic activities, the distribution of the number (Fig. 1A) and the percentage (Fig. 1B) of articles produced from Taiwan were compared and summarized across different periods of time (Fig. 1). The steadily increasing trends in the number (Fig. 1A) and the percentage (Fig. 1B) of articles over time were observed, which demonstrated the academic activity, empirical contribution, and impact of author(s) affiliated with Taiwan institutes in the world (Fig. 1).

The distribution of the number of published articles from 1987 to 2020 was illustrated (Fig. 2A). In addition, the frequency distribution (Fig. 2B), and citation counts (Fig. 2C) of top 100 most-cited articles in seven consecutive time periods “1987-1991,” “1992-1996,” “1997-2001,” “2002-2006,” “2007-2011,” “2012-2016,” and “2017 to the present” were illustrated. The trends of annual citation averages ($p < 0.001$), but not citation counts ($p = 0.982$), were significantly associated with age of publication (Fig. 2D).

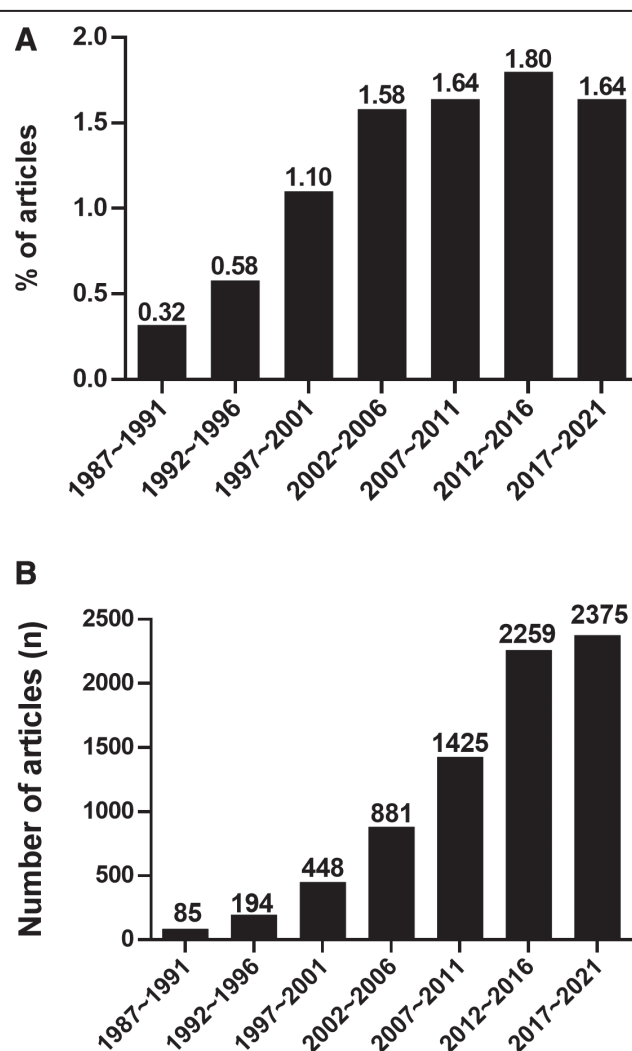


Fig. 1 The distribution of the number and the percentage of articles produced from author(s) affiliated with Taiwan institutes to the world were compared and summarized across different periods of time (1987 to present). A, The distribution of the number of articles produced from author(s) affiliated with Taiwan institutes. B, The distribution of the percentage of articles produced from author(s) affiliated with Taiwan institutes.

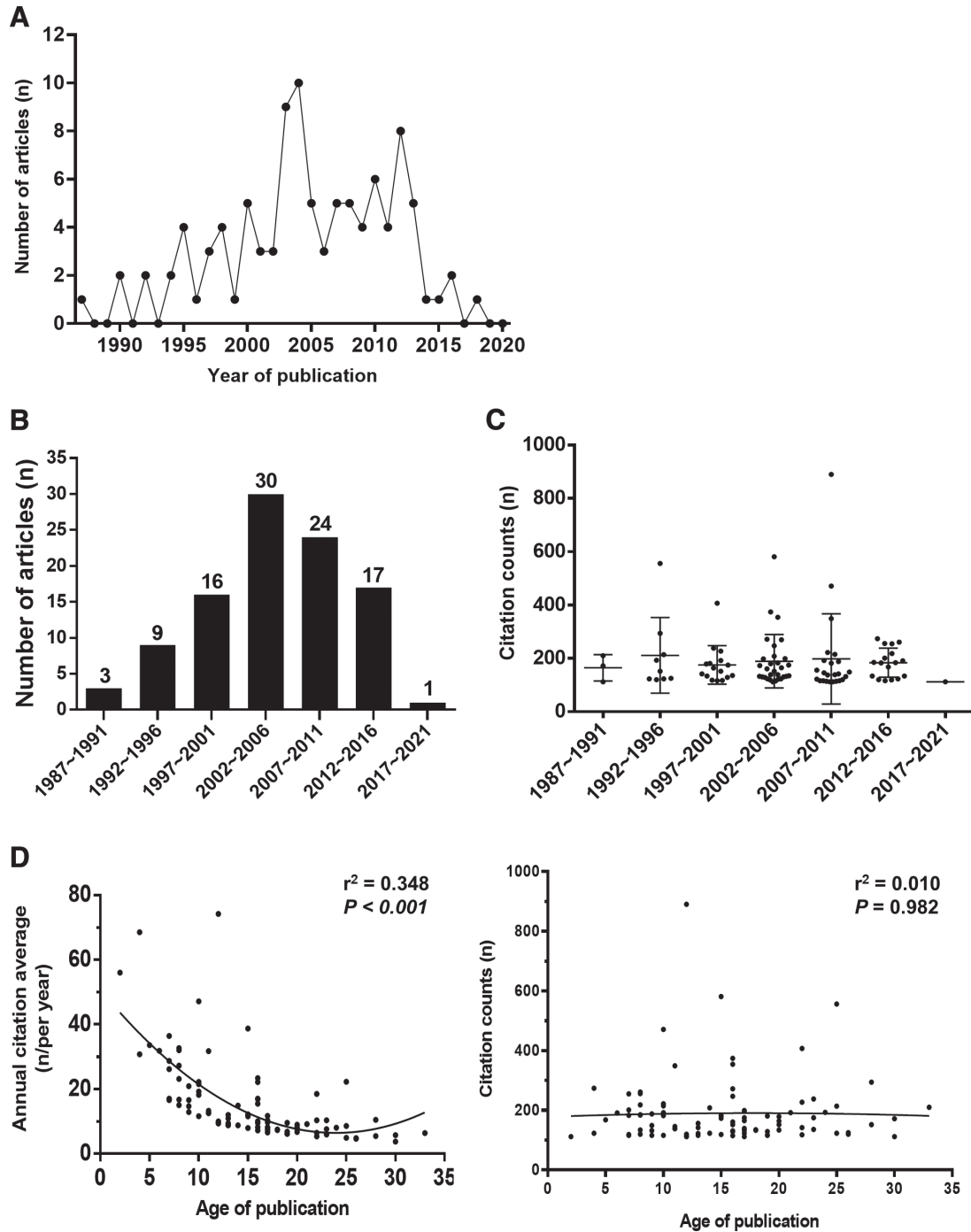


Fig. 2 The distribution, citation counts, and annual citation averages of top 100 most-cited articles. A, The distribution of the number of top 100 most-cited articles (n) with year of publication. B, Frequency distribution of top 100 most-cited articles (n) in seven consecutive time periods (1987-1991, 1992-1996, 1997-2001, 2002-2006, 2007-2011, 2012-2016, and 2017-2021). C, Total citation counts of top 100 most-cited articles in seven consecutive time periods, which are expressed as mean ± SD. D, Annual citation averages (n/per year) and total citation counts of top 100 most-cited articles with age of publication, which is expressed as mean ± SD.

Among these top 100 articles, the most common study design was the *in vitro* research (n = 55), followed by the epidemiology (case-control or cohort study) (n = 15), and animal experiment (n = 11) (Fig. 3A). However, the animal experiment research has 265.0 average citation counts (citation counts/per article), which is the highest when compared with others (Fig. 3A).

The majority articles have citation half-life is 3-5 and 6-8 years (n = 30) (Fig. 4A). The number and percentage of articles

with shorter citation half-life increased gradually in recent investigated periods when compared with longer citation half-life (ie, 0-8 years vs 12-20 years) (Fig. 4B). The most common self-citation counts were between one to five times (n = 26) (Fig. 4C). There was an increasing trend in self-citation counts during recent years. The number and percentage of articles with higher self-citation counts increased gradually in recent investigated periods, except 2017-2021, when compared with lower

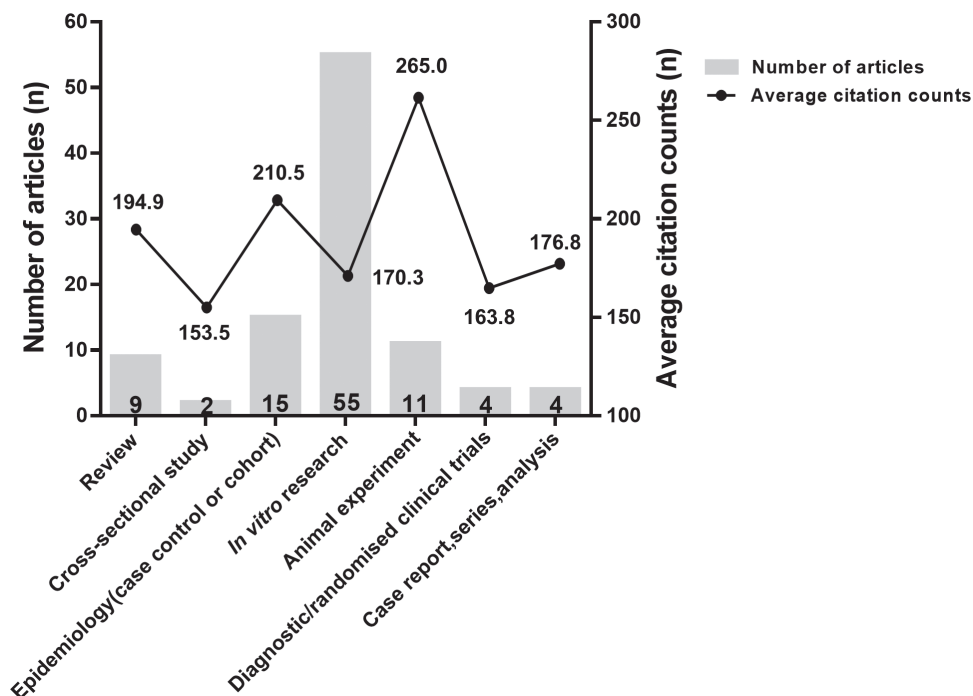


Fig. 3 The analysis and distribution of study design addressed in the top 100 most-cited articles. The distribution of the number of articles (n) and average of citation counts (n) of seven univocal categories.

self-citation counts (ie, 0-10 vs 11-20 and >20 self-citation counts) (Fig. 4D).

International collaboration accounts for 32% of the top 100 most-cited articles, which first author affiliated to foreign institutes was present in 50% of the articles (n = 16) (Fig. 5A). The average citation counts increases with the number of authors and the majority of articles' author number is 4-6 (n = 47) (Fig. 5B), and the leading collaboration country was the United States (n = 30) (Fig. 5C). Notably, the articles collaborating with Canada have the highest mean citation counts and annual citation averages of top 100 most-cited articles produced by international collaboration (Fig. 5D). For first author affiliated institutes, the leading institutes were National Yang-Ming University (n = 18), followed by National Taiwan University/Hospital (n = 17) (Fig. 5E). Similarly, co-authors affiliated with National Taiwan University/Hospital produced the highest number of articles (n = 23), followed by National Yang-Ming University (n = 20) (Fig. 5E).

By using multivariable linear regression in the generalized linear model, the associated factors, such as year of publication, journal, citation half-life, number of authors, and international collaboration, were not significantly correlated with the increasing average citation trends. However, study design (adjusted relative risk = 5.776; 95% confidence interval [CI] = 2.134-9.876; $p < 0.001$) and self-citation (adjusted relative risk = 3.678; 95% CI = 1.206-11.179; $p < 0.001$) were significantly associated with the increasing citation trends (Table 1).

4. DISCUSSION

The bibliometric analysis conducted in this study was an exploratory attempt to provide a relatively objective and comprehensive data on scientific activities being conducted by authors affiliated to Taiwan institutes in the field of dentistry, thereby offering researchers an easier access to current scenario and trends of pertinent research, as well as appropriate researcher(s)

and institute(s) to work in cooperation. Moreover, using such analysis would systematically provide information regarding the strength of current research and highlights of underlying academic trends in Taiwan. For example, in research regarding the correlation of betel quid chewing and development of oral cancer, the top 10 authors (among whom Dr. Kuo-Wei Chang and Dr. Shu-Chun Lin) and their corresponding institutes (in this case School of Dentistry, National Yang-Ming University) were all from Taiwan, which demonstrated that Taiwan plays empirical and leading roles in the field of dentistry.¹⁴

Previous studies postulated that articles with higher citation rates and visibility in scientific community may possess some specific characteristics, such as being published in high-impact dental journals, country of origin, and collaborations with international institutions.²⁴ In this study, the citation characteristics of the top 100 most-cited articles published in dental and non-dental related journals were analyzed to reflect academic development and research activities with author(s) affiliated to Taiwan institutes. The results of this study demonstrated that the number and percentage of articles being published by authors affiliated to Taiwan institutes are gradually increasing over time (1987-2021) (Fig. 1), which highlight their positive impact on academic societies as well as encourage author(s) from Taiwan institutes to contribute further in dentistry.

In the last decade, three major bibliometric databases, that is, Google Scholar, Web of Science, and the Scopus, had been widely employed for research evaluation, which has become an integral part of the landscape of bibliometric studies.¹⁹ In the present study, the Scopus database, which is the largest citation search engine of peer-reviewed literatures, was used to retrieve and analyze published articles. It facilitates researchers not only to access scientific data but also study literature for the purpose of bibliometric analyses. The Scopus database retrieves citations mainly from articles of only peer-reviewed journals, whereas Google Scholar includes citations from books, theses, dissertations, open-access online journals, and non-scholarly

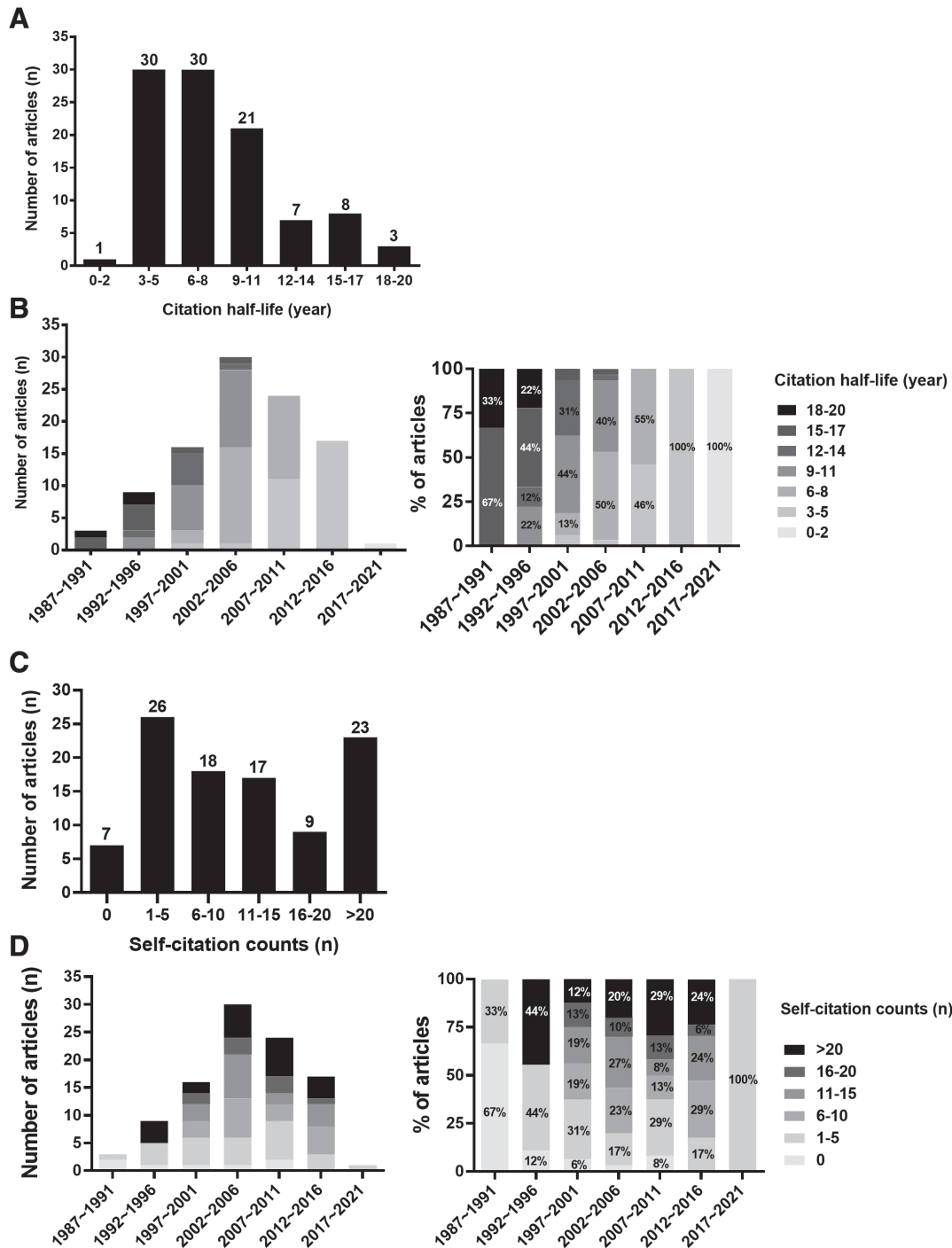


Fig. 4 The analysis and distribution of citation half-life (year), and self-citation counts (n) of top 100 most-cited articles. A, The distribution of the number of top 100 most-cited articles (n) with citation half-life (year). B, The distribution of the number (n) and percentage (%) of top 100 most-cited articles (n) with citation half-life (year) across seven consecutive time periods. C, The distribution of the number of top 100 most-cited articles (n) with self-citation counts (n). D, The distribution the number (n) and the percentage (%) of top 100 most-cited articles (n) with self-citation counts across seven consecutive time periods.

sources.^{10,25} Therefore, the total citation counts were higher in Google Scholar than those in the Scopus database. Notably, the Scopus database could obtain an absolute citation count, because it automatically excludes self-citations and provides 20% more coverage than Web of Science.^{10,26,27} Taken together, these results highlight the importance of an appropriate database and suitable metrics selection, which will benefit accurate and reliable bibliometric analysis in the given research field.

Theoretically, the total number of citations may favor older articles because the total number of citations received by an article can increase over time. In this study, the total citation counts did not completely correspond to the age of publication ($p = 0.982$, Fig. 2D). Our results also revealed that the peak annual citation averages of an article occur between 2 and 8 years after its publication, and that the trend begins to decrease later ($p < 0.001$, Fig. 2D). Notably, the most common citation half-life

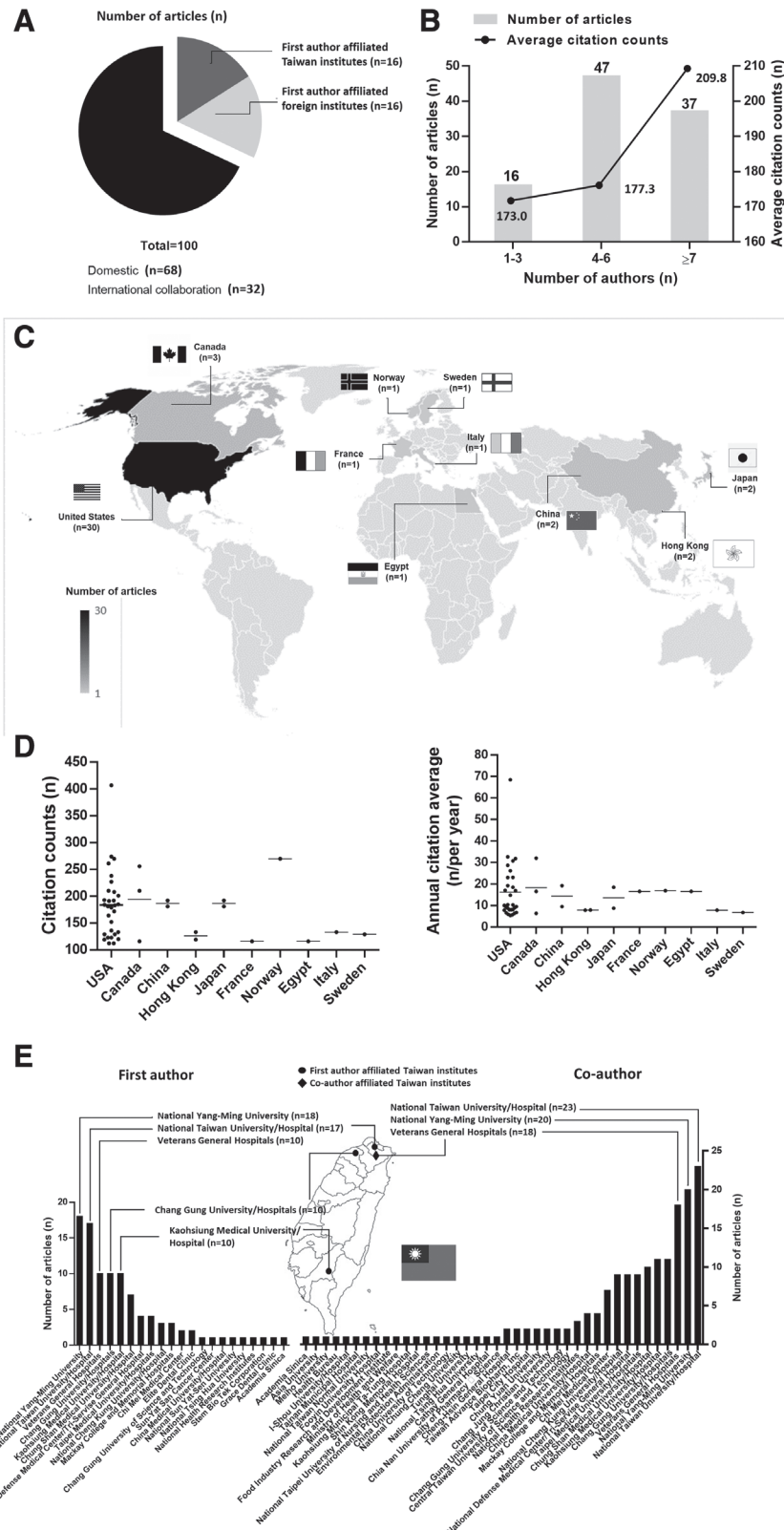


Fig. 5 The analysis and distribution of authorship, institute/country of origin, and international collaboration of top 100 most-cited articles. A, The distribution of articles produced from domestic, and international collaboration, and affiliated institutes of first author. B, The frequency distribution of average citation counts (n/per year) and number of articles (n) with number of authors (n) of top 100 most-cited articles. C, The distribution of country of origin is illustrated. D, The distribution of the citation counts (n) and annual citation averages (n/per year) of top 100 most-cited articles produced by international collaboration. E, The distribution of affiliated institutes of first author (blue dot) and co-authors (red square) from Taiwan.

Table 1**Trends of citation counts and associated factors were analyzed by multivariable linear regression in generalized linear models**

Variables	Crude RR	95% CI		<i>p</i>	Adjusted RR	95% CI		<i>p</i>
		Lower	Upper			Lower	Upper	
Year of publication	0.924	0.031	27.205	0.964	0.401	0.008	12.206	0.917
Journal (reference: non-dental journal)	0.965	0.901	1.034	0.314	0.982	0.911	1.052	0.288
Study design	6.996	3.948	11.316	<0.001	5.776	2.134	9.876	<0.001
Citation half-life	1.601	0.004	282.079	0.986	1.325	0.815	12.001	0.687
Self-citation	19.518	4.740	80.364	<0.001	3.678	1.206	11.179	<0.001
Number of author(s)	4.784	0.014	1621.834	0.599	3.689	0.511	2.285	0.652
International collaboration (reference: domestic)	1.011	0.939	1.088	0.779	1.011	0.896	1.046	0.679

Significance was accepted when the *p* value was <0.05.

CI = confidence interval; RR = relative risk.

is 6-8 years (Fig. 4A), which corresponds to the peak of citation and the lifespan of a latest published article. Although the number of citations that an article receives is not a necessary measure to evaluate the quality of research and the academic performance of that published article, it still reflects the article's recognition in the scientific community, provides a historical perspective on scientific progress, and reveals evolving trends in a specific research field. At present, several metrics have been proposed (eg, h-index and H-Classics) in previous studies, but there is no perfect indicator to illustrate the importance of an article in specific disciplines.³ Nevertheless, without any doubt, these bibliometric metrics should be interpreted with caution in specific situations. There is not a one-size-fits-all bibliometric method for research evaluation; thus, multiple metrics (eg, annual citation averages and citation half-life) have been developed to provide information on various scientific values and contributions of a publication.^{2,3,12}

Inter-discipline and international collaboration are critical to conduct effective research and contribute knowledge translation between disciplines, authors, institutes, countries, and geography regions.^{17,28} In this study, the purpose was focused only on collaboration between institutions in different countries (Fig. 5C, D). The improvement in inter-disciplinary and inter-national recognition may have positive association with rise of scientific impact of publications.^{17,28} However, our results showed that the proportion of internationally co-authored articles in Taiwan's dentistry publications remained low during the study period (Fig. 5A), and international collaboration has limited impact on the trend of increasing citation counts in top 100 most-cited articles (*p* = 0.679, Table 1), which is in line with the previous study regarding clinical medicine research in Taiwan.²⁹ Importantly, the aforementioned results should be elucidated with caution; however, these results might inspire the potential for advancement in inter-discipline and international collaboration in future.

It has been shown the type of study design would affect the citation count.^{24,30} In this study, study design was significantly associated with the escalating citation trend (*p* < 0.001, Table 1). Among these top 100 most-cited articles, the *in vitro* research leads in largest number of top 100 most-cited articles (*n* = 55, Fig. 3A); however, this study design has the relative lower average citation count (Fig. 3A). Furthermore, our results revealed study design, such as review (*p* = 0.004) and epidemiology (*p* < 0.001), had significantly impact on the citation counts when taking *in vitro* research as the reference group (data not shown). Our findings, at least in part, are consistent with previous studies that showed meta-analyses and review articles to be most likely to receive more citation counts among various study designs.^{24,30} Currently, concerns have been raised regarding the impact of self-citation, which is commonly defined as a citation where one or more authors are the same in the citing and cited articles, which other kinds of citation linkages (eg, author, institutional,

and journal self-citations) are also used.³¹ Interestingly, in this study, trends of self-citation have increased in recent time periods (Fig. 4C, D), and is significantly correlated to the trends of citation counts (*p* < 0.001, Table 1). Although self-citation counts for the majority of top 100 most-cited articles were one to five times (Fig. 4C), the citation counts vulnerable to the bias of self-citation were probably limited. However, its impact on the qualitative and quantitative measures of academic productivity and performance needs to be further investigated.³²⁻³⁵

This study was subject to certain limitations that inevitably needed to be acknowledged. First, this study was conducted solely using the Scopus database, therefore some influential articles published in other well-known databases, such as Pubmed, Web of Science, MEDLINE, Embase, Ovid database, etc, may have been omitted. Although discrepancies, coverage, and quality between different databases were reported within specific disciplines,^{36,37} or bibliometric parameters,³⁶ Scopus database is still the leading databases with prestigious scholarly impact in collecting and disseminating academic articles.³⁶ Nevertheless, comparisons in specific bibliometric parameters between various health-related database should be an interesting topic to be investigated in the future. Secondly, articles may not be included in the Scopus database until 1970. It is supposed that the earlier publication date may have opportunity to accumulate higher total citation counts; however, the true academic contribution of published articles, clinical and research values are more important to determine citation counts than age of publication. Additionally, citations appearing in book chapters as well as articles written in non-English were not included in this database. Despite these limitations, the data presented in this study still provided the insightful information regarding the academic, and research achievements and evolving trends for author(s) affiliated with Taiwan institutes over the past decades.

In conclusion, despite the limitations, to our knowledge, this is the first study that provides valuable information regarding the breadth of study design, research field, citation half-life, self-citation, institute of origin, and international collaboration of top 100 most-cited articles for author(s) affiliated with Taiwan institutes over the past decades. The trends of citation characteristics were significantly correlated with study design and self-citation of these top 100 most-cited articles. Through quantitative and objective bibliometric analysis, our results may inspire evolutionary changes and challenges in clinical and basic dental research in future.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at <http://doi.org/10.1097/JCMA.0000000000000264>.

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