



ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Highly cited papers in dental medicine based on Essential Science Indicators

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SUMMARY

Introduction/Objective Essential Science Indicators (ESI) Highly Cited Papers (HCPs) refer to the most influential scientific articles and breakthrough research within a research field in the past decade.

This study aimed to identify the characteristics of ESI HCPs in the subject category Dentistry, Oral Surgery and Medicine, to recognize authors, institutions and countries of origin, and determine research trends that attracted the most scientific interest in dentistry.

Methods A descriptive analysis of bibliographic data, network extraction and visualization were completed. Furthermore, analyzed ESI HCPs were classified according to a field of interest, main research domain, type of study, and level of evidence.

Results The set of 185 dental HCPs was published in 42 journals from 2010 to 2020, with an average number of 211.7 citations per paper. Nearly half of HCPs were issued by the *Journal of Dental Research*, *Dental Materials*, and *Journal of Clinical Periodontology*. There were 765 authors affiliated with 351 institutions from 42 countries. The most productive institutions were the University of Hong Kong, the University of Michigan, and the University of Bern. The United States of America contributed with the highest number of publications, followed by China, and the United Kingdom. Dental materials, dental implantology, periodontology, and oral and maxillofacial surgery represented areas of significant interest within this subject category. The highest proportion of HCPs were narrative and systematic reviews, expert opinions, consensus reports, and *in vitro* or lab studies.

Conclusion Results obtained from this study can provide valuable information for researchers to better identify present and future hotspots in dental research.

Keywords: bibliometrics; social network analysis; knowledge discovery; research fronts; dentistry

INTRODUCTION

The number of citations a scientific article receives describes one aspect of its academic impact. Citing, as one of the principal forms of scientific communication, can be quantified by bibliometric methods. Citation analysis and indicators, such as the total number of citations or h-index, can be used to identify highly cited articles, authors, institutions, countries, or source journals. Additionally, popular research topics can be recognized, allowing scientists to efficiently comprehend current research trends and design future studies.

The Clarivate Analytics' InCites Essential Science Indicators (ESI) stands out as one of the datasets delivering in-depth coverage for efficient analysis and benchmarking research performance [1]. It is an integrated collection of data on the most inspiring, readable, and citable papers in the sciences, including research fronts as one of its features. Highly Cited

Papers (HCPs) represent the most influential research articles in each research field annually. Since its introduction in 2002, ESI HCPs have given great importance to the science of science, significantly supporting the empirical study of scientific practice [2]. They have been widely used to evaluate research performance at different levels (researcher, research institution, university, country of origin) and from different aspects, comparing the quality of an article with the highly-rated papers published each year [3]. ESI HCPs data may be used by various stakeholders in the decision-making process related to research funding or university promotions [4].

Bibliometric performance based on citation data has been widely analyzed in various fields of dentistry. Previously published bibliometric studies have described the most cited (also labeled as highly or top-cited) articles published in the field of dentistry, oral surgery and medicine (DOSM) [5, 6] or in specific journal/s [7, 8]

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or subareas, such as prosthodontics [9], pediatric dentistry [10], endodontics [11], orthodontics [12], dental implantology [13], periodontology [14], oral pathology and medicine [15], or oral and maxillofacial surgery [16]. However, in all these studies, the term highly cited paper refers to articles whose total number of received citations, mostly from the Web of Science (WoS) Core Collection, is equal to or higher than 100, regardless of the papers' publication date. The analysis of dental ESI HCPs, related to the top 1% of papers in the medical research area, has so far not been the subject of bibliometric studies.

The main aim of this study was to identify the characteristics of ESI HCPs in the WoS subject category of DOSM, to recognize authorships, institutions, and countries of origin and determine emerging research trends in dentistry. This knowledge related to the current status within dental research areas of significant interest may provide a valuable reference to original investigations available for decision making and clinical practice support, allowing scientists to efficiently comprehend prevailing research trends and design future studies.

METHODS

Data sources

To identify breakthrough research within the field of dentistry, we searched WoS for all papers published in journals related to the subject category DOSM, using the WoS subject category field. Subsequently, ESI HCPs were selected on the retrieval result page. The identified set of 185 HCPs, obtained on July 12, 2020, was part of the second bi-monthly of 2020 (updated on July 9, 2020), which covered the period from January 1, 2010 to April 30, 2020.

Data extraction

Complete ESI HCP metadata was exported in plain text format from WoS and imported into the R environment for statistical computing and graphics [17]. In addition to bibliographic attributes stored in WoS, such as authors' names and affiliations, year of publication, document title, abstract, publication name, document type, language, citation count, cited references, authors' keywords, or Keywords Plus, Journal Impact Factor (JIF) Quartile in the category DOSM (based on the Journal Citation Reports 2019) was also recorded. Three reviewers classified selected ESI HCPs according to a field of interest, main research domain, type of study, and level of evidence (LoE). Any disagreement between the reviewers was resolved by discussion with the fourth reviewer.

Data analysis

A descriptive analysis of bibliographic data and network extraction were completed using the Bibliometrix R-package version 3.0.2 (Bibliometrix, Naples, Italy) [18]. The main results of the bibliometric analysis describe the

collection in terms of the number of papers, authors, institutions, countries, sources, and keywords. Collaboration analysis was used to identify co-authorships and determine collaboration networks. Word co-occurrence analysis mapped and clustered terms extracted from keywords, titles, or abstracts. Correspondence analysis was performed to illustrate a conceptual structure of the analyzed dataset and K-means clustering to identify clusters of papers that express common concepts. Bibliometric networks were graphically presented using VOSviewer software (VOSviewer, Leiden, the Netherlands) [19] and the R packages Bibliometrix version 3.0.2 [18], as well as Wordcloud2 (R project, Vienna, Austria) version 0.2.1. Geomapping was completed using the R project Rworldmap version 1.3.6 [20].

RESULTS

The search yielded the top 185 papers related to the category of DOSM that had been identified in the ESI database. A complete list of analyzed HCPs is given in Appendix Table 1 (Available from: <http://srpskiarhiv.rs/global/pdf/tables/AppendixTable1.pdf>). Of the 185 papers, 168 journal articles and 17 proceedings papers published in English were selected for the analysis. The annual distribution of all HCPs published from 2010 to 2020 is presented in Table 1. The average number of years since the publication in the dataset was 5.3 years. One of the HCPs was published early online [21]. Almost half (44.9%) of HCPs ($n = 185$) were Open Access articles, mostly published in *Journal of Dental Research* ($n = 18$), *Journal of Clinical Periodontology* ($n = 13$), *Dental Materials* ($n = 8$), or *Journal of Periodontology* ($n = 7$). More than half of dental HCPs (56.8%) were funded studies, published mainly in *Journal of Dental Research* ($n = 25$), *Journal of Clinical Periodontology* ($n = 21$), *Journal of Periodontology* ($n = 10$), and *Dental Materials* ($n = 9$) respectively.

Table 1. Annual distribution of Highly Cited Papers

Year	N	mTCA	mTCY	Citable Years
2010	14	420.7	42.1	10
2011	16	383.8	42.6	9
2012	23	310.3	38.8	8
2013	23	237.4	33.9	7
2014	16	288.5	48.1	6
2015	24	192.2	38.4	5
2016	9	162.1	40.5	4
2017	13	104.9	35.0	3
2018	25	74.2	37.1	2
2019	11	24.3	24.3	1
2020	11	32.7		0

N – the total number of articles; mTC_a – mean total number of citations per article; mTC_y – mean total number of citations per year

Authorship, institution and country of origin

The analysis showed that 765 authors were responsible for 1058 authorships and affiliated to 351 institutions from 42

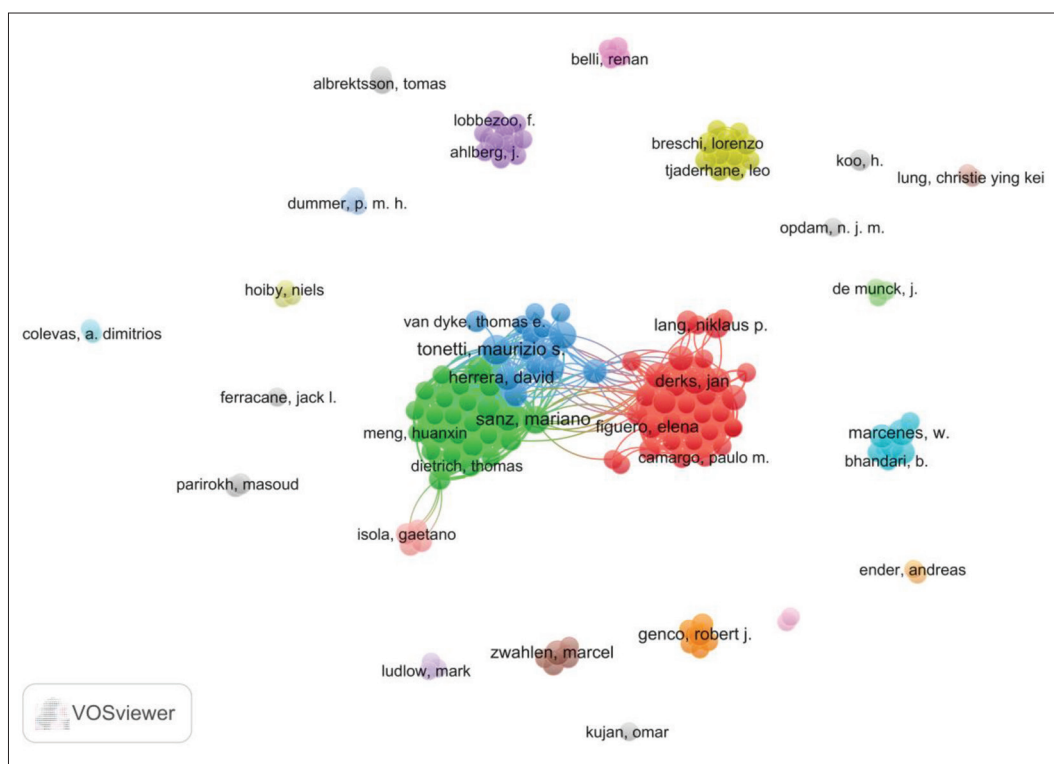
Table 2. Study design and the distribution of Highly Cited Papers within the pyramid of evidence

Study design/LoE	0	I	II	III	IV	V	VII	Total
Case control study					1			1
Case series						7		7
Cohort study					4			4
Controlled clinical trial				3				3
Cross sectional study						6		6
N/A; economic evaluation	2							2
Epidemiological report					2			2
Expert opinion and panel consensus							25	25
In vitro/lab studies	15							15
Meta-analysis		1						1
Narrative literature review							70	70
RCT			3					3
N/A; short communication/ others	1							1
Systematic literature review	2	20			12	3		37
Systematic review and meta-analysis		5			3			8
Total	20	26	3	3	22	16	95	185

RCT – randomized clinical trial; LoE – level of evidence; LoE I – systematic review or meta-analysis of RCTs; LoE II – randomized controlled clinical trial; LoE III – controlled clinical trials; LoE IV – cohort study, case control study, systematic review or meta-analysis of cohort and case control; LoE V – cross-sectional study and case series, systematic review or meta-analysis of cross-sectional studies and case series; LoE VI – case report; LoE VII – narrative literature review, panel and expert opinions; LoE 0 – animal research, in vitro / lab studies; the level of evidence of systematic reviews and meta-analyses depend on the types of studies reviewed

countries. The number of authors in HCPs ranged 1–34, while the average number of authors per article was 4.14. Of the 185 HCPs in dentistry, eight (4.3%) were single-authored, 41 (22.2%) were written by two, 28 (21.5%) by three, and the remaining 41.6% by four or more authors.

Ferracane [22, 23] (Oregon Hlth & Sci Univ, USA) stood out as the only author who had written two single-authored HCPs, both dealing with resin composites and being published in *Dental Materials*. Appendix Table 2 (Available from: <http://srpskiarhiv.rs/global/pdf/tables/AppendixTable2.pdf>) provides a list of the 30 most productive authors of dental HCPs. The ranking of authors was based on their number of total articles and adjusted frequency that reflected multiple-authored articles (for instance, if an article was published by two authors, each received half a credit). According to number of total articles, the most productive author who appeared in nine HCPs was Tonetti MS, whose fractionalized frequency was equal to 1.7, considering the number of co-authors. However, based on adjusted frequency, two other top productive authors with 2.17 fractionalized frequency were Parirokh M (Kerman Univ Med Sci, Iran) and Torabinejad M (Loma Linda Univ, USA). Authors of the analyzed HCPs were also ranked based on dominance factor, which reflected the proportion of the number of multi-authored publications of an author as the first author to the total number of multi-authored publications of an author. According to dominance factor value, Isola G (Univ Catania, Italy) and Eke PI (CDC, Ctr Dis Control & Prevent, USA) dominated their research teams as they were the first authors in all of their papers (four for Isola G and three for Eke PI). Scientific collaboration network is given in Figure 1, which discovers regular study groups, hidden scholarly groups, and pivotal authors of the HCPs in dentistry.

**Figure 1.** Author collaboration network

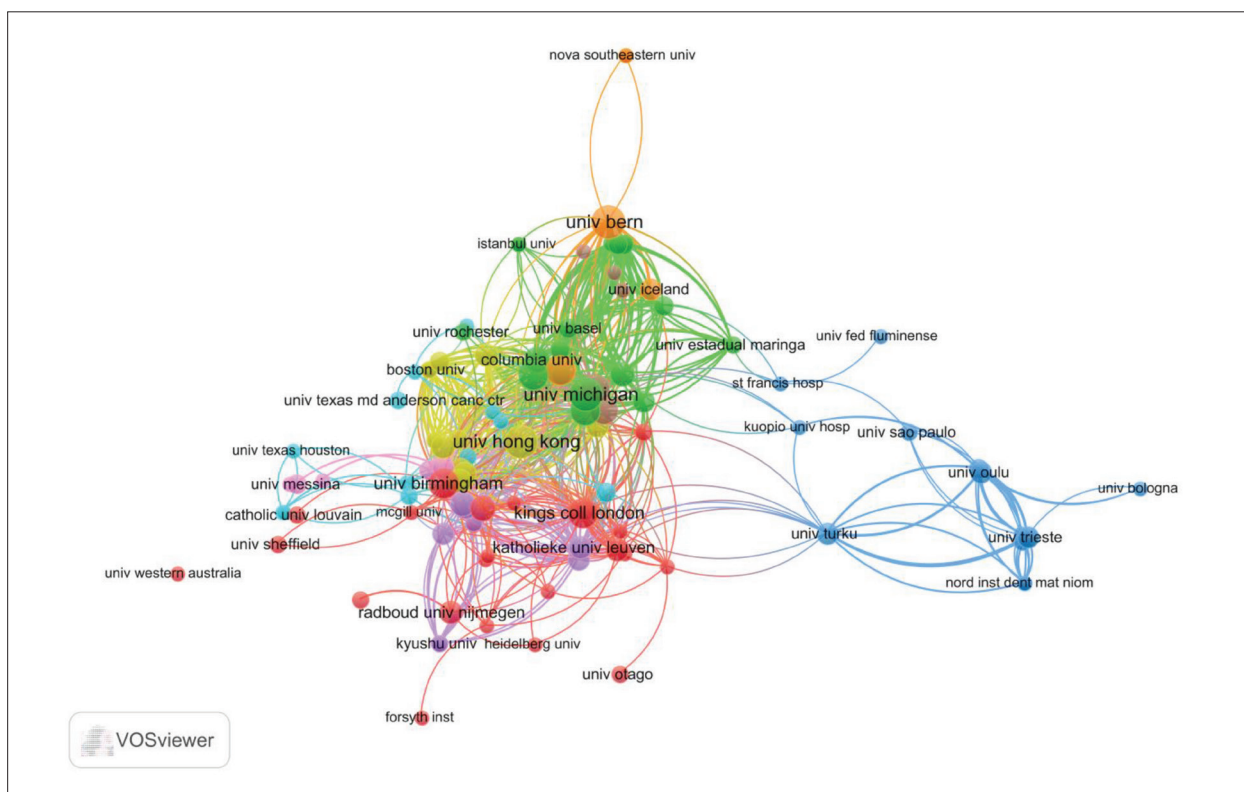


Figure 2. Institutional collaboration network

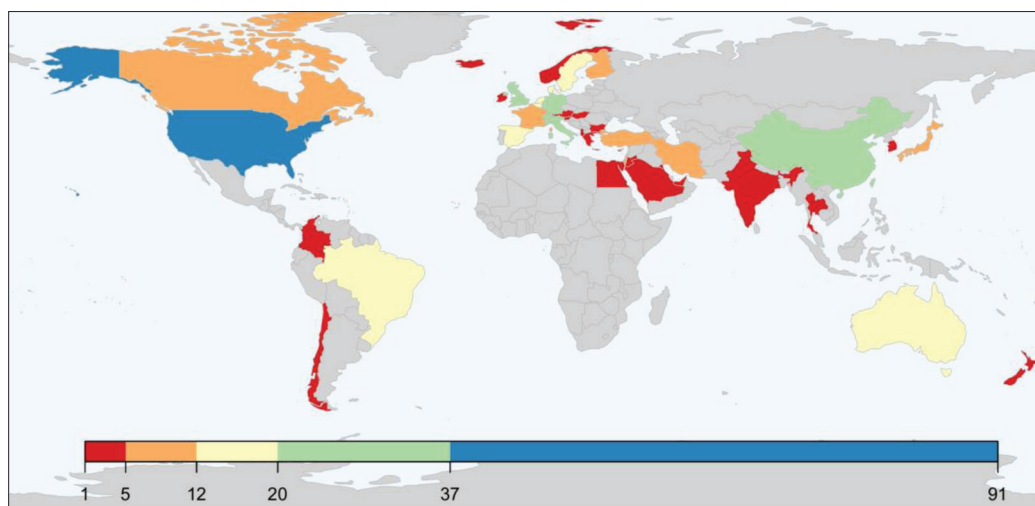


Figure 3. Participation of each country in the distribution of Highly Cited Papers

Almost a quarter of the analyzed HCPs ($n = 43$) were single-institution papers. Appendix Table 3 (Available from: <http://srpskiarhiv.rs/global/pdf/tables/AppendixTable3.pdf>) presents the institutions with at least five HCPs, ordered according to the number of total articles. Among 351 institutions, the most productive institution was the University of Hong Kong ($n = 17$), followed by the University of Michigan ($n = 16$), the University of Bern ($n = 16$), the Complutense University of Madrid ($n = 13$), and the University of Birmingham ($n = 13$). The collaboration network among the 70 most productive institutions is given in Figure 2, color-coded by clusters. The Complutense University of Madrid, Spain was the most

collaborative institution, having the greatest number of links ($n = 64$).

The top 185 HCPs originated from 42 countries, including 22 European, 11 Asian, five American, two Oceanian, and two transcontinental countries (Turkey and Egypt) (Appendix Table 4 (Available from: <http://srpskiarhiv.rs/global/pdf/tables/AppendixTable4.pdf>)). Nearly half of the ESI HCPs (47.6%) were single-country papers, originating from 20 countries. Figure 3 shows the participation of each country in the distribution of HCPs. The USA stood out as the most productive country with an apparent advantage ($n = 91$), followed by China, the United Kingdom, and Germany. In addition to total HCPs Appendix Table

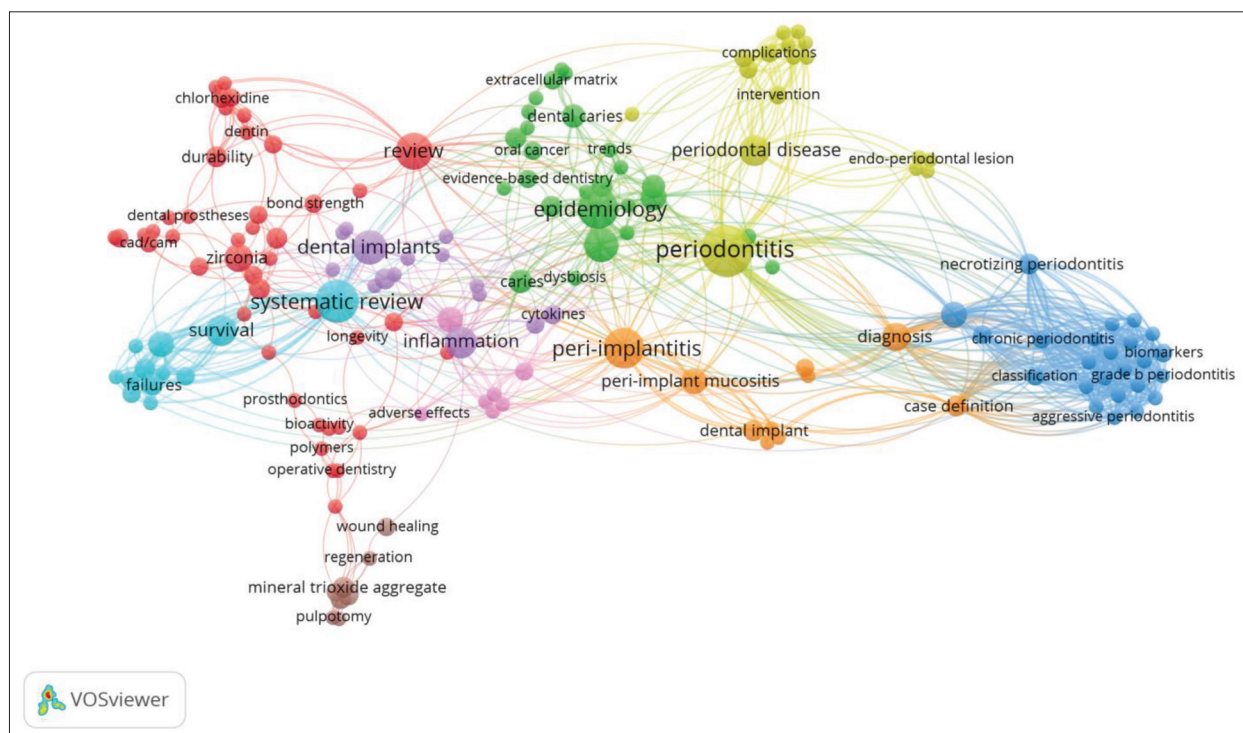


Figure 4. The most frequently used author's keywords

4 (Available from: <http://srpskiarhiv.rs/global/pdf/tables/AppendixTable4.pdf>) presents the number of HCPs based on the corresponding author's country of origin, as well as the number of single or multi-country papers. Among 91 HCPs from the USA, 54 were papers in which the corresponding author was from the USA. The 31 papers originated from single-country, while 60 were the result of international collaboration.

Journals

HCPs in DOSM were published in 42 journals. Appendix Table 5 (Available from: <http://srpskiarhiv.rs/global/pdf/tables/AppendixTable5.pdf>) shows journals' information regarding the JIF 2019 Quartile in DOSM Category, the total number of published HCPs, the total number of received citations, the average number of citations per paper, and the year when the first HCP was published in a journal. The highest number of HCPs (43.24%) was published in the *Journal of Dental Research*, followed by *Dental Materials* and *Journal of Clinical Periodontology*. HCPs published in these journals were papers with the highest total number of received citations. The highest number of average citations per paper had articles published in the *Journal of Oral & Facial Pain and Headache* ($mTC_A = 820$) and *Journal of Oral and Maxillofacial Surgery* ($mTC_A = 771$). Most of the HCPs were published in the first (42.1%) and second (31%) JIF Quartiles in DOSM.

Citations

The 185 HCPs received a total of 39,161 citations, ranging 4–1471 citations per paper. The average number of



Figure 5. Word cloud of the most frequently used author's keywords

citations per paper was 211.7, while the average number of citations per year per paper was 31.34. The 20 most influential HCPs ranked by the total number of citations and the total citations per year are presented in Appendix Table 6 (Available from: <http://srpskiarhiv.rs/global/pdf/tables/AppendixTable6.pdf>). The most cited HCP was published in the *Journal of Dental Research* [24], with a total of 1,471 citations. However, when the date of publishing is taken into account, the HCP published in the *International Journal of Oral Sciences* [25] stood out as the most cited paper, with 135 total citations per year. Among the top 20 cited HCPs, 65% were review articles including seven narrative and six systematic literature reviews. The citation analysis revealed that the most cited papers were from the USA with a total of 15,307 citations, followed by the UK (total citations = 3621), China (total citations = 2744), and Germany (total citations = 2229).

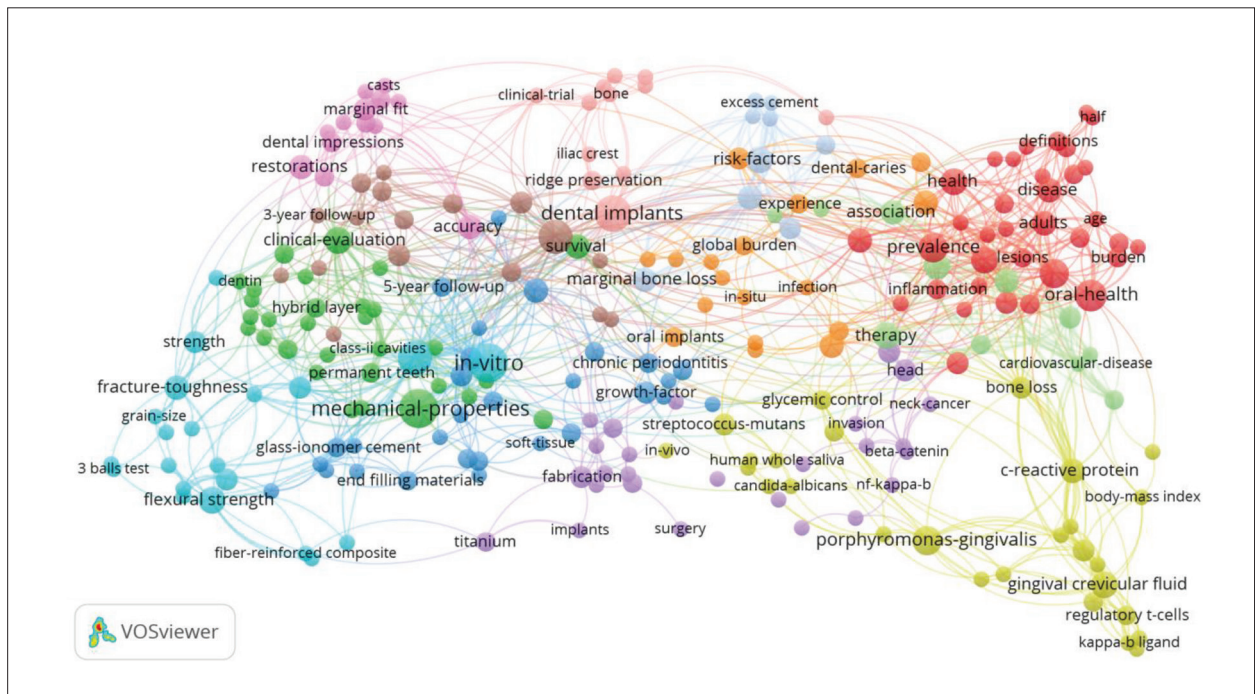


Figure 6. The most frequently used Keywords Plus

Note: Keywords Plus – keywords obtained from the titles of references that were not necessarily provided by the authors

Research topics

Hot topics of ESI HCPs in DOSM are shown in Figure 4 and through the word cloud of the most frequently used author's keywords (Figure 5). The size of the displayed terms indicated that papers related to 'periodontitis' and 'periodontal diseases', as well as 'dental implants', comprised a substantial portion of HCPs in dentistry. Other keywords such as 'review', 'systematic review', 'epidemiology', 'peri-implantitis', 'adhesion', 'inflammation', or 'mineral trioxide aggregate' were also highly prevalent. Figure 6 illustrates the co-occurrence network of used Keywords Plus.

Field of interest, study design, research question and level of evidence

Analysis of 185 HCPs based on a field of interest classification, revealed that almost 25% of papers were related to dental materials, followed by 21.62% and 16.22% related to periodontology and dental implantology respectively (Appendix Table 7 (Available from: <http://srpskiarhiv.rs/global/pdf/tables/AppendixTable7.pdf>)). In addition to papers focused on therapy (56.22%), the most common research issues were etiology (16.22%), pathogenesis (12.97%), diagnosis (11.89%), and epidemiology (10.81%). The highest proportion of HCPs were narrative (37.84%) and systematic (24.32%) literature reviews, followed by expert opinion and panel consensus papers (13.51%) and in vitro/lab studies (8.11%) (Table 2). The lowest portion of HCPs were case-control studies and short communications (1.08%). The highest number of HCPs were within LoE VII ($n = 95$), followed by LoE I ($n = 26$), LoE IV ($n = 22$), and LoE 0 ($n = 20$).

DISCUSSION

This bibliometric study is the first of its kind to identify and describe the main characteristics of ESI HCPs in the field of DOSM. The analysis of 185 HCPs published 2010–2020 revealed key concepts of dental research, prominent individuals, institutions, articles, journals, and countries that have contributed to the advancement of the field.

Most of the analyzed HCPs were published in 2018, which supports the fact that the time of publication of the article does not necessarily have to be a critical factor for inclusion in the ESI database [26]. Moreover, one of the most recent HCPs published in 2020 was the article with the highest number of received citations per year [25]. The paper, dealing with the potential routes of 2019-nCov infection of the oral cavity mucosa, directly reflects ESI's capacities for recognizing hot topics and future research directions.

The characteristics of the analyzed set of HCPs are mostly in line with the verified features of the ESI highly cited articles in terms of a large number of authors and significant international cooperation [4, 27]. More than half of analyzed HCPs (63.1%) were written by three or more authors, with an average number of authors per paper being 4.14, which is slightly higher compared to other studies exploring the most cited documents in dentistry [6]. The central position of the largest identified co-authorship network is occupied by the most productive author Tonetti MS, who achieved the greatest number of links (co-author relationships, $n = 35$). International cooperation, previously recognized as one of the main qualities of highly cited articles, appears to be less significant [28]. The present study found that only 52.43% of dental ESI HCPs are the

result of international collaboration. Additionally, most of the analyzed HCPs (73.1%) were published in the journals from the first and second JIF Quartiles in DOSM, which was in line with the results of the previously conducted bibliometric studies in dentistry [5]. The close relationship between citations and impact is confirmed by the fact that 43.24% of the HCPs are published in three journals (*Journal of Dental Research*, *Dental Materials*, and *Journal of Clinical Periodontology*), representing the core sources of ESI HCPs in DOSM.

Regarding the field of study, dental materials, dental implantology, periodontology, and oral and maxillofacial surgery represent areas of significant interest within the DOSM category. The results of this study are supported by previous research that demonstrated a greater interest in surgical rather than prosthodontic topics [29]. The notable portion of the analyzed HCPs addresses issues related to the classification, prevalence, incidence, and risk factors of periodontal and peri-implant diseases and conditions. Furthermore, a significant number of HCPs explores the association between periodontal and systemic diseases such as diabetes and cardiovascular diseases. These papers aim to draw attention to gaps in knowledge and emphasize the opportunities for oral rehabilitation, periodontal and general health improvement, highlighting the global burden of tooth loss due to untreated caries and severe periodontitis. In this context, the scientific evidence of high reputation should be instrumental in the alignment of national public interest and initiatives in strategies for prevention and oral health promotion.

In general, there was no positive relationship in dental research between citation counts and the LoE. The overall set of the analyzed HCPs was populated by a large number of lower-level evidence studies. Narrative literature reviews, expert opinions, and consensus reports with LoE VII were the most frequent types of study design (51.35%). Higher-level evidence studies, such as systematic reviews (24.32%), clinical trials, and cohort studies (3.24%), represented nearly a third of the sample. However, only half of the systematic literature reviews (55.56%) were systematic reviews of RCTs with the highest LoE I. The remaining systematic reviews, consisting of a cohort, case-control, or cross-sectional studies, were graded as studies of LoE

IV or V. A notable portion of analyzed HCPs consisted of *in vitro* studies (8.11%), conducted mainly in the fields of dental materials, prosthodontics, and oral medicine. Only three RCTs (LoE II) and one case-control study (LoE IV) related to oral and maxillofacial surgery were included in ESI HCPs. These findings are consistent with previous data implying that the overall LoE in highly cited dental literature is low, with a high prevalence of narrative reviews [5, 30].

The limitation of the study was the inclusion of self-citations in the total number of citations, which could have inflated the citation rate. Nevertheless, the data in this study still provides significant insight into the evolving trends of dental research and prominent individuals, institutions, articles, journals, and countries that have significantly contributed to the progress of the field.

CONCLUSION

The present study outlines the main characteristics of the most recent 185 ESI HCPs in the field of DOSM published in the last decade. The majority of HCPs were narrative and systematic literature reviews in the field of dental materials, implantology, or periodontology. The highest number of frequently cited and most inspiring articles was published by the *Journal of Dental Research*, *Dental Materials* and *Journal of Clinical Periodontology*, which are the core sources of ESI HCPs representing the highest standards of research and clinical practice in dentistry. Since the citation counts are continuously evolving and the ESI HCPs are updated every two months, the results presented in this study provide a snapshot of the most prominent contemporary dental research fronts.

To provide more comprehensive insight into this research system, it would be valuable to conduct further analysis of existing co-citation and bibliographic coupling networks. Future studies comparing previous bimonthly clusters of ESI HCPs over longer periods are desirable to explain the evolution of dental research and the identification of rapidly growing or changing areas.

Conflict of interest: None declared.

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Високо цитирани радови из области стоматологије на основу сервиса Суштински научни показатељи (*Essential Science Indicators*)

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САЖЕТАК

Увод/Циљ Високо цитирани радови на основу сервиса Суштински научни показатељи (*Essential Science Indicators*) обухватају најутицајније научне чланке и револуционарна истраживања протекле деценије.

Циљ ове студије је да идентификује карактеристике високо цитираних радова на основу сервиса *Essential Science Indicators* у области стоматологије, оралне хирургије и медицине, да препозна ауторе, институције и земље порекла и утврди трендове истраживања који су привукли највише научног интереса.

Метод Спроведена је дескриптивна анализа библиографских података, екстракција мрежа и њихова визуализација. Даље, анализирани радови класификовани су према области интереса, главном домену истраживања, врсти студије и нивоу доказа.

Резултати Скуп од 185 високо цитираних радова објављен је у 42 часописа у периоду од 2010. до 2020. године, са просечним бројем цитата по раду 211,7. Готово половина ових

радова објављена је у часописима *Journal of Dental Research*, *Dental Materials* и *Journal of Clinical Periodontology*. Заступљено је 765 аутора из 351 институције и 42 земље. Најпродуктивније институције биле су универзитети у Хонг Конгу, Мичигену и Берну. Највећи број публикација потиче из САД-а, Кине и Велике Британије. Стоматолошки материјали, зубна имплантологија, пародонтологија и орална и максилофацијална хирургија представљали су подручја од значајног интереса у овој категорији предмета. Највећи део високо цитираних радова били су наративни и систематски прегледи литературе, стручна мишљења, консензус извештаји и *in vitro* или лабораторијске студије.

Закључак Резултати добијени овом студијом могу пружити драгоцене информације истраживачима ради бољег препознавања садашњих и будућих актуелних тема стоматолошких истраживања.

Кључне речи: библиометрија; анализа друштвених мрежа; откривање знања; фронтови истраживања; стоматологија