Bibliometric Analysis of Dental Informatics via Pubmed

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Abstract

Introduction: This study examines the main characteristics of dental informatics research using bibliometric analysis of articles in the online journal database PubMed, to identify the main trends of research in dental informatics. The study aims to identify trends, geographic distribution of papers and authors, rates of collaboration, and performances of journals and institutions.

Methods: Information on dental informatics was extracted solely from the PubMed online journal database from January 1989 to September 2019. A three-phase search approach was employed. Bibliometrics was used to examine the growth and progress of dental informatics over time.

Results: A total of n=236 papers on dental informatics were identified, with an average of 7.9 papers per year. The trend of papers published increased over time with 41 countries represented in this study. There were only 15 countries which had 10 or more representatives, seven of which came from Europe. North America produced the most research in dental informatics, with 149 paper affiliations and ten were cross regional, in 61% of the total papers.

Discussion: The topic of dental informatics began in the mid to late 1980s, with the most productive years in the last decade, reaching a high point in the mid 2010s. There was a low level of international collaboration, and few conducted across different continents.

Conclusion: There is steady increase in the pace of research in dental informatics, with growing interest in exploring various implementation methods. Collaboration has become a product of a globalised world, with the potential to share data and exchange ideas using cutting-edge technologies. As these trends continue, the field of dental informatics may see further growth and development, with more technology available to provide communication and share data points and methods becoming widespread.

Introduction

The recent advances in computing have given rise to the discipline of health informatics and health information technology (HIT) that has grown steadily over the past few decades, coinciding with the vast increase in power that computing has been able to achieve in a relatively short amount of time (Eysenbach, 2000; Gandhi, Khanna & Ramaswamy, 2016). The literature indicates there is a great and growing diversity in sub-disciplines of health informatics, including medical informatics and clinical informatics.

One of the more recent areas of technology integration in healthcare has come in dentistry. Progress in dentistry relies heavily on progress in information technology. The term "dental informatics" was coined by Zimmerman et al., in 1968. Dental informatics is a subfield of health informatics that focuses on the application of computer and information science to improve dental care, research, education, and management (Chhabra et al., 2016). It encompasses a wide range of areas, including electronic health records, clinical decision support systems, telemedicine, imaging technologies, and data analytics. By leveraging technology and data, dental informatics seeks to improve patient outcomes, enhance the efficiency and effectiveness of dental practices, and advance the field of dentistry as a whole. Among the more recent breakthroughs in dental informatics are diagnostic tools, computer-aided design and manufacturing, digital acquisition of 2D or 3D images, and computer-assisted surgery (Islam et al., 2018; Schleyer, 2003; Benoit et al., 2022). Due to the high importance of dental health, there is a constant need to improve patient care, as well as training and education for future dental practitioners (Masic 2012).

With the progress of IT has come a reduction in the size of medical devices, as increased power has also coincided with a decrease in computer size (Hovenga et al.,2010). Many computing advances have been made over the last decade, with the technological landscape now being dominated by both user-carried smart devices, as well as non-invasive implantable devices (Hovenga et al., 2010). Similarly, during the COVID-19 pandemic, there was a growing realisation of the potential usefulness of Information Technology (IT) tools in providing remote clinical services and educating patients, where appropriate (Golinelli et al., 2020). This was also seen in dentistry, where there was a changing view of the workforce during the pandemic as dental health practitioners contributed to the public health practice of testing, monitoring, tracking cases and staffing in healthcare services. It was also an opportunity to reflect on competencies of dental practitioners in the HIT and the interoperability of electronic medical and dental records (London & Boroumand, 2022).

Currently, the most used technology is electronic patient records. Maintaining accurate records is a vital responsibility from both a professional and legal standpoint. Nevertheless, investigations globally demonstrate that standard requirements for clinical record keeping face barriers, including countries and regions such as the UK, Australia, and Scandinavia (Sittig et al., 2020; Sheikh et al., 2021; Rexhepi et al., 2021). Any application of dental informatics should prove its practical value by enhancing the standard of care and accessibility, improving management, promoting efficiency and safety, empowering and enabling patients, facilitating medical research, and promoting sustainability.

Healthcare in itself is a highly resource heavy sector, and due to its importance, there is a constant need for the resources to be available for use (Grosskopf et al., 2006).

There is also a large amount of waste produced from healthcare, most of which comes from either single use objects or hazardous medical waste (Kane et al., 2018). With the steady push for more sustainable healthcare measures as guided by the United Nations' sustainable development goals (SDG) the integration of digital technologies to limit the amount of resources needed by healthcare sectors, including dental care (McCombs & Darby, 2010; Singaraju et al., 2012; Khanna et al., 2022) is evident and supported by the World Dental Federation (FDI). The economic, social and ecological imperative at the heart of innovation is fundamental to societal transformation which support the SDG.

It is important to identify where the primary research is being conducted in the rapidly growing field of dental informatics (Masic, 2012; van Noort, 2012). Research into the current and potential impacts of health informatics has gained significant interest, exploring the history and limitations of the field prior to the digital age. With the emergence of digital technology, there is vast potential in health informatics to not only improve human health but also reduce the environmental impact of healthcare services through minimizing carbon footprints and resource consumption. Despite the documented uses of informatics in other areas of healthcare, there appears to be a scarcity of research on dental informatics, highlighting the need for more investigation in this domain.

This study adopts a bibliometric analysis in order to map out the knowledge structure of health informatics research, a technique proven to be valuable in the evaluation of social science research performance (Van Rann, 2003). This paper also reports a historical review to trace back the evolution of the health informatics concept.

The study aims to provide an illustration and updated analysis of the research that has been conducted in the field of dental informatics, trends in publication, quality, and quantity. With this information we map and evaluate the relevant literature for the purpose of identifying potential research gaps, and knowledge base, exploring the forefront of trends in its development, and exhibiting the boundaries of existing academic work. PubMed was chosen for this source as it is an online literature database and source of information for scientific research spanning the field of biomedicine and health. The NCBI PubMed (Canese & Weis, 2013) database is very important in biomedical literature and data mining (Frisch et al., 2009; Rani et al., 2015). There are more than 35 million citations in PubMed®, representing the largest collection of biomedical literature (National Library of Medicine, n.d.)

We examine the main contributors to the research in terms of countries, institutions and individual authors of papers. Country-specific contributions, degree of local and international research and the impact of the published research. This is revealed by

the cooperation network among various countries, institutions and even individuals in the dental health informatics field.

Methods

Bibliometrics was used to examine the growth and progress of dental informatics over time. All data was extracted exclusively from the PubMed online journal database over a period of 20 years (Jan 1989 to September 2019).

The search was conducted in three phases:

Phase one

The first phase was the initial search for literature. The data were obtained through a keyword search of Dental Informatics and Mesh terms used included dental Informatics, economics, education, ethics history, instrumentation, legislation and jurisprudence, methods, organization and administration, standards, statistics and numerical data, and trends. As the main purpose of this study was to analyse the trends of dental informatics, this is determined as a sufficient method of data extraction. Articles were downloaded into an EndNote database, and then vetted for their relevancy within the study in the second phase.

Phase two

The second phase included vetting the articles for relevancy to the subject. This involved analysing the articles to determine their relevancy in the field of dental informatics. This was completed by reading the titles and abstracts of the articles, as well as analysing the keywords section for the mention of 'dental informatics'. Inclusion criteria considered were articles only in the English language and that they were submitted and uploaded to the PubMed database as late as September 2019.

Phase three

The third phase involved excluding publications from magazine articles, editorials, conference notes and other non-peer reviewed material. After this final stage, 236 articles were remaining for the examination.

All the data used for analysis was manually collected from the articles contained within PubMed. These articles were accessed in electronic form from PubMed, the publisher's database or through the University of Tasmania. Two databases were created in Microsoft Excel 2013 in congruence with the third vetting stage for articles which were entered into the study.

The first database contained information based on the articles overall general information, from which the following information was recorded:

- Author/s
- Year of publication

- Journal of publication
- Institution of research affiliation
- International collaboration
- Geographic region of author/s
- Number of contribution authors

The second database contained information about the contributing authors within the overall dataset, from which the following information was recorded:

- Author name
- Institutional affiliation
- Country
- Region
- Number of contributing articles

To ensure a succinct and accurate analysis, a coding scheme was developed for each of these factors. There were certain factors that did not necessarily need to be coded. For instance, the journal of publication is already listed, and thus could be easily analysed. These data were then coded manually and systematically. As listed above, each paper was given an individual entry into the first database, and then each author was given an individual entry into the second database, irrespective of whether they had authored multiple papers in the first database. This equated to 236 entries in database one, and 671 entries in database two.

For this study, the data within the two created datasets were analysed by using the same Microsoft Excel 2013 program. The two datasets were analysed in isolation of each other, with characteristics of both being compared throughout the analysis of the results in the following chapter. During the data analysis, tables and charts were developed using Excel to categorically illustrate the finding of the analysis.

Results

There was a total of n=236 papers on dental informatics in this study published between 1986-2018. Figure 1 shows the number of papers published by year. Overall, this is an average of 7.9 papers per year. The trend of papers has increased over time, with very slight increases in the first decade of its inception in scientific papers. Whilst there were a few outlier years where productivity doubled and tripled from the previous years, shown in the years 1999, 2002, 2003, 2007 and 2016, the level of output in journals was stable in the first 20 years.

North America produced the most research in dental informatics, with 149 paper affiliations (ten of which were cross regional), in 61% of the total papers. Table 1 shows the distribution of the 236 papers in relation to their regional affiliation. This also provided cross-regional partnership numbers and a total number of paper affiliations by region. Figure 2 shows the total distribution of papers produced by

regions over time. As exemplified by the North American and European regions, there is linear growth in the amount of research into dental informatics as time has progressed.

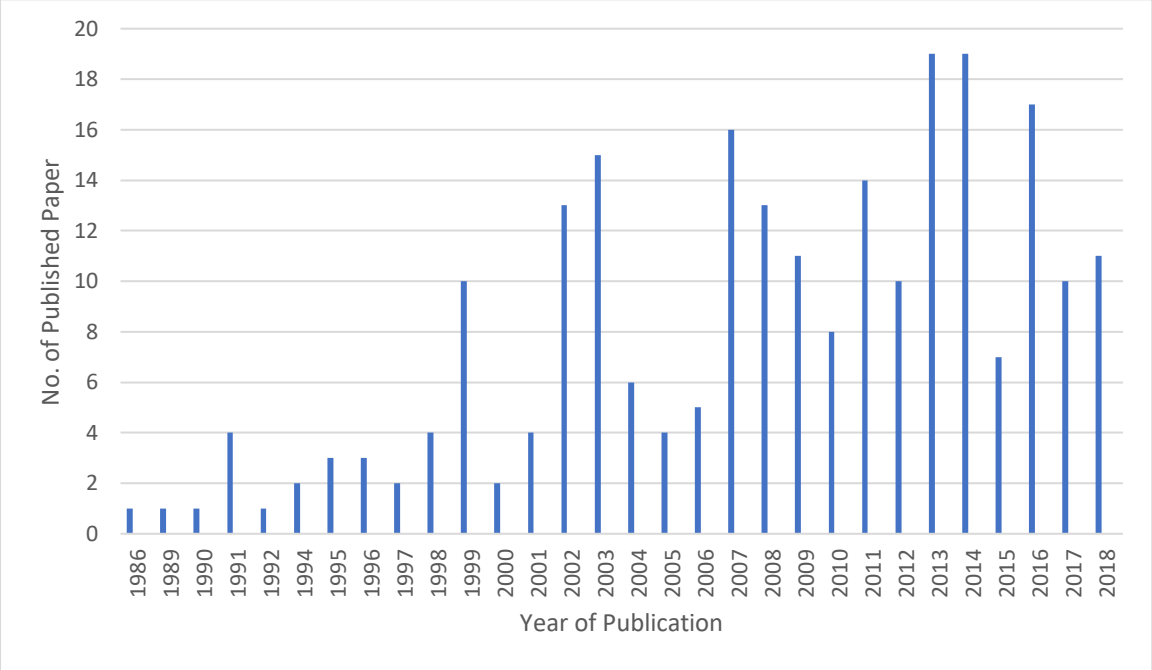

Figure 1: Time span of published papers.

Table 1: Top ten most published journals.

Ranking	Name of Journal Used	No. of papers	% of total papers
1	*Journal of Dental Education*	44	18.6%
2	*Journal of the American Dental Association*	17	7.20%
3	*Studies in Health Technologies and Informatics*	14	5.93%
4	*International Journal of Computerized Dentistry*	11	4.66%
5	*Advances in Dental Research*	8	3.39%
6	*British Dental Journal*	8	3.39%
7	*Dental Clinics of North America*	7	2.97%
8	*European Journal of Dental Education*	7	2.97%
9	*Journal of the American Medical Informatics Society*	6	2.54%
10	*American Journal of Orthodontics and Dentofacial Orthopedics*	4	1.70%

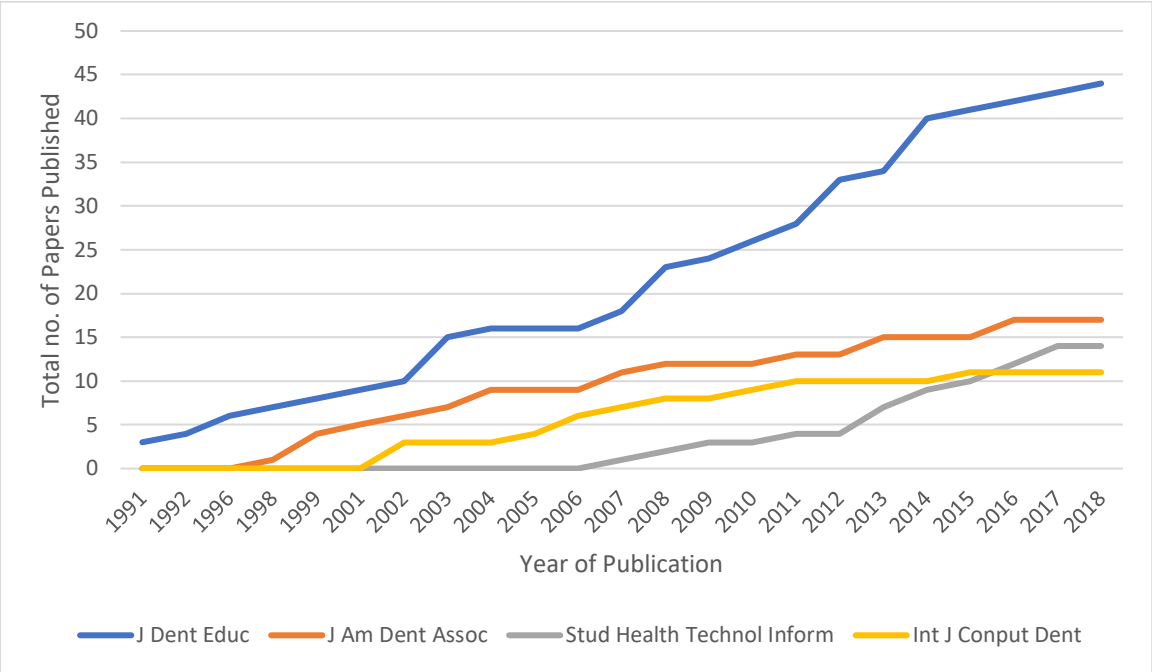

Figure 2: Total number of papers produce by Journal over time.

Table 2 illustrates further the amount of collaboration between institutes through the decades. This increased in the last decade compared to previous years, with an emphasis on cross institutional collaboration as opposed to working within the realms of a single institute. In terms of the number of authors on the papers themselves, there is a high level of colleague collaboration. Whilst the highest proportion of papers feature only one author, there are a large proportion of articles that featured two, three and four authors. Figure 3 shows the proportion of papers by the number of authors featured in the paper. Eight papers featured ten or more authors and one paper contained 26 individual authors.

Table 2: Top ten most productive countries by papers authors.

Ranking	Country	No. of papers	% of total papers
1	United States	144 (15)	61.2%
2	United Kingdom	18 (6)	7.63%
3	Germany	15 (6)	6.36%
4	Australia	8 (1)	3.39%
5	Brazil	8 (3)	3.39%
6	China	6 (3)	2.54%
7	Greece	6 (3)	2.54%
8	Italy	6 (5)	2.54%
9	Thailand	5 (1)	2.12%
10	Sweden	5 (2)	2.12%

Table 3: Distribution of papers by region

Region	No. Papers produced	No papers collaborated	Total paper affiliation	% Papers affiliated
Africa	2	1	3	1.22%
Asia	17	4	21	8.54%
Europe	47	11	58	23.6%
Middle East	4	-	4	1.63%
North America	139	10	149	60.6%
Oceania	7	1	8	3.25%
South America	8	3	11	4.47%

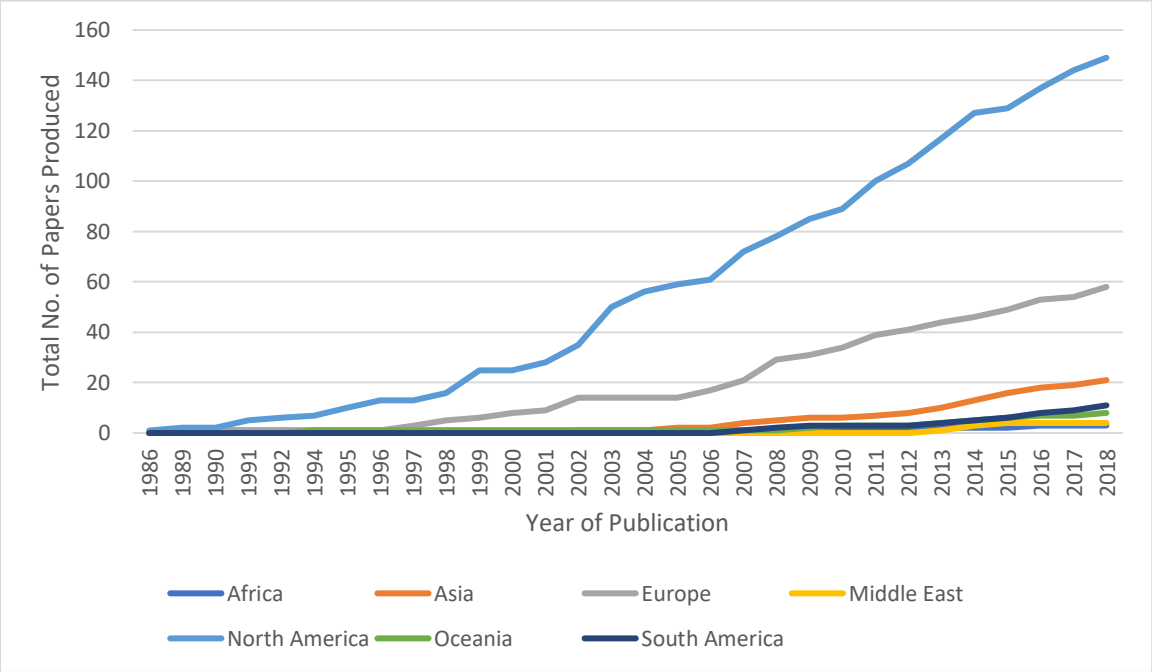

Figure 3: Total number of papers produced by region over time.

Of the 671 individual authors, almost half of them came from North America, with 320 (48.9%) coming from North American Institutions. There were 195 authors from European nations, and 80 from Asian nations (27.6% and 12.2% respectfully). Figure 4 shows the shows the total number of authors by region.

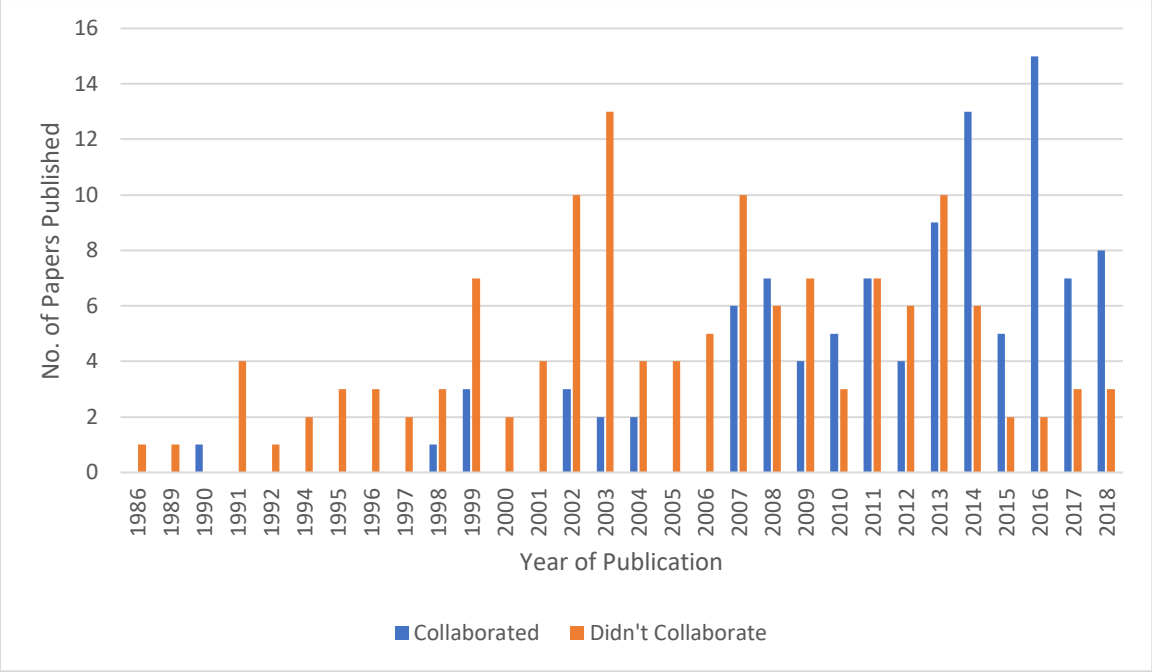

Figure 4: Number of papers produced over time, comparing levels of collaboration.

As mentioned in the previous section, there were 41 countries represented in this study. There were only 15 countries which had 10 or more representatives, seven of which came from Europe. Unsurprisingly, the United States had the highest number of authors, over 50, with 309 (46.1%) from this country. The other top five nations by representation were the only participants to have over 20 authors, with the UK (43), Germany (34), China (29) and Brazil (23) represented by two thirds of the total number of authors (64.2%).

Discussion

The results revealed that research on the topic of dental informatics began in the mid to late 1980s but did not really take off until the turn of the millennia. The most productive years were in the last decade, reaching a high point in the mid 2010s. (Cesnik & Kidd 2010; Kim et al., 2011). The term 'health/medical informatics' was thought of as a concept when the idea that information technology could harness a power for high levels of data storage in the 1960s was starting to become a reality (Fitzmaurice et al., 2002; Tachakra *et al.,* 2003). It was not until the 1980s when the potential of information technology in medicine was realised, primarily though the implementation of computer-aided design and computer-aided manufacturing (CAD-CAM) (Qi et al., 2015; Tapie et al., 2015). Computer processing powers had a mostly linear growth from the 1980s and 1990s, but over the course of the last 15-20 years, this growth in processing power has become more logarithmic (Fitzmaurice, et al., 2002; Tachakra et al., 2003). In this growth in power, there is a higher capacity to use IT for medical purposes. The growth of medical-related computer software, development of programs such as electronic records and mass amounts of data storage have coincided with the growth in computer power (Pavis & Morris 2015).

In terms of geographic distribution of papers and authors, North America featured in 145 papers, or 61.4% of all papers. European authors were present on 47 papers, or around 24%. This demonstrates that America's dental informatics researchers are at the forefront of the current and historical research into dental informatics (Singhal et al., 2018). It also indicates a high level of investment into the development and implementation of dental informatics in the United States (Acharya et al., 2017; Washington et al., 2017; Singhal et al., 2018; Wu, 2020). The introduction of the widespread use of HIT in North America has also been aided by the HITECH Act. This has been established to ensure that electronic health records are implemented throughout the United States, with the supporting technology also provided. This has diverted over USD$19 billion into the integration of HIT into American health facilities (Hoggle, 2012; Washington et al.,2017).

This investment may also act as a drawcard for influential members of the scientific community, which can garner increased funding for projects in this field, and thus increase knowledge and research in the field of dental informatics (Molloy et al, 2011; Wu, 2020). This becomes increasingly apparent when analysing the most prevalent authors within this study, all of which come from the United States, with the top three authors employed by the same institution. Historically, the United states have always been at the forefront of computer technology advancement, and thus it would also make sense that they have developed a high level of research into medical informatics, including dental informatics (Tibbo, 2003; Leidner & Kayworth, 2006; Ozbolt & Saba, 2008; Acharya *et al.,* 2017). Worldwide research is generally thought to have global emphasis and local impacts, but this is not always the case. Developed countries make up the bulk of global research in all areas (Bean et al., 2004; Duque et al., 2005). Whilst tools such as electronic dental records have already improved the efficiency and quality of dental care that patients are receiving, there are barriers to entry of dental informatics in developing countries, who cannot afford the infrastructure for electronics within health systems (Sood et al., 2008; Ahlan & Ahmad, 2014; Qi et al., 2015; Gonzalez-Brambila et al., 2016).

This study found a low level of international collaboration, with only 25 papers featuring international collaboration. Of these, 12 papers were conducted across different continents. Collaboration has become a product of a globalised world, with more technology available to provide communication and share data points and methods becoming widespread (Godoy-Ruiz *et al.,* 2016). In most fields this has generally led to the ability to pool viewpoints, resources, and workloads to produce answers to complex questions (Davidson et al., 1979; Chen et al., 2019).

Whilst benefits of cross-national and cross-regional collaboration are noted, there are limitations to the possibility of collaboration. Possible reasons can include the length of time to develop relationships between institutions and researchers; barriers

in research protocols; barriers in resource gathering; failure of integration of HIT systems; as well as possible security concerns that may occur in implementation of HIT systems (Davidson et al., 1979; Freshwater et al., 2006; Lee et al.,2010; Chinchilla-Rodríguez et al., 2012). It is also an issue for countries who do not have adequate infrastructure to develop HIT systems of their own (Wagner, Park & Leydesdorff, 2015; Nolan et al., 2017). It has been noted that there are considerable difficulties in not only implementing HIT infrastructure, but also maintaining it, with necessary resources like healthcare professionals, hospitals and clinics and readily available access to important structures like the internet being sparse in developing regions (Fraser et al., 2005; Sood et al.,2008). Low-income countries that have attempted to implement HIT have seen improvements in healthcare efficiency, with successes in Brazil and India (Fraser et al., 2005; Sood et al., 2008; Radhakrishna et al., 2014; Bassi et al., 2018).

Whilst the level of international collaboration was low, there was an overwhelming presence in institutional collaboration. Almost half of the total papers in this study, as well as the majority of papers in the last decade, have had cross-institutional involvement. As mentioned, this normally occurs across institutions within the same countries (Ductor 2015). It can be perceived that multiple authors on papers would lead to a higher quality study, as the greater the number of minds working on a project would garner greater and more diverse knowledge on subjects (Edwards et al., 2010; Zare-Farashbandi et al.,2014).

Health informatics has been viewed as the modern way forward in terms of advancement in records management, but more importantly sustainability and improved efficiency in healthcare. The current understandings of the power of using HIT have already been implemented to good effect in developed countries, with the framework for further implementation already underway. This bibliometric study aimed to analyse the current rates of research into dental informatics and may be used to establish where the main bases of knowledge lie on the subject. This study has assembled a collection of characteristics of all current dental informatics within PubMed from 1986 up to 2018. These characteristics highlight the distribution of papers in terms of region, country, and journal, as well as discussion of the most prevalent minds in the field of dental informatics through the analysis of production of papers, institution of origin and the rates of collaboration. This study also provides the basis of new research for future topics of research within the field of dental informatics as it evolves from its current state.

Limitations

Bibliometrics is a quantitative method that is often used to evaluate research performance, identify trends, and inform decision-making, but it provides only one part of the picture. High citations may not always indicate quality but may be refuting its results. They should always be used in conjunction with other data

including funding received, awards granted and peer review. The process used in this study may be limited by manual process rather than use of statistical software, human error and incomplete data processing may have occurred.

Conclusion

Dental informatics is still in its infancy. The rates of research are increasing yearly, with more methods of dental informatics implementation being researched. Health informatics in general has been successful in achieving sustainability, with increased efficiency and reduced resource waste being linked with HIT. Whilst rates of HIT uptake in developed countries is high, it is still quite low in developing countries. Future research is needed to investigate more cost effective and successful methods of dental informatics implementation, to enhance the sustainability of dental healthcare.

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