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A Bibliometric Analysis on the Current Trend of Cone Beam Computed Tomography (CBCT) Related Research in Dentistry

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ABSTRACT

The main objective of this study was to ascertain and characterise different articles published in the field of dentistry based on cone beam computed tomography (CBCT) imaging technique. The search was performed using Scopus database to generate publications relevant to usage of CBCT in relation to dentistry. Additional data comprising of citation information, bibliographic information, abstract, keywords and other information was also included. Bibliometric pointers such as citation and documents, authors, journals and keywords were also investigated. About 411 research papers were available from 2004 and 2020 and were further analysed using VOSviewer 1.6.15. A gradual increase in the number of publications can be seen, however in 2018, highest number of papers was published. USA, Turkey and Brazil were the topmost countries making substantial contributions. The most productive organisation was University of Michigan School of Dentistry, USA. Journal of Dentomaxillofacial Radiology was the most preferred journals by authors. This is one of first bibliometric analysis that aims to identify different research articles published in the field of dentistry that focused on CBCT. This study will be helpful to the investigators who have just started CBCT based research by providing them with a general insight regarding research tendency along with source of possible associations among different authors and countries.

Keywords: *Bibliometric analysis; cone beam computed tomography; dentistry; Scopus; VOSviewer*

INTRODUCTION

The advent of non-invasive radiological imaging techniques has played an essential role within the fields of dental and medical sciences. Back in 1895 radiographs were introduced for the first time by Conrad Roentgen (Brogdon & Lichtenstein, 2000; Venkatesh & Elluru, 2017). Since then, with continued development within the field of radiology particularly with the inception of three-dimensional (3D) imaging techniques such as cone beam computed tomography (CBCT), it has gained attention as a novel, non-invasive diagnostic instrument. CBCT basically implicates innovation of different tomographic imaging methods that leads to consequential volumetric image reestablishment precisely intended for dental procedures (Gondivkar *et al.*, 2018b; Jacobs *et al.*, 2018).

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Presently there has been rapid advancement of CBCT equipment due to the advancement of various innovative technologies. In recent years, numerous studies were published focusing on various features and variations which have been associated with the field of CBCT (Snyder & Raichle, 2012). Moreover, owing to extensive areas which can be examined using CBCT, this study will provide valuable information to researchers to identify main topics which have greater impact amongst the published articles. Depictions of high-impact researches will be helpful for future researchers to recognise the main research domains (Moed, 2009).

Studies based on bibliometric analysis allow discovery of incidence and latest trends of scientific publications related to particular topic and detect association of citations between publications systematically (Shi *et al.*, 2019; Demir *et al.*, 2020). Special emphasis has been placed upon the growing trends of a specific field such as of the total number of publications, highly preferred journals, most dynamic authors and countries producing the highest number of papers.

Currently in dentistry, bibliometric based research has been executed in various dental topics such as oral cancer, endodontics, maxillofacial surgery, orthodontics and oral submucous fibrosis (Brennan & Habib, 2011; Fardi *et al.*, 2011; Hui *et al.*, 2013; Gondivkar *et al.*, 2018a; Pena-Cristóbal *et al.*, 2018). Inspection of citation analysis of experimental applications of CBCT based on this new bibliometric method can detect the advent of the latest topics. This investigation aims to provide researchers not only an understanding regarding the research trend based on the usage of CBCT imaging within the field of dentistry but will also provide a vision regarding the potential research themes and possible collaborative associations.

MATERIALS AND METHODS

The research for this topic was performed on 4th December 2020 using Scopus database as it principally comprises elaborated and high-quality literature sources within its collection. The search was performed by electronic means which was narrowed down to this topic that was incorporated in the title, abstract and keywords.

On the search engine the term "CBCT" and "dentistry" was typed so that only articles containing these words in their title or in keywords were selected. Type of article was restricted to "original research articles" while other publications such as "reviews, conference papers and early access" were marginalised. Furthermore, only articles that had been published in English language were chosen. Then data regarding citation which were title, authors, year of publication, number of citations, sources, abstract, bibliographic information, different keywords and reference evidence of all articles was selected and transferred in a comma-separated values (CSV) file format for additional analyses. The shortlisted articles were then evaluated using specific software designed particularly for bibliometric analysis which is Visualization of Similarities viewer (VOSviewer) version 1.6.15 (Centre for Science and Technology Studies of Leiden University, Netherland) (van Eck & Waltman, 2010; Lou *et al.*, 2020; Yu *et al.*, 2020).

VOSviewer can analytically investigate specific details like the main title of paper, abstracts, keywords, affiliations, countries, authors and organisations. Subsequently after exporting the scopus.csv file, data was further evaluated on Microsoft Office Excel 2018 (Microsoft Corporation, USA).

Specific citation analysis was carried out for documents, sources, authors, organisations and countries. Subsequent records were further visualised using Graph Pad prism. Furthermore, using co-occurrence, all keywords were envisioned using density visualisation. Additionally, maps were formulated that showed "bubbles" which basically represent the number of different publications while the spaces seen in between the bubbles indicate the relationship of two keywords. Likewise, the colour of each bubble represents different meaning within the different visualisations.

To identify keywords with greater influence of co-occurrence, investigation was performed on keywords having a minimum number of 10 co-occurrences. Different keywords related to CBCT and dentistry were also selected. Among the 1,776 keywords, 101 words met the criteria. Additionally, average citation score per document was evaluated by dividing the citations by the total number of documents.

RESULTS

Overall Growth Trend

Research within the domain of CBCT in dentistry was initiated in 2004. The graph demonstrated that from 2012 onwards, dramatic increase in the number of publications was observed. Moreover, 2018 presents with the highest number of publications (n = 80). The number of publications had reduced in 2019, with only 58 publications but then had increased in 2020 (Fig. 1).

Top Countries

Among 63 countries having publications in CBCT related research in dentistry, 13 met the criteria of having a minimum of 10 publications. USA produced the highest number of publications (105 documents, 1,715 citations), followed by India publishing 66 papers but received only 236 citations.

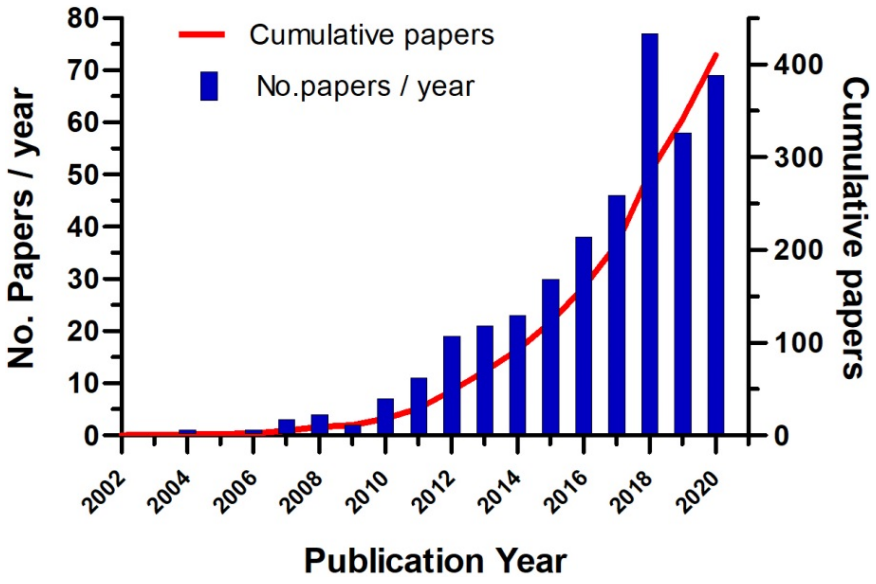

Fig. 1 Number of yearly distribution of publications per year and cumulative publications on CBCT related research in dentistry.

This is followed by Brazil producing 55 publications with 57 citations and Turkey having 39 publication and 264 citations. The highest average citation per paper was received by Belgium and USA which were 19.46% and 16.33%, respectively (Table 1). Total link strengths represent collaborations between countries and they were further portrayed in Fig. 2. USA, Belgium and Brazil were amongst the greatest collaborative countries having link strength in the order of 79, 49 and 35, respectively (Table 1, Fig. 2).

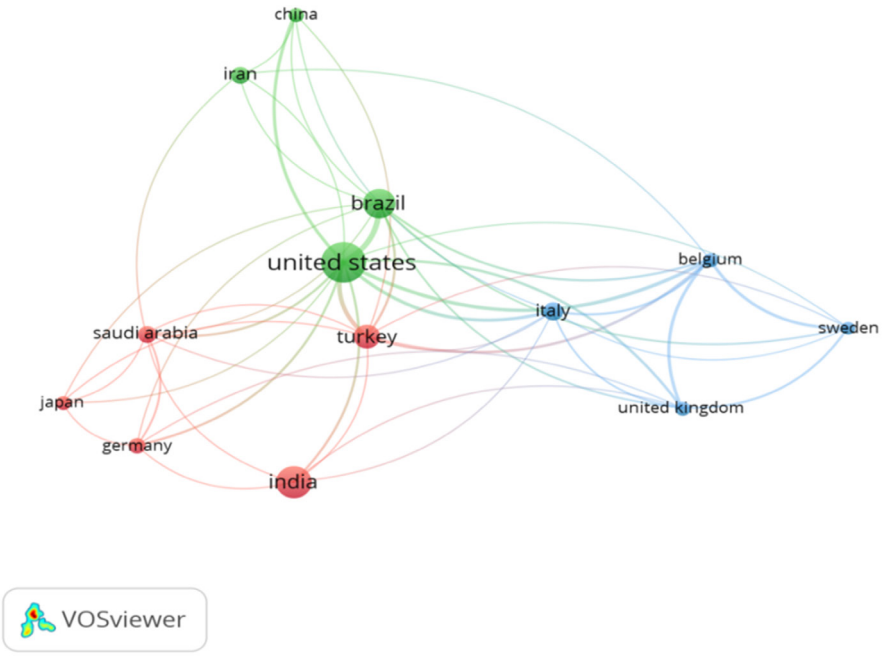

Fig. 2 Collaborative network between countries on publications of CBCT related research in dentistry. Countries with a minimum of 10 papers published were included. The size of bubbles represents number of publications, while the line represents collaboration among countries.

Table 1 Top countries that published a minimum of 10 papers of CBCT related to dentistry, with average citation per paper and total link strength

Country	Number of papers	Citations	Average citation per paper (%)	Total link strength
USA	105	1715	16.33	79
Brazil	55	757	13.76	35
Turkey	39	264	6.77	27
Belgium	13	253	19.46	49
India	66	236	3.58	13
Italy	23	178	7.74	22
Germany	17	155	9.12	13
Japan	14	150	10.71	5
China	14	130	9.29	13
Sweden	10	112	11.20	19
United Kingdom	14	100	7.14	27
Saudi Arabia	20	71	3.55	13
Iran	18	61	3.38	5

Top Organisations

From 115 organisations with publications in CBCT related research in dentistry, only six met the criteria (Table 2). University of Michigan School of Dentistry from USA published three papers and received the highest (36) citations while Karolinska Institutet, Sweden published four papers and received 35 citations. This is followed by Chulalongkorn University, Thailand which published three papers and 29 citations. The highest average citations per paper was received by University of Michigan School of Dentistry, USA (12.00%) followed by Chulalongkorn University, Thailand (9.67%). Only Chulalongkorn University, Thailand and Karolinska Institutet, Sweden has collaborations with other organisations represented by link strengths of nine and two, respectively.

Author Relationship

Table 3 displays the topmost authors who have contributed to this field by publishing more than four papers. Jacobs R, Hassan B, Wang HL and Lin WS had the greatest number of publications. It is interesting to note that even though Hassan B produced only five papers, he received 188 citations and average citations per paper of 37.6%. Jacobs R and Hassan B also have the most collaborations represented by link strengths of 18 and 14, respectively.

Table 2 Top organisations that published a minimum of three papers in CBCT related research in dentistry

Organisation	Country	Number of papers	Citations	Average citation per paper (%)	Total link strength
University of Michigan School of Dentistry, Ann Arbor	USA	3	36	12.00	0
Karolinska Institutet, Stockholm	Sweden	4	35	8.75	2
Chulalongkorn University, Bangkok	Thailand	3	29	9.67	9
Ankara University, Ankara	Turkey	3	25	8.33	0
Nihon University School of Dentistry, Tokyo	Japan	3	7	2.33	0
Jordan University of Science and Technology	Jordan	3	5	1.67	0

Table 3 Top authors who published four or more papers of CBCT related research in dentistry

Author	Number of papers	Citations	Average citation per paper (%)	Total link strength
Jacobs R	10	245	24.50	18
Hassan B	5	188	37.60	14
Turkyilmaz I	4	124	31.00	0
Wang HL	5	49	9.80	0
Lin WS	5	42	8.40	13
Harris BT	4	42	10.50	13
Morton D	4	42	10.50	13
Alam MK	4	37	9.25	3
Yilmaz B	4	35	8.75	7
Estrela C	4	22	5.50	0
Patil S	4	16	4.00	2

Leading Journals

Dentomaxillofacial Radiology published the most articles in CBCT related research in dentistry i.e., 24 papers which received 865 citations. This is followed by *Journal of Prosthetic Dentistry* with 46 articles and 280 citations. Next is *Journal of Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology* which published only five papers but acquired 194 citations (Table 4).

Journal of Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology, *Dentomaxillofacial Radiology* and *Journal of Endodontic* received the highest average citation per paper of 38.80%, 36.04% and 27.67%, respectively. Additionally, *Journal of Dentomaxillofacial Radiology*, *Journal of Prosthetic Dentistry* and *Journal of Endodontics* scored the highest link strengths of 14, 10 and 8, respectively (Table 4). These journal relationships are also presented in Fig. 3.

Articles and Citation Relationship

The software narrowed down the number of articles which received more than 50 citations to 15 (Table 5). The topmost cited article was by Lascala *et al.* (2004) with 355 citations, followed by Pinsky *et al.* (2006) with 211 citations.

Table 4 Top journals that have published five or more papers of CBCT related research in dentistry

Journal	Number of papers	Citations	Average citation per paper (%)	Total link strength
Dentomaxillofacial Radiology	24	865	36.04	14
Journal of Prosthetic Dentistry	46	280	6.09	10
Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology	5	194	38.80	1
Journal of Endodontics	6	166	27.67	8
Clinical Oral Implants Research	7	140	20.00	2
Clinical Oral Investigations	7	134	19.14	7
European Journal of Dentistry	15	126	8.40	4
Imaging Science in Dentistry	6	91	15.17	6
Orthodontics and Craniofacial Research	6	74	12.33	0
Journal of Conservative Dentistry	24	67	2.79	2
General Dentistry	23	55	2.39	4
European Archives of Pediatric Dentistry	8	45	5.63	3
Journal of Oral Science	13	42	3.23	3
Indian Journal of Dental Research	7	41	5.86	1
Contemporary Clinical Dentistry	19	30	1.58	3
Dentistry Today	5	20	4.00	1
Journal of International Society of Preventive and Community Dentistry	8	9	1.13	1
Cumhuriyet Dental Journal	11	7	0.64	2
Journal of Applied Oral science	5	7	1.40	1
Saudi Dental Journal	5	3	0.60	1

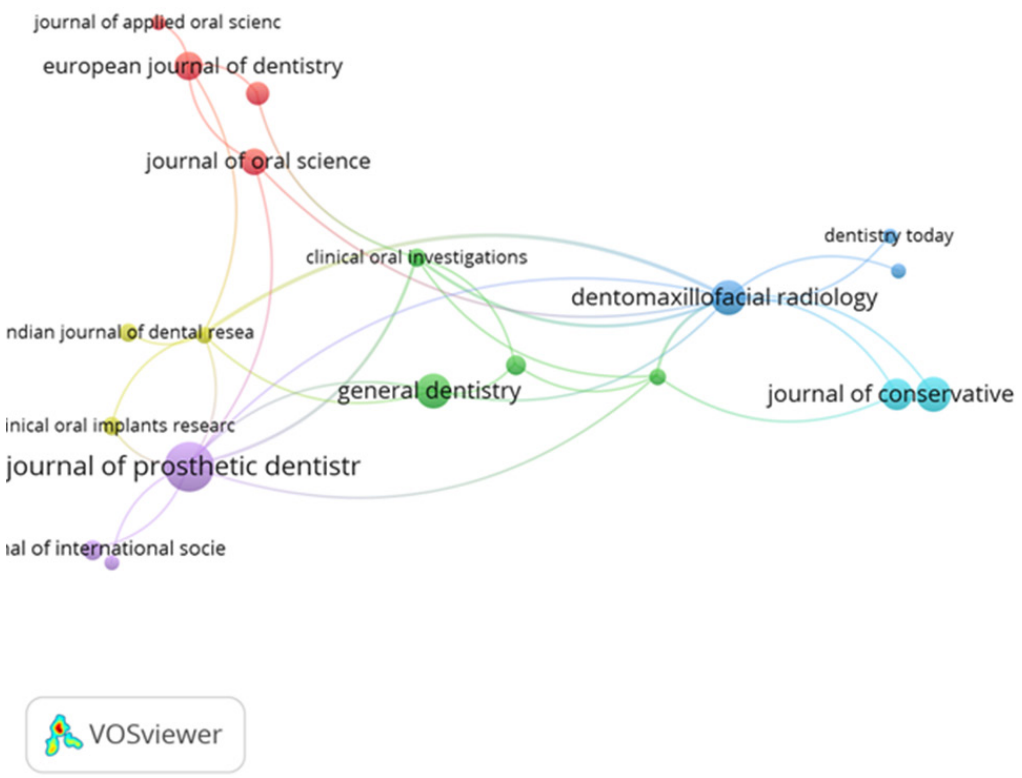

Fig. 3 Sources and citation relationship of journals that published papers of CBCT related research in dentistry.

Table 5 Top articles of CBCT related research in dentistry with more than 50 citations

Articles	Citations	Total link strength
Lascala *et al*. (2004)	355	1
Pinsky *et al*. (2006)	211	1
American Academy of Oral and Maxillofacial Radiology (2013)	166	0
Bernardes *et al*. (2009)	114	0
Hatcher (2010)	110	0
Idiyatullin *et al*. (2011)	90	0
Januário (2008)	83	0
Li (2013)	72	0
Hassan *et al*. (2010)	71	1
Al-Rawi *et al*. (2010)	63	1
Patel *et al*. (2010)	61	0
Price *et al*. (2012)	60	0
Enciso *et al*. (2010)	54	0
Turbush & Turkyilmaz (2012)	53	0

Keywords

Fig. 4 identifies the commonly used keywords used in CBCT related research in dentistry and the number of its repetitions. From 1,776 of total keywords, 101 were repeated 10 times hence chosen for evaluation. The most used keywords include "cone beam computed tomography" (265), "cone-beam computed tomography" (280), "diagnostic imaging" (87), and "three dimensional imaging" (51).

Specific Dental Fields

Fig. 5 displays the highest five dentistry fields which have used CBCT as their methods. The highest number of publications were in the field of dental implants, which started in 2003, with dramatic rise in the number of publications each year till 2020 (n = 125). Orthodontics contributed the second large number publications in CBCT, initiating in 2005, with constant publication from 2012 to 2015, experiencing a decline in 2016 and was followed by a steady inclined trend until 2019 where only 36 papers were published in that year. Publication of CBCT articles related to dental pathology started in 2006 with increasing trends each year and a slight decline in 2015. Publications increased in 2016 and 2017 but declined again from 2018 until 2020. CBCT publications related to third molars experienced a steady slight increase in publications each year starting in 2009 with highest number of papers in 2019 (n = 21). Lastly, CBCT publications on dental trauma also started in 2009 with almost constant number of papers each year.

DISCUSSION

To the best of our knowledge, this is one of the first bibliometric analyses that aims at summarising numerous research articles published in the field of dentistry that utilised CBCT imaging technique. CBCT is a newly evolved field and plays a fundamental role in dental imaging (Demir

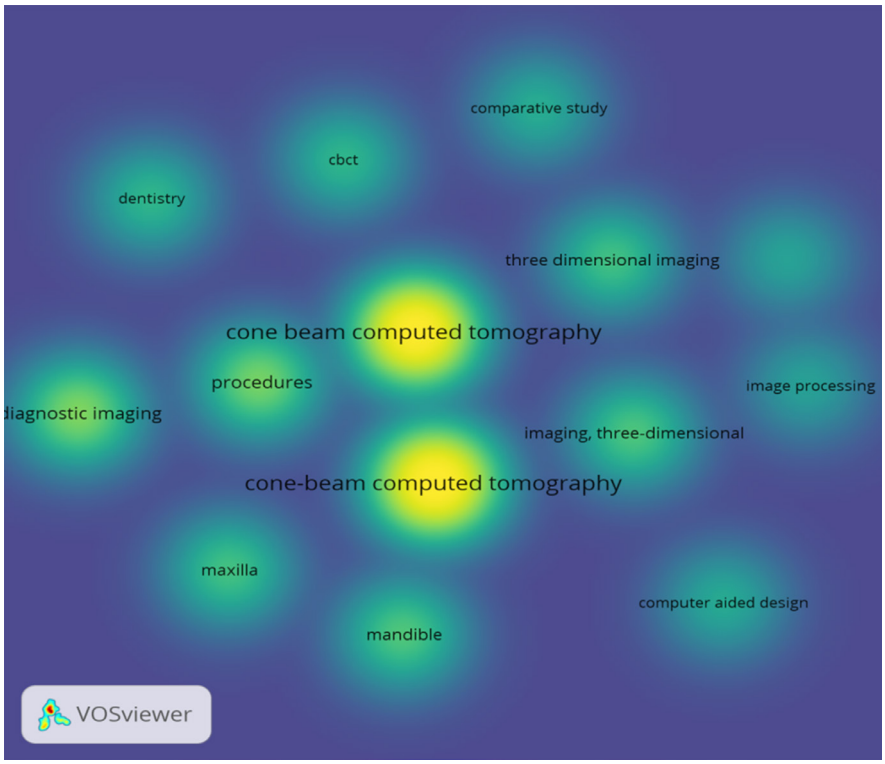

Fig. 4 Density visualisation of different keywords used in CBCT related research in dentistry. The spacing in between them is related to the closeness of the interactions in between two words.

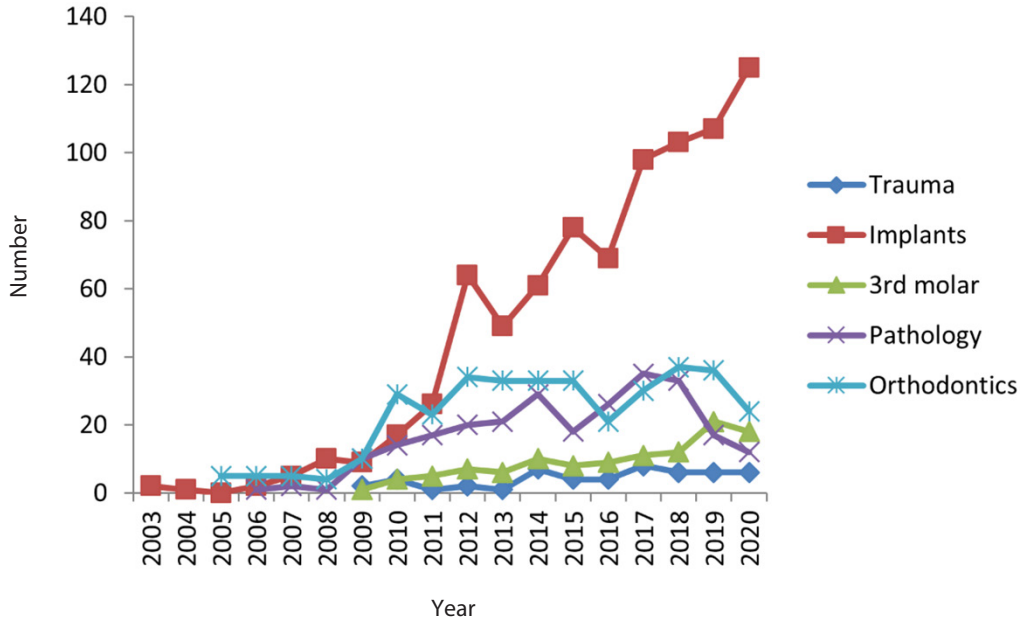

Fig. 5 Number of yearly distribution of publications per year of the highest dentistry fields with CBCT related research.

et al., 2020). This bibliometric analysis will permit a quantifiable, methodical and unbiased calculation regarding the number of publications in this specific area that aids investigators to develop understanding regarding the previous and existing trend as well as a complete vision regarding future direction (Kumar & Kaliyaperumal, 2015; Shi *et al.*, 2019).

Advent of digital journal archives such as PubMed, Scopus and Web of Science, along with progress of computer software have facilitated analysis of archived data. VOSviewer is one of the software that helps making the procedure of bibliometric investigation straightforward and time-saving. Consequently, the trend of bibliometric analyses in several fields has increased tremendously (Gualdi-Russo & Fonti, 2013; Ozsoy & Demir, 2018). Scopus database was the medium used in this study as it is one of the largest search networks and provides a large source of abstracts and literatures. It tends to ease the researchers access to systematic data as well as provides literature for the purpose of investigation (Falagas *et al.*, 2008; Celeste *et al.*, 2016).

Overall Trend of Publication

One of the most remarkable outcomes from the existing study is the rapid growth in the quantity of articles related to CBCT in dentistry since the early 2000. In 2018, the highest number of papers (n = 80) in this particular field were published. The trend of publication continued till date but not as high as it was in 2018.

Top Countries

USA gained first position in publishing highest number of articles (n = 105) and received highest number of citations (n = 1,715). Similar results have been received by previously conducted bibliometric analysis (Gutmann, 2009). This increase in scientific contribution can be attributed to high funding and support provided to researchers by the USA government mainly via the National Institute of Dental and Craniofacial Research.

Cluster analysis performed in Fig. 2 illustrates countries having close cooperative associations. Geographical location plays an important role in terms of associations

between different countries (Demir *et al.*, 2020). However, results from the present analysis did not capture any specific association between the geographic locations and cooperative network of the different countries. Greatest collaboration was seen between USA, Brazil and Turkey, all of which are geographically apart.

Most Productive Organisation

In conformity with the previously conducted research, academic organisation from USA which is University of Michigan School of Dentistry was identified as the most productive organisation in publishing and receiving the highest citations (Paladugu *et al.*, 2002; Baltussen & Kindler, 2004; Lefaivre *et al.*, 2010). This could be due to the presence of greater number of scientific faculty and massive monetary resources provided to the researchers (Shadgan *et al.*, 2010; Ahmad *et al.*, 2020). Karolinska Institutet, Stockholm in Sweden published comparatively more papers but received slightly less citations comparatively.

Top Contributing Authors

Jacobs currently affiliated with University of Leuven, Belgium published 10 papers and received the highest citations (n = 245). This is followed by Hassan, associated with University of Madrid, Spain who published the second highest number of papers. This could be due to their research domain is mainly in CBCT related research in dentistry and they have access to the facility and receives excellent computer support.

Most Preferred Journals

The *Dentomaxillofacial Radiology* was the most highly cited journal within this field. It published 24 articles and had 865 citations with similar results discovered by previously conducted bibliometric analysis (Gondivkar *et al.*, 2018b). The *Journal of Prosthetic Dentistry* published more papers (n = 46) but received less citations of only 280. The co-citation analysis illustration in Fig. 3 demonstrates that *Journal of Prosthetic Dentistry* was the greatest cluster group and had greater publications with other journals.

Keywords

Keywords form an essential constituent of a research article. When searching the literature, the usage of keywords retrieves additional pertinent outcomes rather than using various phrases. These keywords basically act in way as "codes" to source the required systematic research papers hence it is vital to select keywords wisely that will help in future searches (Natarajan *et al.*, 2010). The keyword exploration in this research identified three main clusters with the greatest keywords with occurrence were "cone beam computed tomography", "cone-beam computed tomography", "diagnostic imaging", and "three dimensional imaging".

Specific Dental Fields

Most dentistry field articles published in relation to CBCT were based on dental implants. It can be attributed to the fact that scientific publications and association within the field of implant has increased tremendously in recent years. Significant increase in the number of CBCT dental implant publications also found by Tarazona *et al.* (2017). Orthodontic and dental pathology evaluation with CBCT also have similar increase in the number of publications though with decreasing trends from 2018. In contrast, Liu *et al.* (2020a) identified tremendous increase in dental pathology publications each year. Surprisingly CBCT was not used as much in third molars and trauma evaluations. Other researchers however found huge increase in the number of publications in the field of dental traumatology (Liu *et al.*, 2020b) and analysis of third molars (Balel, 2021).

A few limitations from the current analysis were identified. In the present study, Scopus database was solely utilised to gather information. Scopus database generally provides about 20% additional analysis

compared to Web of Science and gives more predictable outcomes compared to Google Scholar (Patil *et al*., 2020). Although Scopus is considered an authentic source, it cannot in true sense represent the whole peer-reviewed literature. Therefore, the likelihood of excluding significant articles from other sources such as Google Scholar, PubMed and Web of Science cannot be ruled out. Another drawback is occasionally authors tend to increase their citation number by self-citation which can lead to biasness.

CONCLUSION

To the best of our knowledge, this is one of the first bibliometric analysis to identify different research articles published in the field of dentistry that focused on CBCT. It can be clearly seen that the trend of using CBCT in dentistry has increased over the last eight years. In this respect, this study will be helpful to the investigators who have just started CBCT based investigation by providing them with a general perception regarding the current research tendency along with source of possible teamwork among different authors.

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