Bibliometric analysis of research on dental age estimation

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KEYWORDS

Dental age estimation, Bibliometric; dentistry, forensic odontology, Citation analysis

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ABSTRACT

Dental age estimation plays a key role in therapeutic, medicolegal, forensic, and anthropological applications. The purpose of this study is to evaluate the research progress on dental age estimation using bibliometric analysis. Data were gathered from Scopus, Web of Science and PubMed. Keyword co-occurrence analysis, collaboration network analysis, and descriptive analysis of bibliographic data were all completed using VOS viewer and Biblioshiny software. There has been an ongoing but gradual rise in research regarding dental age estimation, with notable increase since 2014. The country with the most publications published (205) was India. The year of 2018 (TP = 92) and 2021 (TP = 100) saw a rapid spike in publications and citations, respectively. The Shanghai Jiao Tong University School of Medicine, which has 153 citations, was the most productive institution. Forensic Science International was the journal with the greatest number of publications (73). Author Cameriere had the maximum number of publications (30). The increase in publications associated to collaboration across numerous authors, nations, and institutes serves as evidence of the significant improvement in dental age estimation. This citation analysis allows for the identification of the most relevant and pertinent research fields while providing a view on the development of research in the field of dental age estimation.

INTRODUCTION

Dental age estimation is one of the major parts of forensic dentistry that helps in identification and dental profiling of an individual. [1] The literature acknowledges that various methods exist to determine dental age, which are broadly divided into three types: morphological, biochemical, and radiological methods.[1] Morphological methods rely on the visual examination of dental features, such as tooth mineralization stages, eruption patterns, root formation, and dental crown morphology. Biochemical methods involve the analysis of biological markers within teeth, such as stable isotopes, enamel proteins, or DNA. Radiological methods utilize imaging technologies, such as dental radiographs or cone-beam computed tomography (CBCT), to assess dental development. [2] Every individual has a unique morphology and arrangement of teeth which makes them an identifiable aspect in forensic dentistry. [2] The first publication of information about dental implications in age assessment was a pamphlet called "Teeth A

Test of Age" in 1837, which was presented to the English parliament by dentist Edwin Saunders. [3,4] Due to the fact that teeth start to form in the early stages of embryonic development, this field has undergone substantial research. Additionally, the information offered by the chronology of dental growth is more trustworthy than that from bone development. [5] The consistency and predictability of dental development allow for the establishment of robust age estimation methods based on dental growth stages. These methods involve the examination of specific dental characteristics, such as tooth mineralization, tooth eruption patterns, root formation, and dental crown morphology. By analyzing these features, forensic experts and anthropologists can accurately estimate an individual's age with a higher level of confidence compared to bone development methods. [6] The trustworthiness of dental growth chronology surpasses that of bone development due to the consistent and predictable nature of dental development. Dental age estimation methods provide reliable and valuable information in forensic and anthropological contexts, aiding in accurate age estimation and identification. [6,7,8] These advantages make dental growth chronology a valuable tool in age assessment, underscoring its significance in forensic investigations and anthropological research. [9,10] Due to recent emigration of different population into many countries, dental documentation is becoming more important for surviving persons who lacks appropriate identity documents to attribute a true age for various legal purposes. [11,12] In order to determine the age of children and adults, dental age estimation methods were developed based on the relationship between age and features of the tooth structure. Literature states that there are several methods found to determine the dental age, which are broadly divided into three types namely, morphological, biological and radiological methods. [1]

It is possible to weigh the significance of research or a publication by counting the number of citations it receives in the scientific literature. In addition to researchers and publications, the institute where the study was conducted also benefits from the volume of citations. [13] Bibliometric analysis is currently a widely recognised study as it analyses the progress of a particular area of research. In order to emphasize the most important sources, authors, institutions, and nations active in the field, or to portray the current state and research tendencies of a given scientific topic, bibliometric analysis has come to be regarded as a valid method. The key conclusions of this analysis may also aid researchers, academics, and students in characterising scientific findings involving dental age estimation, assessing diagnostic approaches, and identifying crucial subjects and difficulties that may aid in the design of future research.

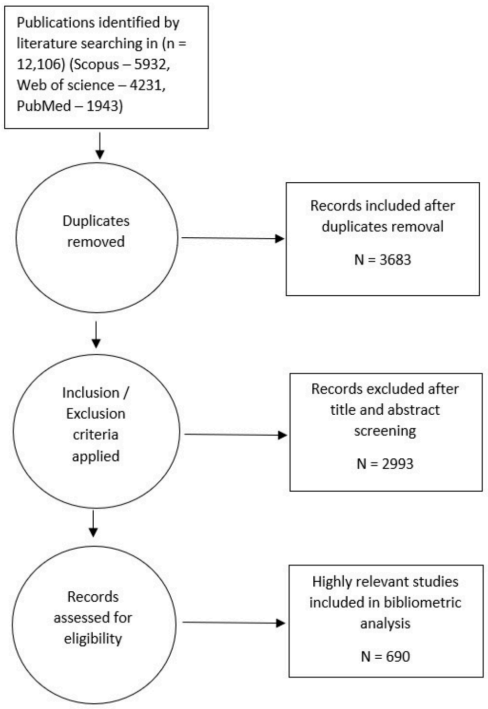
Despite of these vast literature and various methods in evaluating the dental age, studies on this area brings light on the fact that further research is required to arrive at a concrete result. [14] Forensic odontologist still searches towards the best approach for estimating age. It must be noted that there are numerous dental age estimation techniques that can be employed. Each has advantages and limitations, so it is always best to use a variety of techniques, repeating measurements and computations to ensure the highest level of reproduction. [15] While significant progress has been made in this area, it is acknowledged in the literature that further research is necessary to enhance the accuracy and reliability of dental age estimation techniques. [14] It is important to note that the field of dental age estimation encompasses numerous techniques, each with its own advantages and limitations. [15] Considering the complexity and variability in dental development, it is recommended to employ a combination of techniques, repeating measurements and computations to ensure the highest level of accuracy and reproducibility. So, there is a need to evaluate the progress and the course of scientific literature in this area to bring a clarity. Hence, the aim of this study is to evaluate the research progress on dental age estimation using bibliometric analysis and we further hypothesize that trends on knowledge the results change from time to time.

METHODOLOGY

An extensive literature search was done in the Clarivate Analytics' Web of Science (WoS), Science Citation Index Expanded (SCI-E) section of the Scopus database and PubMed on 9th September 2022 from year 1964 without language exception (Figure 1). The keywords used were "age estimation", "age determination", "dental age", "forensic odontology", "forensic dentistry", "dentistry". All the type of studies pertaining to dental age estimation was included. Studies done

with age estimation using methods other than dental structures were excluded. Two reviewers separately inspected the titles and abstracts of all the publications located through the search (SP and AV). The whole texts were analysed in cases when an abstract was insufficient to offer the relevant details. The third reviewer (GS) was consulted, in case of any disagreements regarding the papers. Regarding the publication date or status, no limits were imposed. The following information was retrieved from the papers and reviewed separately by two authors (SP and SS): study characteristics and citation characteristics (journal, title, year of publication, citations, and authors) (study design and the topic addressed). The VOS viewer software (version 1.6.13; Leiden University Center for Science and Technology Studies, Netherlands) and Biblioshiny (Version 4.0) were used for analysis and network visualization of the authors, nations, and keywords were created.

Figure 1. Flowchart on inclusion of articles



RESULTS

Main information

Table 1 represents the overall description of the scientific literature on dental age estimation. A total number of 690 articles are finally included in this study after careful screening of the articles. The first article published was on 1966. The annual growth rate percentage was about 6.32%. The total number of authors involved are 2260. Among the 690 articles, majority were original article (643) and review article (32).

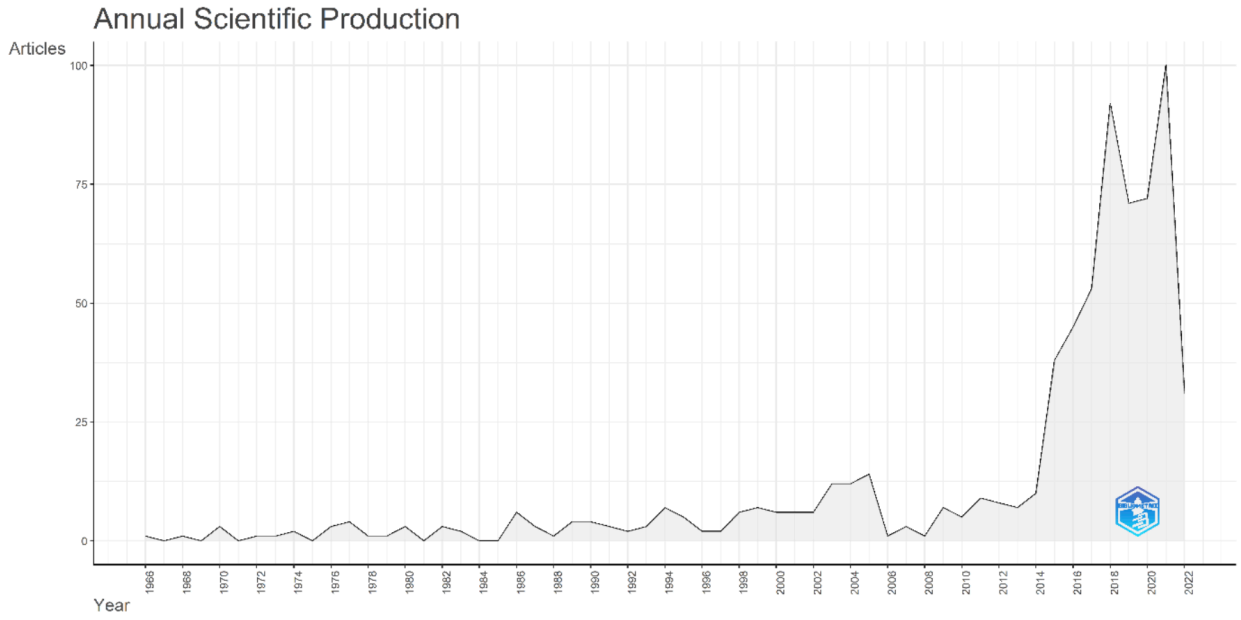
Table 1. Overall description of the scientific literature on dental age estimation

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1966:2022
Sources (Journals, Books, etc)	177
Documents	690
Annual Growth Rate %	6.32
Document Average Age	8.72
Average citations per doc	15.25
References	16996
DOCUMENT CONTENTS	
Keywords Plus (ID)	1389
Author's Keywords (DE)	1033
AUTHORS	
Authors	2260
Authors of single-authored docs	37
AUTHORS COLLABORATION	
Single-authored docs	41
Co-Authors per Doc	4.49
International co-authorships %	20.58
DOCUMENT TYPES	
article	643
book chapter	1
conference paper	4
editorial	1
letter	7
note	2
review	32

Overall growth trends

Figure 2 presents the overall growth trend on dental age estimation. It explains how much this area has developed over the last few decades. Since the first publication was released in 1966, there hasn't been much improvement in the first few years. There have been 87 total publications (TP) in the first 35 years (1966-2000), however the development has been slow and has increased each year. The number of prominent publications began to rise in 2014 and has been steadily rising each year thereafter. The years 2018 (TP = 92) and 2021 (TP = 100), respectively, saw a boom in publications and citations.

Figure 2. Annual scientific production



Citations

Table 2 displays the annual publishing and citation details of dental age estimation research. The mean of Total citation (TC) per article and mean TC per year which started increasing after 1992 with high values seen during 2006, 1992 and 2001. The average citations per document is around 15.25 having totally 16996 references (Table 1).

Table 2. Annual publishing and citation details

Year	N	MeanTC perArt	MeanTC perYear
1966	1	0.00	0.00
1967	0	0.00	0.00
1968	1	24.00	0.44
1969	0	0.00	0.00
1970	3	68.00	1.31
1971	0	0.00	0.00
1972	1	0.00	0.00
1973	1	13.00	0.27
1974	2	18.00	0.38
1975	0	0.00	0.00
1976	3	16.33	0.36
1977	4	3.25	0.07
1978	1	3.00	0.07
1979	1	0.00	0.00
1980	3	34.00	0.81
1981	0	0.00	0.00
1982	3	32.00	0.80
1983	2	0.00	0.00
1984	0	0.00	0.00
1985	0	0.00	0.00
1986	6	69.00	1.92
1987	3	11.00	0.31
1988	1	3.00	0.09
1989	4	5.00	0.15
1990	4	22.50	0.70
1991	3	16.67	0.54
1992	2	119.50	3.98
1993	3	58.33	2.01
1994	7	29.57	1.06
1995	5	91.40	3.39
1996	2	24.00	0.92
1997	2	43.00	1.72
1998	6	60.33	2.51
1999	7	26.00	1.13
2000	6	87.33	3.97
2001	6	99.00	4.71
2002	6	67.67	3.38
2003	12	44.50	2.34
2004	12	71.50	3.97
2005	14	47.79	2.81
2006	1	194.00	12.13

2007	3	54.00	3.60
2008	1	15.00	1.07
2009	7	14.57	1.12
2010	5	25.80	2.15
2011	9	18.67	1.70
2012	8	17.13	1.71
2013	7	4.71	0.52
2014	10	14.70	1.84
2015	38	14.71	2.10
2016	45	12.40	2.07
2017	53	9.13	1.83
2018	92	8.12	2.03
2019	71	5.63	1.88
2020	72	1.82	0.91
2021	100	0.67	0.67
2022	31	0.00	0.00

Leading countries

Table 3 shows the countries with the highest number of publications were India (205), Turkey (41), and Brazil (40). Publications from the India had been cited 685 times with a frequency of 0.162. Despite a lower publication volume as compared to the India, Belgium and Germany led the way in way in citations with a total of 1084 and 1015 citations respectively and a frequency of 0.022 and 0.041 respectively.

Table 3. Top 50 countries with highest number of publications

Country	Articles	SCP	MCP	TC	Freq
INDIA	205	184	21	685	0.162
TURKEY	41	37	4	410	0.059
BRAZIL	40	26	14	383	0.058
CHINA	30	25	5	254	0.043
GERMANY	28	22	6	1015	0.041
UNITED KINGDOM	25	19	6	630	0.036
ITALY	23	18	5	688	0.033
USA	23	15	8	449	0.033
MALAYSIA	17	13	4	116	0.025
SPAIN	17	15	2	399	0.025
AUSTRALIA	15	7	8	230	0.022
BELGIUM	15	10	5	108	0.022
IRAN	15	15	0	87	0.022
JAPAN	15	14	1	323	0.022
FRANCE	12	9	3	447	0.017
INDONESIA	12	8	4	16	0.017
SAUDI	11	10	1	52	0.016
THAILAND	11	10	1	54	0.016
CANADA	10	5	5	443	0.014
CROATIA	10	4	6	144	0.014
FINLAND	9	5	4	141	0.013
NORWAY	7	7	0	462	0.01
POLAND	7	7	0	66	0.01
PORTUGAL	7	5	2	49	0.01
SERBIA	7	5	2	69	0.01
SOUTH AFRICA	7	7	0	54	0.01
KOREA	5	4	1	102	0.007
PAKISTAN	5	5	0	36	0.007
EGYPT	4	2	2	9	0.006
ROMANIA	4	4	0	3	0.006
DENMARK	3	2	1	37	0.004
JORDAN	3	3	0	3	0.004
MALTA	3	0	3	21	0.004
NEPAL	3	1	2	3	0.004
SWEDEN	3	2	1	104	0.004
TUNISIA	3	3	0	17	0.004
ARGENTINA	2	1	1	2	0.003
CHILE	2	0	2	43	0.003
COLOMBIA	2	2	0	2	0.003
HONG KONG	2	0	2	3	0.003
IRAQ	2	2	0	0	0.003
SRI LANKA	2	1	1	9	0.003
SWITZERLAND	2	1	1	15	0.003
BOSNIA	1	1	0	1	0.001
CAMBODIA	1	0	1	0	0.001
CZECH REPUBLIC	1	1	0	0	0.001
GHANA	1	0	1	0	0.001
GREECE	1	1	0	0	0.001
ICELAND	1	1	0	2	0.001
ISRAEL	1	0	1	3	0.001

Leading Institutions

According to Table 4, Shanghai Jiao Tong University School of Medicine had the maximum number of publications in dental age estimation literature. It had a total of 56 publications with a total of 153 citations. The second and third most

institution with maximum number of publications is University of Malaya and University of Sao Paulo with a total of 48 and 44 publications with citations of 88 and 43 respectively.

Table 4. Top 50 Institution with highest number of publications

Affiliation	Articles
SHANGHAI JIAO TONG UNIVERSITY SCHOOL OF MEDICINE	56
UNIVERSITY OF MALAYA	48
UNIVERSITY OF SÃO PAULO	44
XI'AN JIAOTONG UNIVERSITY	34
UNIVERSITY OF MACERATA	32
UNIVERSITY OF WESTERN AUSTRALIA	32
KANAGAWA DENTAL COLLEGE	31
MANIPAL COLLEGE OF DENTAL SCIENCES	31
UNIVERSITY HOSPITAL MÜNSTER	31
CHIANG MAI UNIVERSITY	29
KATHOLIEKE UNIVERSITEIT LEUVEN	29
UNIVERSITAS AIRLANGGA	27
UNIVERSITY OF GRANADA	25
GOVERNMENT DENTAL COLLEGE AND HOSPITAL	23
CENTRAL SOUTH UNIVERSITY	22
KING KHALID UNIVERSITY	21
PANINEEYA MAHAVIDYALAYA INSTITUTE OF DENTAL SCIENCES	21
FEDERAL UNIVERSITY OF PARAÍBA	20
UNIVERSITY OF BELGRADE	20
SICHUAN UNIVERSITY	19
UNIVERSITY OF FLORENCE	18
UNIVERSITY OF OSLO	18
ALL INDIA INSTITUTE OF MEDICAL SCIENCES	16
NEW HORIZON DENTAL COLLEGE AND RESEARCH INSTITUTE	16
NOTREPORTED	16
QUEEN MARY UNIVERSITY OF LONDON	16
JSS DENTAL COLLEGE AND HOSPITAL	14
UNIVERSITY OF PRETORIA	14
PEKING UNIVERSITY SCHOOL AND HOSPITAL OF	13
UNIVERSITY OF BRESCIA	13
UNIVERSITY OF JORDAN	13
XI'AN JIAOTONG UNIVERSITY HEALTH SCIENCE CENTER	13
HAMADAN UNIVERSITY OF MEDICAL SCIENCES	12
PANJAB UNIVERSITY	12
THE UNIVERSITY OF WESTERN AUSTRALIA	12
TOKYO MEDICAL AND DENTAL UNIVERSITY	12
UNIVERSITY OF COPENHAGEN	12
UNIVERSITY OF DUNDEE	12
ANKARA UNIVERSITY	11
FACULTY OF DENTAL MEDICINE UNIVERSITAS AIRLANGGA	11
INSTITUTE OF LEGAL MEDICINE	11
INTERNATIONAL MEDICAL UNIVERSITY	11
UNIVERSITY OF BARI	11

UNIVERSITY OF COIMBRA	11
UNIVERSITY OF ZAGREB	11
MCMASTER UNIVERSITY	10
UNIVERSITY OF HELSINKI	10
UNIVERSITY OF INDONESIA	10
ERASMUS UNIVERSITY MEDICAL CENTRE	9
KING'S COLLEGE LONDON DENTAL INSTITUTE	9

Authors

To determine the most productive authors, the data was ranked based on the total number of publications from different authors. Table 5 shows data on authors with the number of their total number of articles and articles fractionalized. An individual author's contributions to a published set of paper are denoted by article fractionalization. Cameriere is the author with maximum number of publications (30) pertaining to dental age estimation. Following that, Liversidge HM (15) and Willems G (15) have the maximum of publications. Cameriere have H index of 38, Willem G has 50 and Galic I has 22.

Table 5. Top 50 authors with highest number of publications

Authors	Articles	Articles Fractionalized
CAMERIERE R[19]	30	5.49
LIVERSIDGE HM[7]	15	6.20
WILLEMS G [22,23]	15	5.15
FRANCO A [25]	12	2.10
NAMBIAR P[26]	12	2.47
SCHMELING A [12]	12	1.94
CHEN T [27]	11	1.44
GALIĆ I [9]	11	1.80
OHTANI S [28]	11	3.97
GUO Y-C [27]	10	1.20
BALLA SB [9]	9	1.16
FERRANTE L[19]	9	1.91
KVAAL SI[21]	9	2.26
OLZE A[12]	9	1.32
ROBERTS G[29]	9	2.23
JAYARAMAN J[29]	8	2.19
JI F[30]	8	1.18
TAO J [30]	8	1.18
ASIF MK[31]	7	1.35
FIEUWS S [32]	7	1.35
JANHOM A [33]	7	1.77
KRUGER E [14]	7	1.56
LUCAS VS [34]	7	1.85
PFEIFFER H [35]	7	1.06
ROBERTS GJ [36]	7	2.14
TENNANT M [14]	7	1.56
THEVISSEN P [32]	7	1.30
BIAZEVIC MGH[37]	6	1.28
CHU G [27]	6	0.89
DE LUCA S [38]	6	0.95
HEGDE S [39]	6	1.75
NYSTRÖM M [40]	6	1.65
SANTIAGO BM [41]	6	0.88
SOLHEIM T [21]	6	2.78
YANG Z [42]	6	0.75
CARDOSO HFV [43]	5	1.39
CINGOLANI M [19]	5	1.31
DIXIT U [39]	5	1.58
DJURIC M [44]	5	0.83
DUANGTO P [33]	5	1.32
IAMAROON A [33]	5	1.32
IBRAHIM N [31]	5	0.90
KARKHANIS S [45]	5	0.90
MÂNICA S [46]	5	1.55
MCDONALD F [34]	5	1.03
PINCHI V [47]	5	0.74
SCHULZ R [48]	5	0.60
SEHRAWAT JS [49]	5	2.53
TIMME M [50]	5	0.88
WANG J [30]	5	0.78

Journals

Table 6 denotes the total of top 50 journals information regarding the total number of articles, H-index, G-index, M-index, Total citation, Publication start year. Forensic Science International had the maximum of 73 publications with H-index of 24, G-index of 46, M-index of 0.558. Its total citation count was 2244 and publications started in year 1980. This is followed by International journal of legal medicine with publications of 62 and journal of forensic sciences with publications of 33.

Table 6. Top 50 journals with highest number of publications

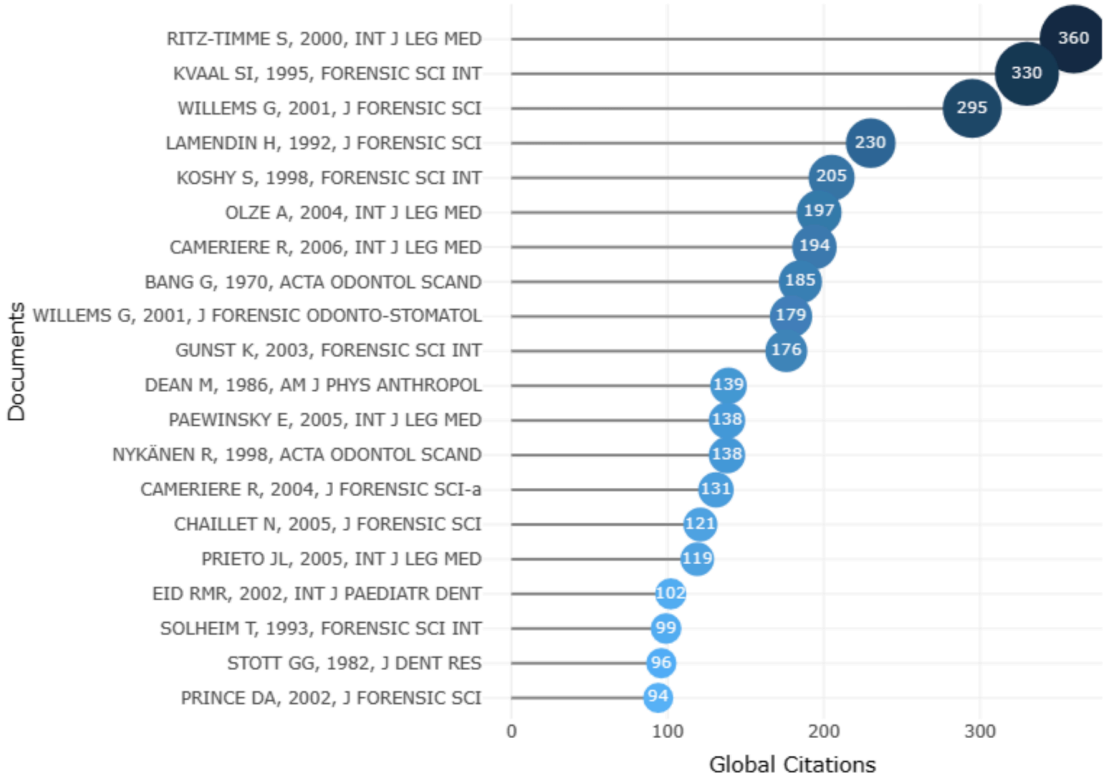
Element	h_index	g_index	m_index	TC	NP	PY_start
FORENSIC SCIENCE INTERNATIONAL	24	46	0.558	2244	73	1980
INTERNATIONAL JOURNAL OF LEGAL MEDICINE	17	40	0.607	1708	62	1995
JOURNAL OF FORENSIC SCIENCES	17	33	0.362	1693	33	1976
JOURNAL OF FORENSIC AND LEGAL MEDICINE	11	18	1.375	346	23	2015
AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY	10	14	0.27	562	14	1986
JOURNAL OF FORENSIC ODONTO-STOMATOLOGY	9	21	0.25	461	27	1987
LEGAL MEDICINE	8	15	0.444	239	26	2005
ACTA ODONTOLOGICA SCANDINAVICA	7	10	0.132	433	10	1970
ARCHIVES OF ORAL BIOLOGY	7	12	0.25	190	12	1995
ANNALS OF HUMAN BIOLOGY	6	8	0.75	122	8	2015
AUSTRALIAN JOURNAL OF FORENSIC SCIENCES	5	5	0.625	59	26	2015
DENTOMAXILLOFACIAL RADIOLOGY	5	5	0.185	73	5	1996
JAPANESE JOURNAL OF LEGAL MEDICINE	5	8	0.088	70	9	1966
AMERICAN JOURNAL OF FORENSIC MEDICINE AND PATHOLOGY	4	6	0.108	57	6	1986
EUROPEAN JOURNAL OF ORTHODONTICS	4	4	0.286	108	4	2009
JOURNAL OF INDIAN SOCIETY OF PEDODONTICS AND PREVENTIVE DENTISTRY	4	7	0.308	58	7	2010
JOURNAL OF ORAL AND MAXILLOFACIAL PATHOLOGY	4	4	0.5	24	5	2015
ORAL SURGERY, ORAL MEDICINE, ORAL PATHOLOGY	4	4	0.073	124	4	1968
BMC ORAL HEALTH	3	4	0.333	55	4	2014
BRAZILIAN ORAL RESEARCH	3	4	0.25	45	4	2011
BRITISH DENTAL JOURNAL	3	3	0.214	85	3	2009
CONTEMPORARY CLINICAL DENTISTRY	3	3	0.333	44	3	2014
DENTAL RESEARCH JOURNAL	3	3	0.375	24	3	2015
FORENSIC SCIENCE, MEDICINE, AND PATHOLOGY	3	5	0.375	30	5	2015
IMAGING SCIENCE IN DENTISTRY	3	6	0.3	37	6	2013
JOURNAL OF INDIAN ACADEMY OF ORAL MEDICINE AND RADIOLOGY	3	5	0.333	30	11	2014
RECHTSMEDIZIN	3	4	0.15	45	4	2003
SAUDI DENTAL JOURNAL	3	4	0.375	26	4	2015

AMERICAN JOURNAL OF HUMAN BIOLOGY	2	4	0.061	37	4	1990
ANNALS OF ANATOMY	2	2	0.286	18	2	2016
ARCHIV FUR KRIMINOLOGIE	2	3	0.1	14	3	2003
BRAZILIAN JOURNAL OF ORAL SCIENCES	2	2	0.154	8	2	2010
CLINICAL ORAL INVESTIGATIONS	2	2	0.667	7	5	2020
COMMUNITY DENTAL HEALTH	2	2	0.091	34	2	2001
DENTAL CLINICS OF NORTH AMERICA	2	2	0.043	7	2	1977
EGYPTIAN JOURNAL OF FORENSIC SCIENCES	2	4	0.286	19	10	2016
EUROPEAN JOURNAL OF ORAL SCIENCES	2	3	0.069	69	3	1994
FA YI XUE ZA ZHI	2	2	0.5	6	2	2019
INTERNATIONAL JOURNAL OF MORPHOLOGY	2	2	0.333	5	3	2017
INTERNATIONAL JOURNAL OF PAEDIATRIC DENTISTRY	2	2	0.095	127	2	2002
JOURNAL OF APPLIED ORAL SCIENCE	2	2	0.125	51	2	2007
JOURNAL OF CLINICAL FORENSIC MEDICINE	2	2	0.083	56	2	1999
JOURNAL OF CONTEMPORARY DENTAL PRACTICE	2	2	0.5	4	3	2019
JOURNAL OF FORENSIC RADIOLOGY AND IMAGING	2	3	0.333	15	4	2017
JOURNAL OF INTERNATIONAL DENTAL AND MEDICAL RESEARCH	2	3	0.333	14	4	2017
MEDICINE AND LAW	2	2	0.067	7	2	1993
MEDICINE, SCIENCE AND THE LAW	2	3	0.063	9	3	1991
MINERVA STOMATOLOGICA	2	2	0.057	26	2	1988
NIGERIAN JOURNAL OF CLINICAL PRACTICE	2	3	0.25	33	3	2015
PESQUISA BRASILEIRA EM ODONTOPEDIATRIA E CLINICA INTEGRADA	2	2	0.286	6	4	2016

Top cited articles

Figure 3 denotes the top 20 cited articles of dental age estimation. The top most cited article is "Age estimation: The state of the art in relation to the specific demands of forensic practise" by Ritz-Timme published in the year 2000 in the International journal of legal medicine. [16] The article is cited for 360 times.

Figure 3. Top 20 cited articles of dental age estimation



Keywords

Figure 4 represents the top 20 commonly used words in dental age estimation. The top most common word in male is repeated around 761 times, followed by the word female which is repeated around 750 times. Figure 5 represents the word cloud of the most common word used, with the sizes increasing based on the number of times used. The top most common word male is largest in size.

Figure 4. Top 20 commonly used words of dental age estimation

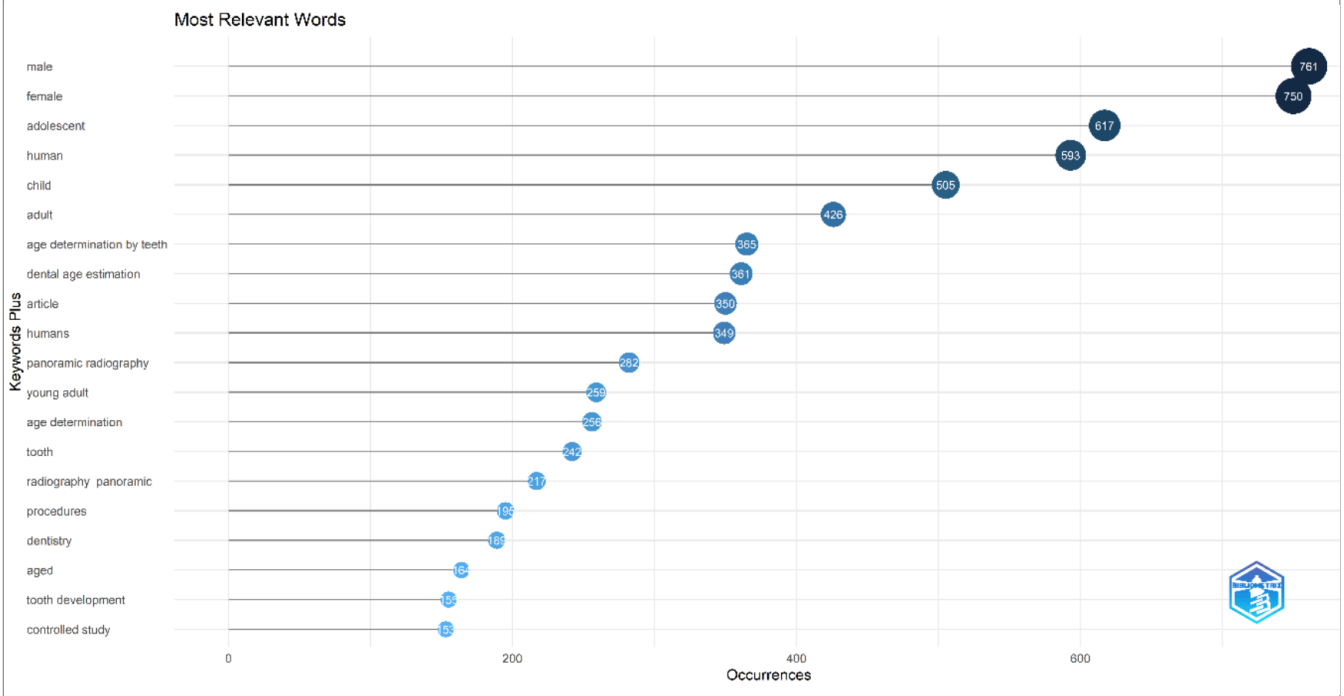


Figure 5. Word cloud of most commonly used words

Thematic evolution and Co-occurrences of keywords

Figure 6 shows the thematic evolution of keywords during three stages of its publication years which are 1966-2000, 2000-2010 and 2010-2022. During the year from 1966 to 2000, forensic odontology followed by tooth development was the most commonly used keywords. In the years between 2000-2010 also forensic odontology was the commonly used followed by age determination. But during the years 2010-2022, age estimation was the most common keywords used. Figure 7 shows the co-occurrences of keywords in which the highest is shown by the keyword "Human" which had 544 occurrences, 209 links with total link strength of 10828. This is followed by the word "Male" which had 450 occurrences, 209 links with total link strength of 9699.

Figure 6. Thematic evolution of keywords

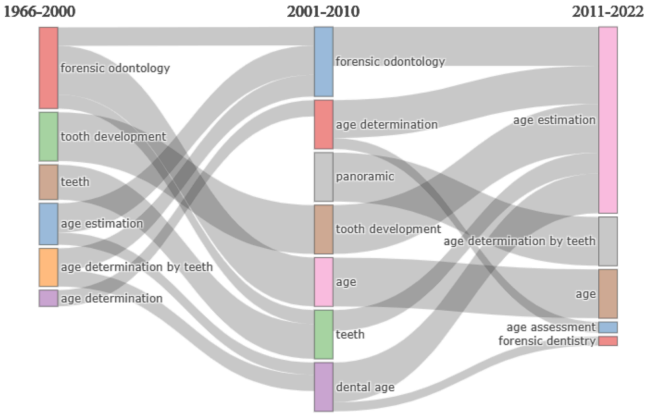
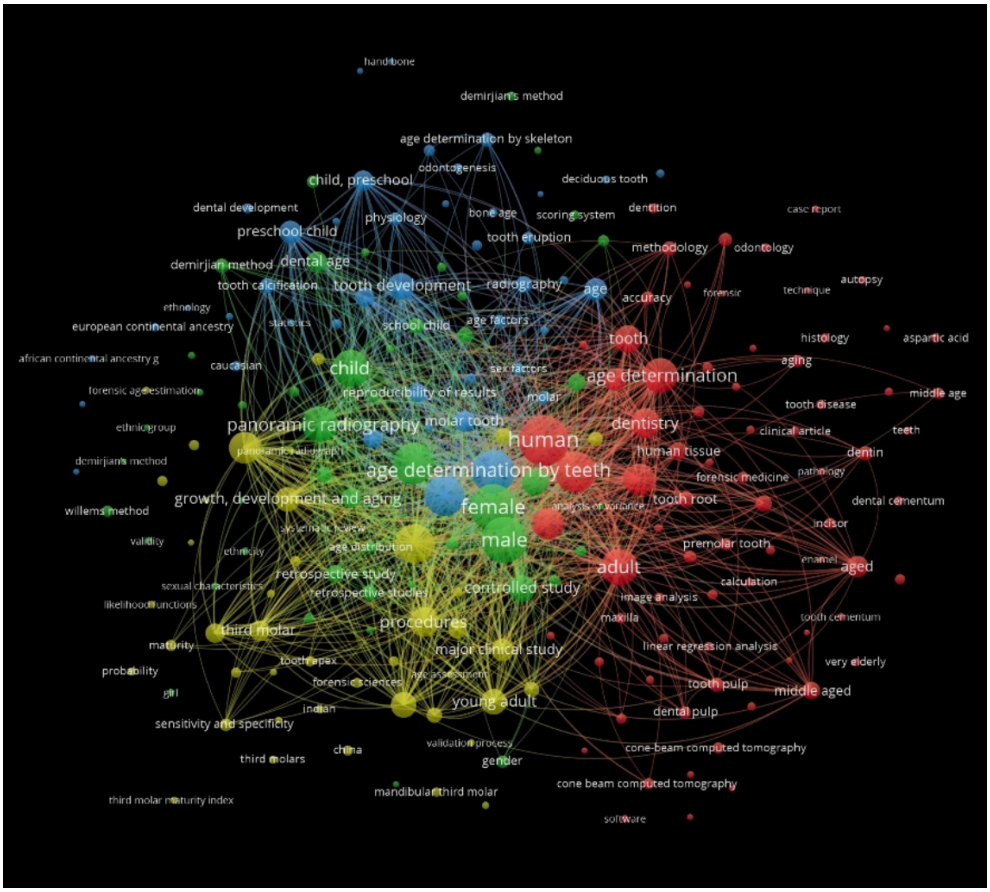


Figure 7. Co-occurrences of keywords

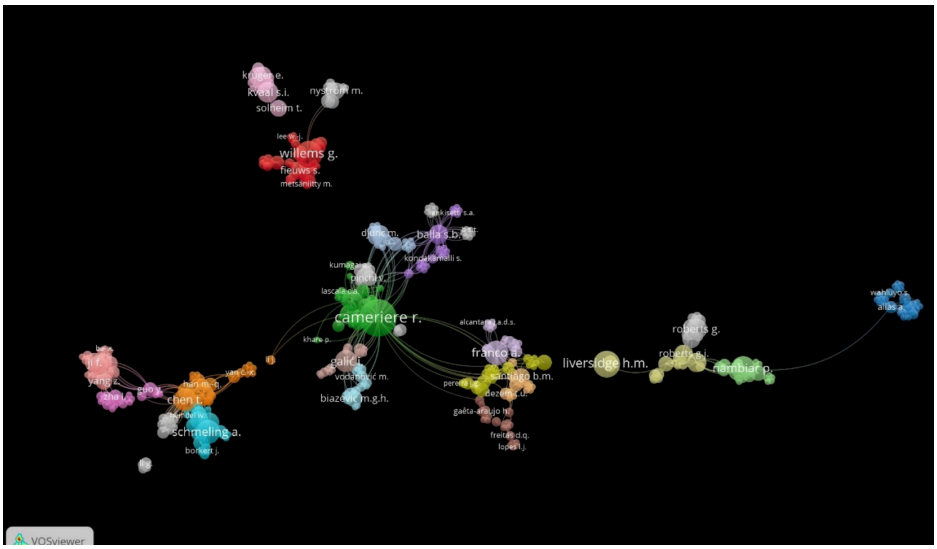


Bibliographic networking

Co-authorship with authors

Figure 8 represents the networking map of co-authorship and authors. Out of all the authors involved only 425 authors showed links with other authors. The connections within each set of authors are denoted by clusters. This map shows a total of 26 clusters all over the world. The Author with the top most number of publications is Cameriere (29) who has 70 links with 115 link strength. It is followed by Liversidge HM (15) and Willems G (15) with 4, 22 links and 8, 37 link strength respectively.

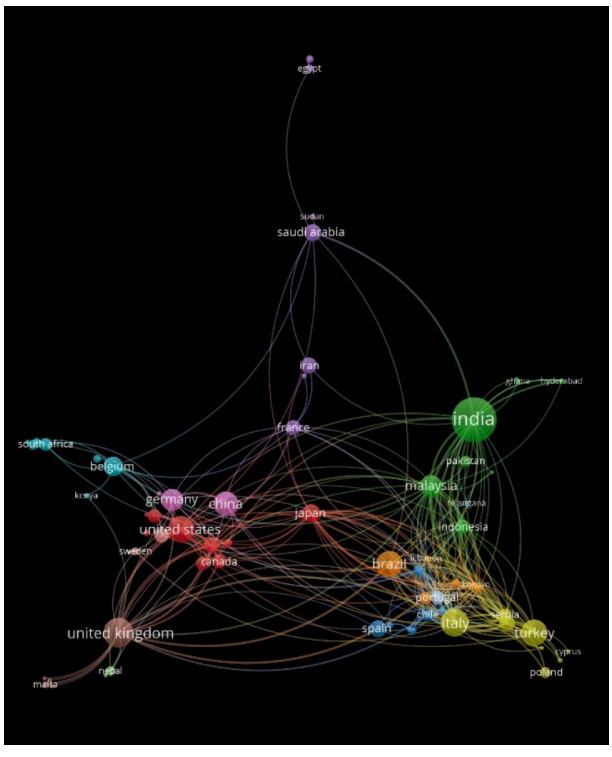
Figure 8. Networking map of co-authorship and authors



Co-authorship with countries

Figure 9 represents the networking map of co-authorship and countries. Out of all the authors involved only 74 countries authors showed links with other countries. This map shows a total of 12 clusters all over the world. The country which has most number of co-authors in publications is India with 135 documents, 30 links and 48 total link strength. This is followed by United Kingdom having 60 documents, 24 links and 60 total link strength.

Figure 9. Networking map of co-authorship and authors



Networking of Citation and Document, author and countries

Figure 10 represents the networking map between citations and document. The paper written by author Ritz-timme in 2000 has a total of 360 citations with 58 citation links. [16] Figure 11 represents the networking map between citations and authors. The author Cameriere has a total of 30 articles with 232 citation links. Figure 12 represents the networking map between citations and countries. The country India has a total of 135 articles with 63 citation links.

Figure 10. Networking map of citation and documents

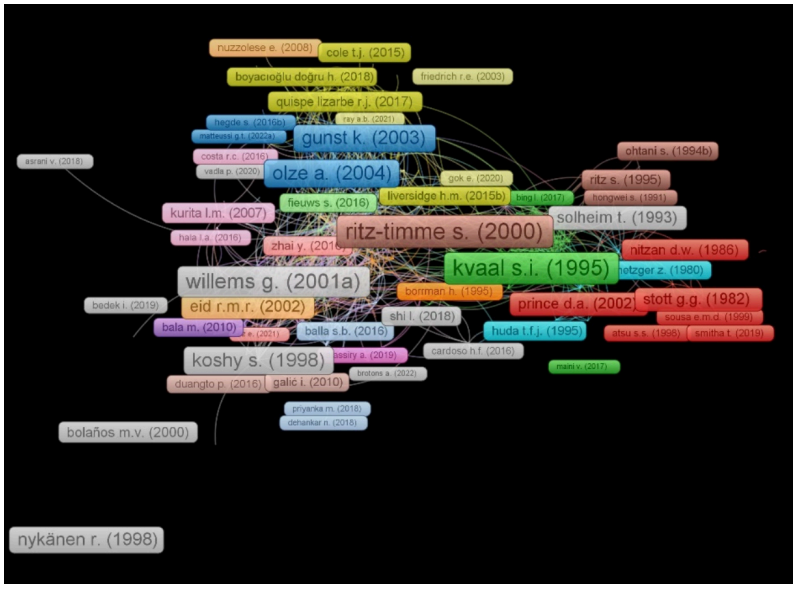


Figure 11. Networking map of citation and authors

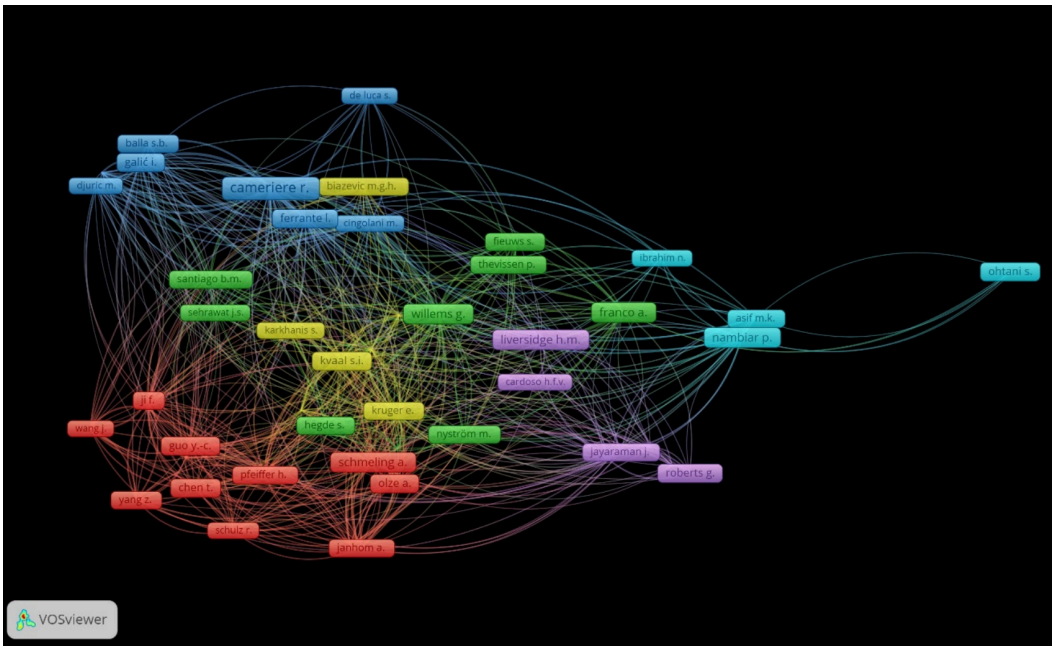
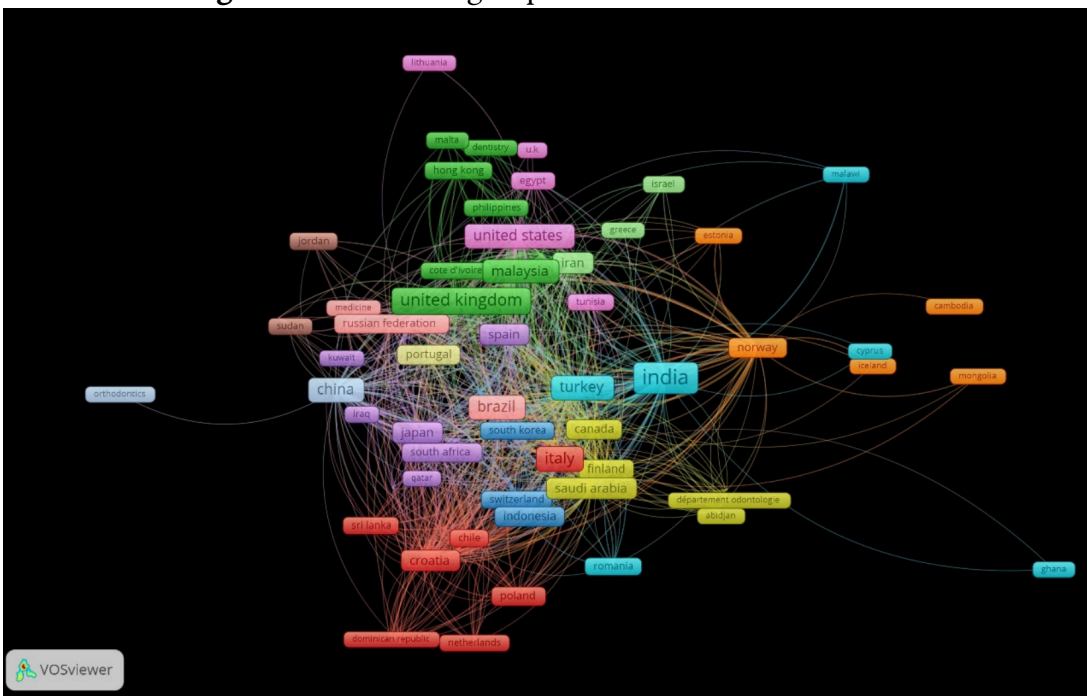


Figure 12. Networking map of citation and countries



Co-citation with References and Sources

Figure 13 shows the networking map of co-citation with cited references for a minimum of 10 times. The document with most citations are "A new system of dental age assessment" by Demirjian in the year 1973[17]. It has been cited for 79 times, with 39 links and 228 total link strength. Figure 14 shows networking map of co-citation with sources. There is a total of three clusters in this map. Forensic Science International was the journal with top most publications and co-citations.

Figure 13. Networking map of co-citation with cited references for a minimum of 10 times

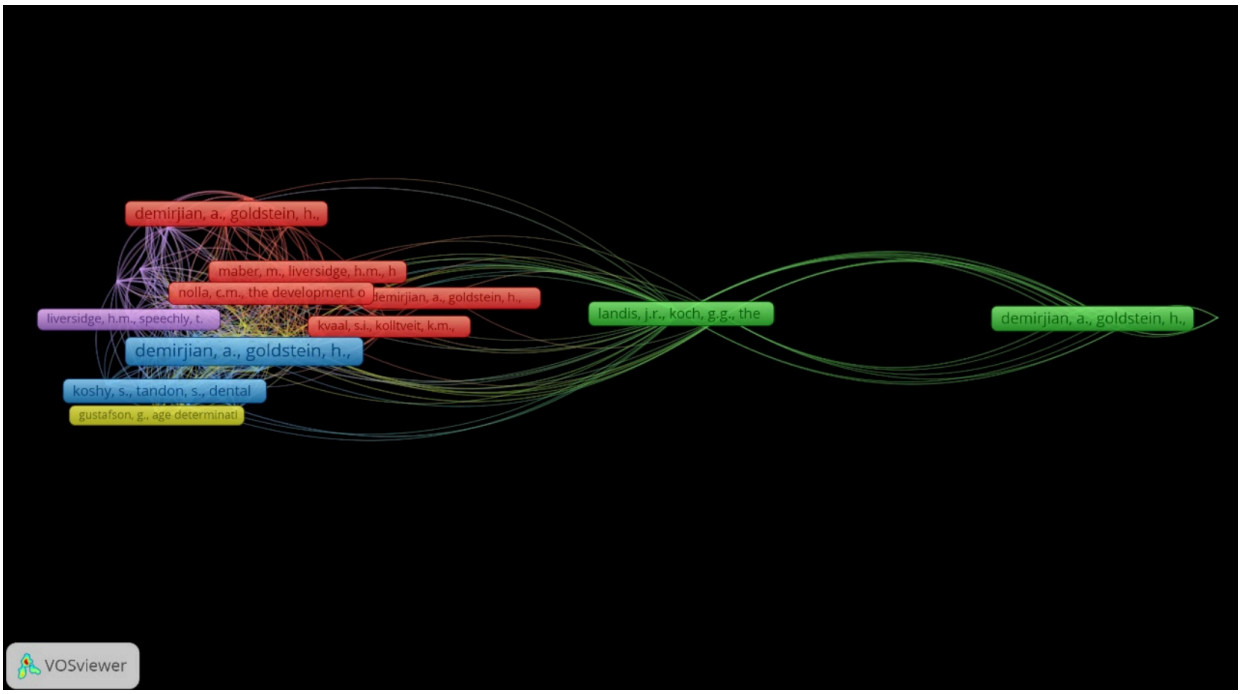
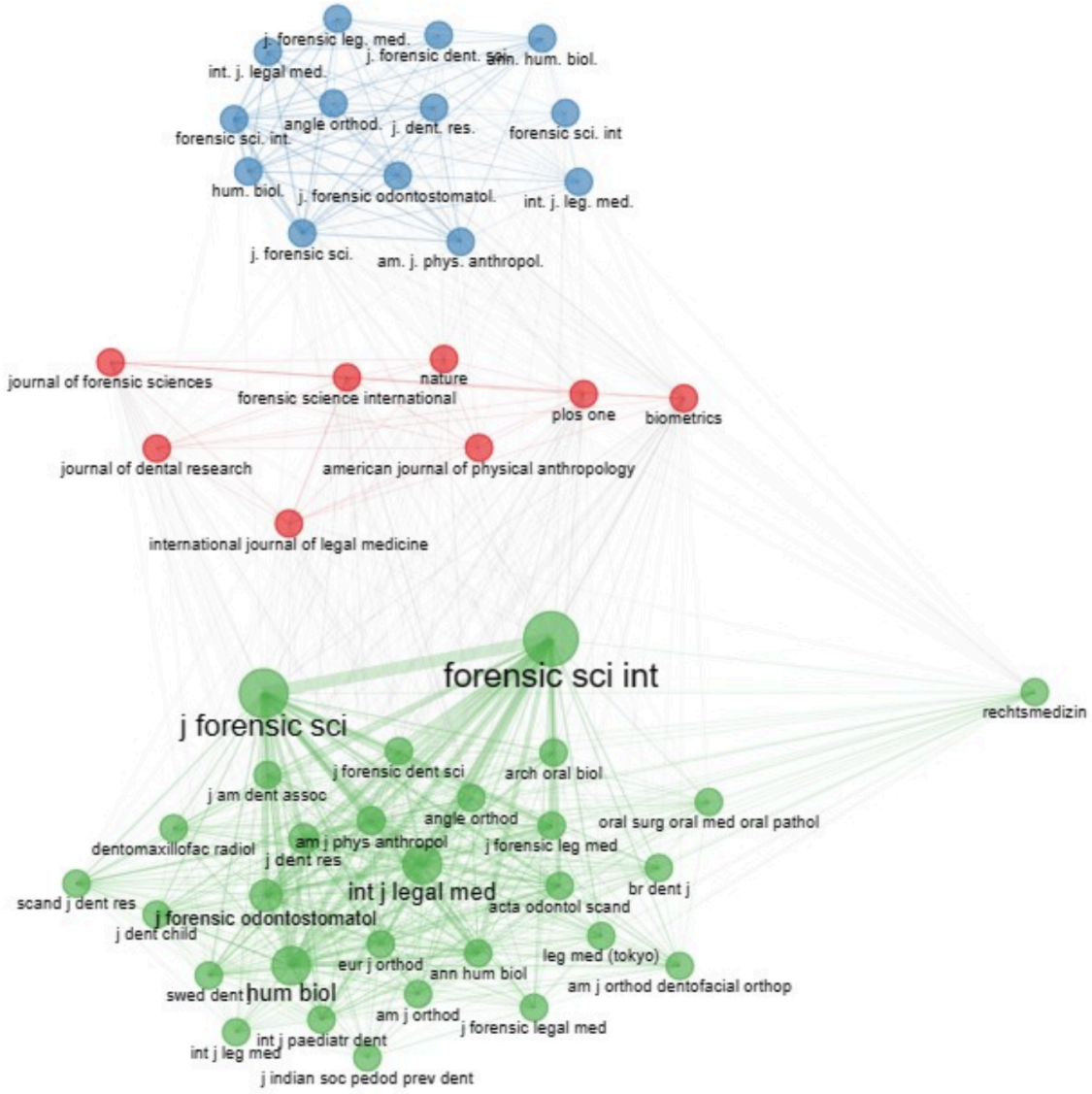


Figure 14. Networking map of co-citation with cited references for a minimum of 10 times



DISCUSSION

The goal of this novel bibliometric analysis was to locate and qualitatively assess the scientific research articles on dental age estimation in the field of forensic sciences. This study was performed using the most commonly used databases worldwide like Scopus, PubMed and Web of science.

Among the 690 articles that was included, the first article was published in the year 1966 titled "A new method of age estimation in dentistry" by Mukai S in Japanese journal of legal medicine. Evidently, validation studies have augmented the body of relevant scientific literature since the early 2000s. [18] In general, this research examined the performance and application of known techniques in populations that were dissimilar to the original. [18] A new type of study in the dental age estimation literature emerged as a result of the growing number of validation studies[18]. Hence there has been exponential growth happening in the research pertaining to dental age estimation since 2014, with discovery of new techniques in various populations.

The top most cited article with 360 citations is "Age estimation: The state of the art in relation to the specific demands of forensic practise" by Ritz-Timme published in the year 2000 in International journal of legal medicine. This review article describes the credibility of the literature evidence on dental age estimations. The average citations per document is around 15.25% with the high citation values seen during 2006. The primary reason for this increase can be attributed to the article authored by Ritz-Timme, where they presented an innovative and distinctive dental method for age estimation in children using open apices tooth.[19] This

pioneering approach garnered significant attention from the scientific community, leading to the higher citation values observed in that specific period.

The study results highlight the fact that India is the country with most number of publications followed by Turkey and Brazil. Research on age estimation is especially important in India because of the country's problematic birth registration laws and child rights concerns. [20] The rights of children without birth certificates and those who have made false age claims must be urgently protected. [20] Though Belgium and Germany have only 15 and 28 articles each, the number of citations is considerably high. Belgium has 1084 citations, which is the highest among the countries, followed by Germany with 1015 citations. This is due to the fact that articles published from Belgium countries got highly cited due to the high novelty of the study and new techniques of dental age estimation.

Among the most productive organisations, Shanghai Jiao Tong University School of Medicine, University of Malaya and University of Sao Paulo have the greater number of publications. These universities belong to China, Malaysia and Brazil respectively. The productivity of a particular university is attributed to the fact that many research groups with a shared area of interest would have existed in the same institution. The analysis of citation data reveals that the most cited papers in the field of dental age estimation originate from Germany and Belgium. Despite the significant impact of these publications, it is important to note that Asian countries dominate the overall research landscape in dental age estimation, with a substantial number of studies originating from research institutions in the Asian region.

Among the journals that published many literature on dental age estimation, Forensic Science International (Elsevier) followed by International Journal of Legal medicine (Springer) and Journal of forensic sciences (Wiley). The highly cited papers by Ritz-timme et al [16], followed by Kvaal et al [21] and Willems et al [22] were published in International Journal of Legal medicine, Forensic Science International and Journal of forensic sciences, respectively. These top three articles are published in England, making a trend that shows the developed country have been significantly contributing to this field of study

The primary themes in dental age estimation research and the dominant patterns in publications on this speciality were also identified in this study. In order to find the pertinent publications about this research area, these keywords can be used in order to narrow their search. Researchers are able to target published research articles with the right terms by employing the analysis of the more often used keywords. The publications chosen for study exhibited a particular trend in the keywords. Typically, keyword co-occurrence networks are built using terms that have been taken directly from publication titles, abstracts, or even author-generated keyword lists. In the same title/abstract or citation context, two keywords are said to co-occur. In addition, the correlation between their separation and keyword similarity is practically inverse. As a result, terms that are more relevant are typically found to be closer to one another. The most frequent used keyword is “male”, followed by “female” and “adolescent”. The results of the analysis revealed that “forensic odontology” (1966-2010), which has been used continuously since the beginning, and changed to “age estimation” (2010-2022) in the recent years. This symbolises the fact that gender prediction in the age estimation was an important aspect that is growing in this field of research. Gender prediction in age estimation research is gaining importance, with growing recognition of the impact of gender-related dental variations. Incorporating gender information in age estimation models has shown to enhance accuracy and applicability, making it a crucial aspect in the field. Recent studies emphasize gender-specific age estimation techniques, contributing to advancements in forensic and anthropological research.

The goal of the bibliographic coupling study is to show how a single source is used in two different documents. India, Turkey, Brazil, Belgium and Germany were among the top performers and had the most connections when this study was performed for individual nations. Among the documents, the publication by Ritz-timme (2000) [16] and Willems (2000b) [23] had got the most connections. Among the sources, Forensic Science International followed by International journal of legal medicine had the most number of connections. Among the authors, Cameriere, followed by Willem had the greatest number of connections.

Co-citation network analysis of authors is a method for analysing a bibliographic analysis's underlying specialty in a field in terms of the groups of writers who have been referenced collectively in the pertinent literature. Additionally, it provides insights into how authors, who are subject-matter experts, view the connections between published works. [24] Author from Italy, Cameriere, from Belgium, Willems G, from London, Liversidge H have been found as the major contributors in this area of research who have dominated this area of research so far.

The findings of this study show that the nature and size of the collaborating teams in dental age estimation research have varied significantly. An extensive number of publications had many authors, according to the analysis of the authorship pattern and network structure. This may be connected to the regular interactions between several institutions, nations, and scholars to hasten the advancement of this field of study. It's noteworthy that a large percentage of authors had very few publications. It might be due to the fact that the number of publications is influenced by various factors, including the researcher's research productivity, collaborations, research focus, and individual contributions to the scientific community.

Limitations of this study is that there is a slight delay in reflecting the most recent research because bibliometric analysis is based on the published literature. Secondly, not all the databases are included in this study. Thirdly, literature search was done only from 1946, which did not include many landmark key articles on dental age estimation.. Despite its shortcomings, the research on dental age estimation may help future researchers by pointing out potential directions for investigation and revealing research gaps.

The recommended method is represented by a number of scientific organisations, each of which has a unique set of methodological guidelines and evaluation techniques. As a result, comparability, repeatability, and verification are severely constrained. There are currently no standards for age estimation quality assurance that are widely acknowledged. Although performing blind trials would undoubtedly be feasible in the field of age estimate, the crucial tool of external quality control is not used at all. In order to guarantee quality standards and acceptable solutions to the significant legal and societal issue of age estimation in forensic medicine, efforts in these directions are required.

CONCLUSIONS

The overall number of publications on dental age estimation and information about their citation patterns from 1966 to 2022 are both usefully revealed by this bibliometric research. It has demonstrated that there has been a general upward trend in publishing on the subject, with a notable increase in articles after 2014. Additionally, it has identified the top nations and organizations engaged in dental age estimation research as well as associated research trends. Despite the fact that dental age estimation has been widely used for a few decades, notable scientific articles have just recently been made. It is envisaged that this study would enable aspiring and seasoned researchers to envision and create potential future scenarios for interdisciplinary research collaborations on the use of age estimation in dentistry.

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