

World trends in Dental Ergonomics research: A Bibliometric Analysis

by Wita Anggraini

Submission date: 13-Feb-2024 07:05AM (UTC+0700)

Submission ID: 2293291048

File name: ometric_analysis_World_trends_in_Dental_Ergonomics_research.docx (909K)

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Bibliometric analysis: World trends in Dental Ergonomics research

Wita Anggraini¹, Dewi Ranggaini², Annisaa Putri Ariyani¹, Indrani Sulistyowati¹

¹Anatomy Subsection - Department of Oral Biology, Faculty of Dentistry, Trisakti University

²Physiology Subsection - Department of Oral Biology, Faculty of Dentistry, Trisakti University

Abstrak

Background: Publications with the theme of ergonomics and dentist have been around since the 1960s. **Objective:** To get quantitative information and visualization of all articles about ergonomics and dentists in Scopus indexed journals. **Method:** Data mining using Boolean expressions: "Ergonomic" AND "Dentist" on the Scopus database until April 2023. Software and data extraction using Open Refine software version 3.5.2., VOSviewer software version 1.6.17., VOSviewer thesaurus, Microsoft Excel, and Tableau Professional software version 2020.1.2. **Results:** 682 research publications on ergonomics and dentistry were written by English-language journals from the 1960s to 2023. The United States had the most significant number of documents (89 articles) and the highest citations (1321 citations). Work (Netherlands) is the journal with the highest number of publications (19 articles), and the Journal of The American Dental Association is the journal with the most citations (460 citations). The author's ten keywords most frequently used in sequence are ergonomics, musculoskeletal disorders (MSDS), dentists, dentistry, dental students, posture, risk factors, dental ergonomics, occupational hazards, and prevalence. **Conclusion:** World research trends related to dental ergonomics revolve around the prevalence, diagnosis, management, and evaluation of musculoskeletal disorders in dentists, dental students, dental assistants, and dental technicians.

Keywords: Bibliometric analysis, Ergonomics, Dentist, Musculoskeletal disorders

Introduction

Ergonomics focuses on humans and their interactions with products, equipment, facilities, procedures, and the environment in which humans live and work daily. Ergonomics seeks to prevent work-related musculoskeletal disorders by identifying, evaluating, and controlling workplace physical risk factors.¹

Work-related musculoskeletal disorders (WMSDs) are a subcategory of musculoskeletal disorders (MSDs). The Occupational Safety and Health Association (OSHA) defines musculoskeletal disorders (MSD) as disorders of the skeletal muscles, nerves, tendons, ligaments, joints, cartilage, or vertebral discs, which occur slowly over time due to repetitive wear and tear or microtrauma.^{2,3} The dental profession always involves repetitive movements, forceful movements, awkward postures, and inadequate recovery time. This profession requires precision and high visual requirements due to the narrow working area, namely the oral cavity. Therefore, dentists are at increased risk for WMSDs.⁴

MSDs have been discovered since a dentist was still a clinical dental student. In their research, Yusof et al. found significant differences in posture between clinical students in years 3, 4, and 5. Body pain and the development of MSDs in students in the 4th year were caused by poor posture in the legs, while in the 5th year, students were caused by poor posture of the forearms. Students tend to work with awkward postures that are dangerous because they are inexperienced and prioritize their patients. High levels of stress exacerbate this condition to complete treatment on time.⁵

The prevalence of MSDs in dentists worldwide varies from 10.8% to 97.9%.⁶ Batham and Yasobant found that 92.7% of dentists experienced MSDs during the last 12 months, and in the last seven days, there were 84.7% of dentists with complaints of MSDs.⁷ The problem of MSDs is multifactorial; the role of dental ergonomics in preventing MSDs is also multifactorial. Dentists' most common musculoskeletal disorders are back pain, neck pain, shoulder pain, high trapezius muscle tension, tendinitis, carpal tunnel syndrome, pinched nerves, early arthritis, myopia, and auditory changes.^{8,9} Muscle pain is an alarm in the body before the risk of paralysis and injury occurs which can cause premature career loss.¹⁰

Publications on ergonomics and dentist have been around since the 1960s. However, the number of articles is not significant; these various articles have emerged as principles of dental ergonomics, which aim to ensure that dentists work ergonomically to prevent MSDs as early as possible.¹¹ Articles about dentists and dental ergonomics have also resulted in various strategies for preventing MSDs.^{12,13}

This research presents world trends in dental ergonomics publications using bibliometric analysis with VOSviewer software. ¹³ Bibliometric analysis is the newest method for exploring and analyzing large amounts of scientific data from databases so that developments and even evolution in a particular field can be known.¹⁴

This research aims to obtain quantitative and visual information from articles about dental ergonomics in Scopus-indexed publications from 1990 to 2023. The analysis ⁵ in this research was carried out based on performance analysis, analysis of journals and articles, analysis of collaboration between authors and between countries, and analysis of the intellectual structure of authorship, which maps publication countries, sources, authors, citation networks, and cocitation networks between authors.

Research Methods

Two keywords with Boolean expressions were used to identify journals: "Ergonomic" AND "Dentist." The journals studied were all journals up to April 2023. All search results were exported into Comma Separated Value (CSV) files in Microsoft® Excel.¹⁵ The software for bibliometric analysis is VOSviewer, and data cleaning for keywords is done using Thesaurus_text in VOSviewer. In the Thesaurus step, keywords with the same meaning (synonyms/hyponyms) are combined or deleted. Bibliographic analysis attributes in the VOSviewer software include ³¹ co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation of authors, organizations, and countries.¹⁶ The bibliometric analysis flow can be seen in Figure 1.

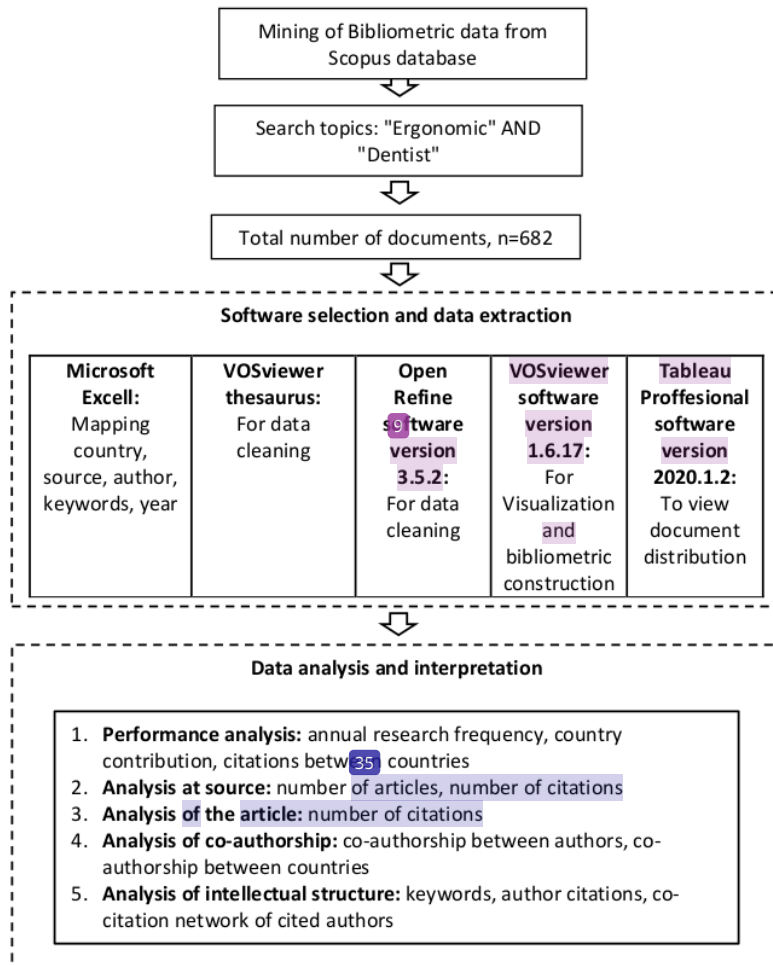


Figure 1: Research methods and flow

Results

1. Performance Analysis

1.1. Publication frequency by year

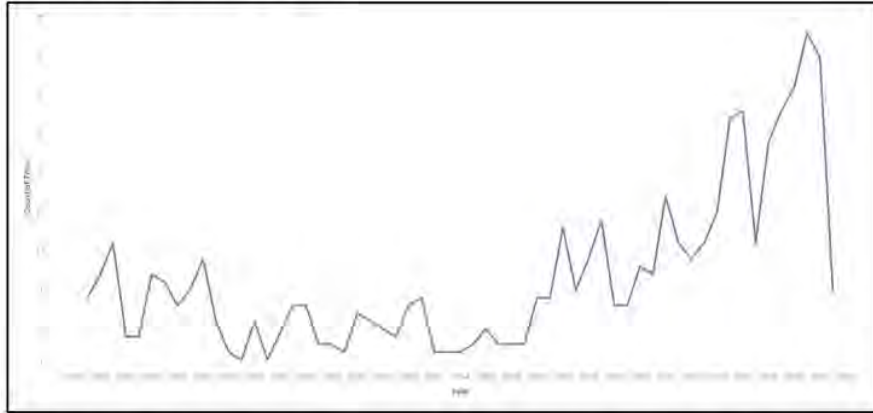


Fig.2: The trend of a count of titles for the year. The year and count of titles filter the view. The year ranges from 1965-2023. The count of the title filter ranges from 1 to 43.

1 There were 682 research publications on ergonomics and dentistry written by English language journals from 1965 to 2023 in the Scopus database. Figure 2 shows the decrease in the number of publications in 1979 (1 publication); 1985 (2 publications); 1992 (2 publications); 1993 (2 publications); 1994 (2 publications); 1995 (3 publications); 1997 (3 publications). Since 2020, publications on dental ergonomics have increased sharply and reached a peak in 2021 of 43 publications.

1.2. Contribution of countries to the field of dental ergonomics

1 A bibliometric coupling analysis was used to evaluate the number of articles researchers wrote based on their country. There were 90 countries with at least one article and zero citations. The United States occupied the highest position for ergonomic-dentist publications with 89 articles. The ranking of countries based on the number of articles can be seen in Table 1.

Table 1. 20 countries with the most significant number of documents

Rank	Country	Region	Cluster	Docs.	Citations weight	Links	Total link strength
1	United States	America	12	89	1321	53	9801
2	India	Asia	3	66	577	51	10642
3	Brazil	America	4	29	223	49	4335
4	Germany	Europe	7	25	227	50	7187
5	Saudi Arabia	Asia	4	22	288	51	4634
6	Sweden	Europe	4	22	633	49	3407
7	United Kingdom	Europe	5	22	252	53	2742
8	Iran	Asia	4	21	307	49	6730
9	Romania	Europe	9	19	97	44	803
10	Italy	Europe	9	18	169	49	2301
11	Turkey	Eurasia	3	15	152	48	2776
12	Canada	America	8	14	209	41	715
13	Poland	Europe	3	13	206	47	1446
14	Australia	Oceania	8	12	236	49	5514
15	France	Europe	8	9	29	48	1218
16	Malaysia	Asia	10	8	120	49	4210
17	Spain	Europe	1	6	109	48	1479
18	Finland	Europe	6	6	107	44	358
19	China	Asia	7	6	41	41	623
20	Croatia	Europe	2	6	25	33	180

1.3. Number of Article Citations by Country

Citation analysis was carried out on country analysis units with a maximum limit of 25 countries in one article, a minimum of 1 article, and one citation per country. The results of this analysis are that out of 90 countries, 69 meet these limits. Of the 20 countries with the highest citation weight, the United States is also in first place with 1321 citations for its 89 articles. The exciting thing is, Greece with three documents, it obtained 287 citations and was ranked 6th

Table 2. 20 countries with the highest number of citations

Rank	Country	Region	Cluster	Docs.	Citations weight	Links	Total link strength
1	United States	America	1	89	1321	43	381
2	Sweden	Europe	2	22	633	37	197
3	India	Asia	5	66	577	36	266
4	Iran	Asia	4	21	307	30	160
5	Saudi Arabia	Asia	1	22	288	30	108
6	Greece	Europe	2	3	287	30	78
7	United Kingdom	Europe	2	22	252	24	71

8	Australia	Oceania	6	12	236	34	147
9	Germany	Europe	8	25	227	30	139
10	Brazil	America	7	29	223	30	106
11	Canada	America	4	14	209	22	69
12	Poland	Europe	3	13	206	19	51
13	Netherlands	Europe	4	5	178	18	35
14	Italy	Europe	10	18	169	27	80
15	Turkey	Eurasia	5	15	152	20	70
16	Malaysia	Asia	3	8	120	24	90
17	Spain	Europe	2	6	109	21	52
18	Finland	Europe	9	6	107	18	28
19	Romania	Europe	12	19	97	9	19
20	South Korea	Asia	2	3	79	21	45

2. Analysis of the Source

2.1. Source analysis based on the number of documents

Source analysis based on the number of documents or articles using VOSviewer with bibliographic coupling carried out on the sources unit, with a threshold for each journal having at least 1 article and zero citations. The aim of providing zero citations is so that all sources can be presented through this application. The results show that 323 Scopus-indexed sources have published the 682 articles obtained in data mining, and the most extensive collection of connected sources consists of 174. In Table 3, it can be seen that Work is the first top source, which has 19 articles, followed by Dentistry Today (18 articles), the International Journal of Environmental Research and Public Health (14 articles), and the Journal of The American Dental Association (12 journals).

Table 3. Top-ranking sources with a minimum of 5 documents

Rank	Sources	Negara	ISSN	Docs.	Citations weight	h-index	SJR (2022)	Q	Publication Type
1	Work	Netherlands	18759270 10519815	19	338	58	0.509	Q2	Journals
2	Dentistry Today	United States	87502186	18	73	27	0.102	Q4	Journals
3	International Journal of Environmental Research and Public Health	Switzerland	16617827 16604601	14	80	167	0.828	Q2	Journals
4	Journal of The American Dental Association	United States	00028177 19434723	12	460	128	0.520	Q2	Journals
5	Applied Ergonomics	United Kingdom	18729126 00036870	11	262	119	0.922	Q1	Journals

6	Journal Of Dental Education	United States	00220337 19307837	11	126	76	0.558	Q2	Journals
7	European Journal of Dental Education	United Kingdom	16000579 13965883	11	115	49	0.523	Q2	Journals
8	Journal Of Contemporary Dental Practice	United States	15263711	9	194	47	0.295	Q3	Journals
9	BMC Musculoskeletal Disorders	United Kingdom	14712474	7	421	112	0.716	Q2	Journals
10	Ergonomics	United Kingdom	00140139 13665847	7	98	124	0.676	Q1	Journals
11	British Dental Journal	United Kingdom	00070610 14765373	7	50	91	0.506	Q2	Journals
12	Indian Journal of Dental Research	India	19983603 09709290	7	150	50	0.264	Q3	Journals
13	International Journal of Dental Hygiene	United Kingdom	16015029 16015037	6	164	44	0.635	Q1	Journals
14	International Journal of Occupational Safety and Ergonomics	United Kingdom	10803548	6	80	43	0.513	Q2	Journals
15	Advances In Intelligent Systems and Computing	Germany	21945365 21945357	6	16	58	Discontinued (2021)	-	Book Series
16	Annals of Daaam and Proceedings of The International Daaam Symposium	Austria	17269679	6	3	19	Not yet assigned a quartile	-	Conferences and Proceedings
17	International Dental Journal	Netherlands	00206539 1875595X	5	63	73	0.733	Q1	Journals
18	Journal of Clinical and Diagnostic Research	India	0973709X 2249782X	5	52	64	Discontinued (2018)	-	Journals
19	Lecture Notes in Networks and Systems	Switzerland	23673370 23673389	5	1	27	0.151	Q4	Book Series

2.2. Citation analysis on sources

This citation analysis uses VOSviewer in the sources unit, with a minimum threshold of having 1 document and zero citations. The aim of providing zero citations is so that all sources can be presented through this application. As a result, 323 sources indexed by Scopus were recruited, and the largest collection of connected sources consisted of 162 sources. In Table 4, there is an analysis of sources based on citations, where the Journal of The American Dental Association is the top source with a citation weight of 460, followed by BMC Musculoskeletal Disorders (421 citations), Work (338 citations) and Applied Ergonomics (262 citations).

Table 4. Top 15 ranked sources with the most citations

Rank	Sources	Country	ISSN	Citations weight	Docs	h-Index	SJR (2022)	Q	Subject Area
1	Journal of The American Dental Association	United States	00028177 19434723	460	12	128	0.520	Q2	Dentistry Medicine
2	BMC Musculoskeletal Disorders	United Kingdom	14712474	421	7	112	0.716	Q2	Medicine
3	Work	Netherlands	18759270 10519815	338	19	58	0.509	Q2	Medicine
4	Applied Ergonomics	United Kingdom	18729126 00036870	262	11	119	0.922	Q1	Engineering Health Professions Social Sciences
5	Journal of Contemporary Dental Practice	United States	15263711	194	9	47	0.295	Q3	Dentistry
6	Journal of The California Dental Association	United States	10432256	188	10	44	Not yet assigned a quartile	-	Dentistry Medicine
7	International Journal of Dental Hygiene	United Kingdom	16015029 16015037	164	6	44	0.635	Q1	Dentistry
8	Indian Journal of Dental Research	India	19983603 09709290	150	7	50	0.264	Q3	Dentistry Medicine
9	Swedish Dental Journal	Sweden	03479994	134	3	37	Not yet assigned a quartile	-	Dentistry Medicine
10	Journal of Dental Education	United States	00220337 19307837	126	11	76	0.558	Q2	Dentistry Medicine Social Sciences
11	European Journal of Dental Education	United Kingdom	16000579 13965883	115	11	49	0.523	Q2	Dentistry Social Sciences
12	Indian Journal of Public Health Research and Development	India	09765506 09760245	111	4	21	Not yet assigned a quartile	-	Medicine
13	Annals of Agriculture and Environmental Medicine	Poland	12321966 18982263	107	1	61	0.389	Q3	Agricultural and Biological Sciences Environmental Science Medicine
14	Medicina Oral Patologia Oral y Cirugia Bucal	Spain	16986946 16984447	106	2	66	0.587	Q2	Dentistry Medicine
15	Journal of Occupational Health	Japan	13489585 13419145	103	3	67	0.689	Q2	Medicine

3. Analysis of the article

Analysis of articles or documents aims to find out which articles have the most influence on research trends on the topics 'ergonomics' and 'dentists' or, in other words, research trends in the field of dental ergonomics. The analysis uses VOSviewer with the type of citation analysis and the unit of analysis documents. The lower citation threshold

is zero to obtain all article data in this research. VOSviewer displays 682 articles with information, including authors' names, titles, source information (source name, volume, issue, page), and year of publication.

The article 'Prevalence of musculoskeletal disorders in dentists' published by **BMC Musculoskeletal Disorders** in 2004 occupied the top citation position. Alexopoulos E.C., Charizani F., and Stathi I.C. wrote this article. The significant citation weight in the article shows the author's enormous contribution to the development of dental ergonomics, and in Table 5 shows the 15 most frequently cited articles.

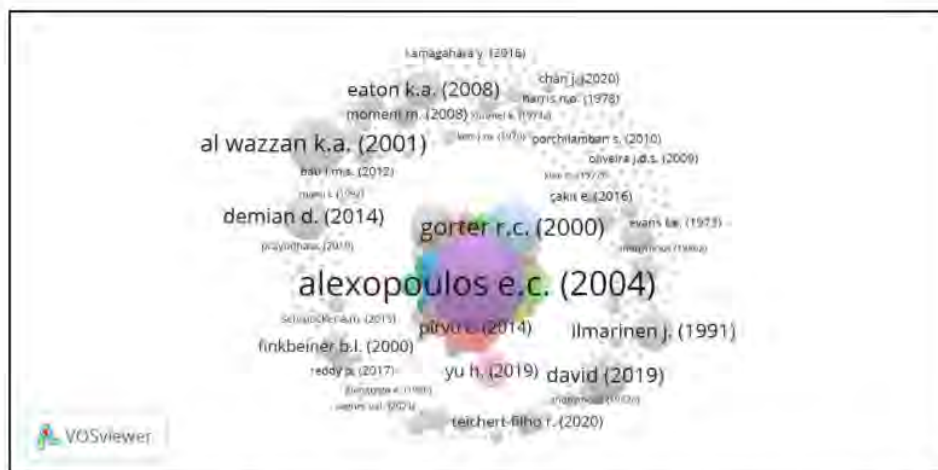


Figure 3. Network visualization in the analysis of the most frequently cited documents. There are two groups, namely, the first group includes colorful circles, dominated by Alexopoulos E.C. (2004) with the largest circle, and the second group includes transparent gray circles, dominated by Al Wazzan K.A. (2001) with the largest circle. This coloring difference indicates no relationship between the first and second groups. Regarding circle size, the higher the citation weight, the bigger the circle.¹⁷

Table 6. Top 15 most cited documents

Rank	Judul	Authors	Journal	Year	Citations
1	Prevalence of musculoskeletal disorders in dentists	Alexopoulos E.C.; Stathi I.-C.; Charizani F.	BMC Musculoskeletal Disorders	2004	274
2	Preventing musculoskeletal disorders in clinical dentistry: Strategies to address the mechanisms leading to musculoskeletal disorders	Valachi B.; Valachi K.	Journal of The American Dental Association	2003	139

3	4 Reports of body pain in dental student population	Rising D.W.; Bennett B.C.; Hursh K.; Plesh O.	26 Journal of The American Dental Association	2005	114
4	25 Disorders of the musculoskeletal system among dentists from the aspects of ergonomics and prophylaxis	Szymańska J.	Annals of Agriculture and Environmental Medicine	2002	107
5	2 Musculoskeletal disorders of the neck and shoulder in the dental professions	Morse T.; Bruneau H.; Dussetschleger J.	Work	2010	102
6	17 Work characteristics and upper extremity disorders in female dental health workers	Lindfors P.; Von Thiele U.; Lundberg U.	Journal of Occupational Health	2006	99
7	15 Burnout and health among Dutch dentists	Gorter R.C.; Eijkman M.A.J.; Hoogstraten J.	European Journal of Oral Sciences	2000	99
8	11 Back & neck problems among dentists and dental auxiliaries	Al Wazzan K.A.; Almas K.; Al Shethri S.E.; Al Qahtani M.Q.	Journal of Contemporary Dental Practice	2001	93
9	19 Work-related musculoskeletal disorders among dentists-a questionnaire survey	Kierklo A.; Kobus A.; Jaworska M.; Botuliński B.	Annals of Agriculture and Environmental Medicine	2011	90
10	8 The effect of tool handle shape on hand muscle load and pinch force in a simulated dental scaling task	8 Dong H.; Loomer P.; Barr A.; Laroche C.; Young E.; Rempel D.	Applied Ergonomics	2007	82
11	5 Low back problems and possible improvements in nursing jobs	5 Vieira E.R.; Kumar S.; Coury H.J.C.G.; Narayan Y.	Journal Of Advanced Nursing	2006	70
12	20 Evaluating dental office ergonomic risk factors and hazards	Bramson J.B.; Smith S.; Romagnoli G.	26 Journal of The American Dental Association	1998	61
13	4 Evaluation of ergonomic interventions to reduce musculoskeletal disorders of dentists in the Netherlands	Droeze E.H.; Jonsson H.	Work	2005	61
14	4 Perceived musculoskeletal symptoms among dental students in the clinic work environment	Thornton L.J.; Barr A.E.; Stuart-Buttle C.; Gaughan J.P.; Wilson E.R.; Jackson A.D.; Wyszynski T.C.; Smarkola C.	Ergonomics	2008	59
15	14 Pain and discomfort in the musculoskeletal system among dentists. A prospective study.	Rundcrantz B.L.; Johnsson B.; Moritz U.	26 Swedish Dental Journal	1991	58

4. Analysis of co-authorship

4.1. Co-authorship between authors

Co-authorship analysis examines interactions between authors in a scientific field. Co-authorship is a formal forum for collaboration between writers and experts and can even occur between scientific fields.¹⁸ Co-authorship analyses in the author analysis unit from 1733 authors recruited 42 with a minimum of 4 articles.¹⁹ Next, the study was carried out using Microsoft Excel. In Figure 4, based on the network visualization, 3 clusters have an extensive network, namely clusters 1, 2, and 3. The exciting thing is that the authors from Cluster 1 and Cluster 2, apart from writing together with authors in their cluster, also collaborate between clusters.

The joint writing collaboration between Cluster 1 and 3 shows collaboration in scientific fields and institutions. From clusters 1 and 3, eight authors were found from Social Medicine and Environmental Medicine, Institute of Occupational Medicine, Goethe-University (Germany), namely: Groneberg D.A., Ohlendorf D., Holzgreve F., Wanke E.M., Fraeulin L. Maurer-Grubinger C., Hauck I. and Nowak J. Apart from that, from cluster 1, several different author affiliations were found including one author from the Medical Center of the Johannes Gutenberg, Department of Orthodontics, University Mainz (Germany), namely Erbe C.; one author from the Principles of Prevention and Rehabilitation Department (GPR), Institute for Statutory Accident Insurance and Prevention in the Health and Welfare Services (Germany), namely, Nienhaus A.; and one author from the Department of Dental Radiology, Institute of Dentistry, Goethe-University (Germany), namely, Betz W. In cluster 3, two authors were found from the Institute for Occupational Health and Safety (IFA)-German Social Accident Insurance (DGUV), Germany, namely, Ditchen D. and Hermanns I.

Joint authorship in cluster 2 also shows collaboration between scientific fields and institutions based on author affiliation. From cluster 2, one author was found from the Mechatronics Department, Polytechnic University (Romania), namely Argesanu V.; one author from the Ergonomics Department, Faculty of Dental Medicine, Victor Babes University of Medicine and Pharmacy (Romania), namely Anghel M.D.; one author from Department of Mechanical Machinery, Equipment, and Transport, Polytechnic University of Timisoara (Romania); and two authors from the Department of Periodontology, Faculty of Dental Medicine, Victor Babes University of Medicine and Pharmacy (Romania), namely, Stratul S.I. and Rusu D.

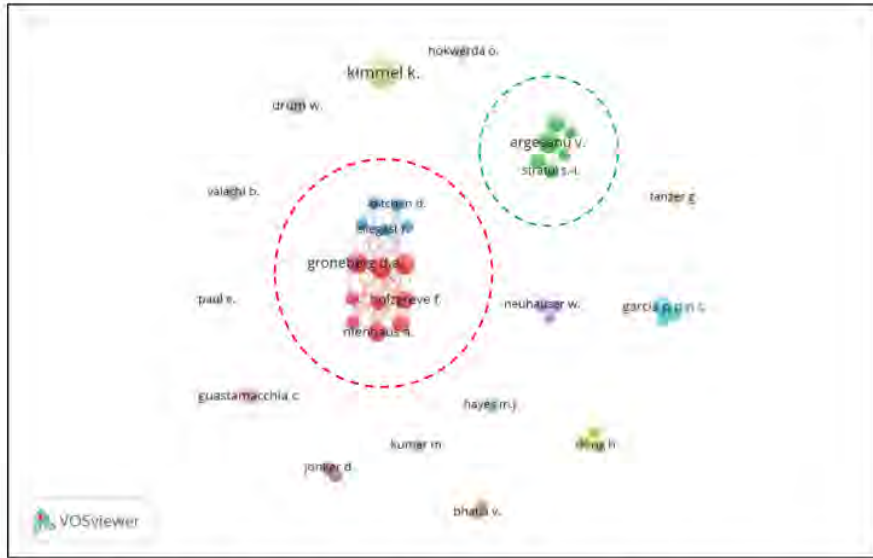


Figure 4. Co-authorship network visualization, in the red circle, is the combined co-authorship of clusters 1 and 3, while in the green circle is the co-authorship of the cluster

4.2. Co-authorship between countries

Co-authorship analysis was carried out on country analysis units with a maximum limit of 25 countries in one article and a minimum of one article per country with a zero citation limit. As a result of this analysis, 90 countries met these limits, and the most extensive set of connected countries comprised 35. In Table 3, the ten countries with the top co-authorship are presented.

Table 7: Top 10 countries in co-authorship

Rank	Country	Cluster	Documents	Citations	Links	Total Link Strength	Collaborating countries
1	United States	3	89	1321	15	25	Brazil, Nigeria, Iran, Malaysia, Australia, India, Germany, China, Canada, Japan, United Kingdom
2	India	1	66	577	5	9	Malaysia, Australia, United Arab Emirates, Saudi Arabia, United States
3	Brazil	10	29	223	3	7	United States, Canada, Portugal
4	Germany	6	25	227	4	4	United States, United Arab Emirates, Lithuania, China
5	United Kingdom	2	22	252	11	19	Netherlands, South Africa, Belgium, Trinidad and

							Tobago, Canada, Australia, United States, Romania
6	Saudi Arabia	4	22	288	5	8	United Arab Emirates, Sweden, India, Egypt
7	Sweden	4	22	633	3	4	Saudi Arabia, Canada, Netherlands
8	Iran	1	21	307	2	3	United States, South Korea
9	Romania	5	19	97	3	4	United Kingdom, Italy, Turkey
10	Italy	5	18	169	2	2	Romania

5. Analysis of the intellectual structure

An intellectual structure analysis aims to determine which authors, articles, or sources influence ergonomic dentistry research trends most.²⁰

5.1. Analysis of the author's keywords

The aim of analyzing the author's keywords is to find the correlation between keywords and the article's topic so that readers will find it easy to search for various dimensions of research on the themes of 'ergonomics' and 'dentistry.' Analysis using the VOSviewer application, namely co-occurrence analysis of the author's keywords with a minimum threshold of 5 keyword occurrences. There were 758 keywords detected, and 34 met the threshold specified above.

Figure 6 shows an overlay visualization of author keywords in 6 clusters with a total link of 482 and a total link strength of 1644. Ergonomics in Cluster 2 is the keyword most frequently used by the author, with 147 co-occurrences linked to 33 other words and a total link strength of 278. The keyword in second place is musculoskeletal disorder (MSDS), found in cluster 2 with 124 co-occurrences, links with 32 other authors' keywords, and has a total link strength of 274. The following keyword up to the keyword The tenth most used by the author are dentists (88 co-occurrences with 31 links and a total link strength of 177), dentistry (65 co-occurrences with 25 links and a total link strength of 113), dental students (35 co-occurrences with 23 links and total link strength 78), posture (28 co-occurrences with 20 links and total link strength 69); risk factors (19 co-occurrences with 19 links and a total link strength of 54), dental ergonomics (16 co-occurrences with 14 links and a total link strength of 22); occupational hazards (16 co-occurrences with 19 links and a total link strength of 42), and prevalence (16 co-occurrences with 15 links and a total link strength of 37).

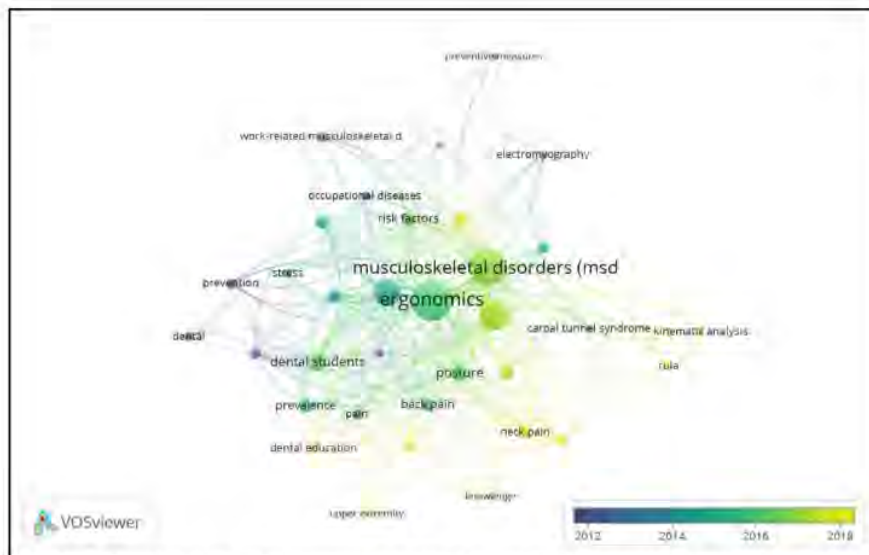


Figure 5: Overlay visualization map of author keywords from the 1990s to 2023. The color of the circles ranges from blue, which indexes articles with publication years around 2012, to green for 2014-2016, to yellow for 2018 to the latest year 2023.²¹

Table 8 lists the authors' keywords based on research subjects, research methods, occupational health and musculoskeletal disorders, ergonomics, and knowledge and education. The purpose of the grouping is to determine world research trends in the field of dental ergonomics.²⁰

Table 8. Grouping of author keyword visualization overlays up to 2023

Category	Author's keywords	Co-occurrences	Link	Total link strength	Avg. pub. year.
Research subject	Dentists	88	31	177	2017.07
	Dental students	35	23	78	2016.40
	Dental hygienists	12	12	29	2015.25
	Dental Staff	6	16	24	2009.17
Method	Survey and questionnaires	12	18	30	2010.75
	Electromyography	8	7	16	2013.25
	Kinematic analysis	8	5	16	2019.50
	Rula	7	7	16	2018.43
Occupational health and MSDs	Musculoskeletal disorders (MSDs)	124	32	274	2016.85
	Risk factors	19	19	54	2016.42
	Occupational hazards	16	19	42	2013.81
	Prevalence	16	15	37	2015.44
	Occupational health	15	15	39	2014.80
	Back pain	13	15	34	2014.46
	Neck pain	10	13	32	2018
	Pain	10	14	28	2015.50
	Prevention	10	12	21	2011.80
	Work-related musculoskeletal disorders	10	9	21	2015
	Lower back pain	9	11	28	2017.78
Occupational diseases	8	10	19	2012.75	

	Stress	8	11	15	2014.88
	Cumulative trauma disorders	7	10	16	2014.57
	Musculoskeletal system	6	17	22	2017.50
	Carpal tunnel syndrome	6	9	21	2016.17
	Upper extremity	5	5	7	2018
Ergonomics	Ergonomics	147	33	278	2015.80
	Dentistry	65	25	113	2014.57
	Posture	28	20	69	2016.25
	Dental ergonomics	16	14	22	2017.19
	Magnification	14	11	32	2018.79
	Dental	8	5	7	2010
	Preventive measurements	5	5	8	2013
Knowledge and Education	Dental Education	6	10	16	2017.67
	Knowledge	5	6	11	2020.60

5.2. Analysis of the Co-citation network of cited authors

Co-citation is 2 (two) articles that are cited together by at least one article published later. In other words, if 2 (two) articles are cited together by at least one article, then the two articles are called co-citations. The number of articles that cite the 2 (two) articles mentioned above together is called the frequency or strength of co-citation.²² These two articles have high co-citation power if more and more articles that cite these two articles are published. Therefore, co-citation patterns change over time.²³ Bibliographic coupling existed earlier than co-citation, but co-citation analysis is considered more recent in reflecting domain structure.²⁴

In this research, analysis of the co-citation network of authors cited using the VOSviewer application obtained 14,317 authors. Within the threshold of the minimum number of citations for an author of 20 citations, 164 authors were recruited. For each 164 authors, the VOSviewer application calculates the total strength of co-citation relationships with other authors. Table 9 presents the 15 authors with the greatest co-citation and total link strength.

Table 9. Top 15 co-cited authors in Ergonomic and Dentist references

Rank	Authors	Cluster	Co-citations	Links	Total link strength
1	Smith, D.R.	4	244	163	9793
2	Valachi, B.	2	167	163	5822
3	Moritz, U.	1	143	163	5093
4	Valachi, K.	2	126	163	4576
5	Cockrell, D.	4	121	163	4606
6	Hayes, M.J.	4	121	163	4901
7	Leggat, P.A.	2	115	163	4940

8	Johnsson, B.	1	110	162	3828
9	Akesson, I.	1	104	163	4013
10	Skerfving, S.	1	92	160	3565
11	Finsen, L.	1	89	163	3229
12	Christensen, H.	1	84	163	3065
13	Ohlendorf, D.	3	76	155	5471
14	Szymanska, J.	2	75	158	2135
15	Kedjarune, U.	2	73	163	3160

Discussion

Bibliometric analysis is a statistical tool for mapping the highest and current levels of scientific development and identifying research gaps and trends for various purposes, such as searching for research opportunities and supporting scientific research.²⁵ This method includes identifying and analyzing articles, authors, institutions, countries, and journals based on the number of citations and presented as descriptive analysis.^{26,27} VOSviewer users can import bibliographic databases from Scopus, Pubmed, or Web of Science.²⁸ Bibliometric analysis techniques have developed continuously to measure the impact of published articles within the scientific community. The expanded analysis presents all data as mapping to describe the relationships between and intra-nodes.²⁹

The results of the bibliometric analysis show that from 1965 to April 2023, there were 682 articles about dentists and dental ergonomics indexed by Scopus. The number of articles per year varies greatly, where the most prominent decline in articles was in 1979, when only one article was published. In contrast to that year, since 2020, publications on dental ergonomics have increased sharply by 36 publications; in 2021, there will be 43 publications, and by the end of 2022, there will be 40 publications. In 2023, up to April, there have been ten publications.

The increase in articles shows that research on ergonomics and dentists is becoming increasingly popular with researchers along with technological advances to overcome the problem of MSDs in dentists, especially as MSDs have been encountered since dental students.^{30,31,32} The main goal of dental ergonomics is to reduce the risk of MSDs and minimize physical and mental stress to improve the quality of the dentist's work.³³ In addition, the increase in the number of articles can be caused by the development of dental ergonomics research, which is focused on dentists and dental students and extends to dental hygienists^{34,35}; dental assistants^{35,36}; and dental technicians.³⁷

The progress of dentistry ergonomics cannot be separated from its history, where dentists initially worked in a standing position. Still, since the 1960s, a four-handed dentistry system has developed where dentists work in a sitting position.³⁸ The four-handed dentistry system is ergonomically designed to minimize unwanted movements and speed up dental treatment procedures.³⁹ The development of world trends in the field of dental ergonomics shows that the United States is ranked highest with 89 articles, followed by India (66 articles), Brazil (29 articles), Germany (25 articles), Saudi Arabia (22 articles), Sweden (22 articles) and United Kingdom (22 articles).

The United States is the country with the most articles written between countries and is the country with the highest citations. The analysis of the most cited countries shows that not all countries with more articles have high citations. Greece is in 6th position out of the top 10 countries with the highest citations because 287 citations were obtained from its three articles, as seen in Table 2. Based on network visualization, five countries have cited articles from Greece in order of link strength level, namely: Sweden (link strength: 10), Germany (link strength: 9), United States (link strength: 7), Iran (link strength: 6), and India (link strength: 5).

Journal of The American Dental Association (JADA) is the journal with the highest number of citations and next is BMC Musculoskeletal Disorders, respectively receiving 460 and 421 citations. JADA is the leading open access journal in the United States and has been around since 1913 and has a Q2 ranking with an h-index of 128, subject areas specifically in dentistry and medicine. BMC Musculoskeletal Disorders since 2000 has been an open access journal, ranked Q2 with an h-index of 112 subject areas Orthopedics, Sports Medicine and Rheumatology.⁴⁰ In third place is Work, with a total of 338 citations. Work has been around since 1990 with the subject Prevention, Assessment & Rehabilitation, which is an interdisciplinary journal ranked Q2 with an h-index of 58. Applied Ergonomics has 262 citations in the following ranking, with a Q1 ranking and an h-index of 119. This open-access journal is aimed explicitly at ergonomists and professionals who apply human factors in designing, planning, and managing technical and social systems. This bibliometric analysis shows that journal age, open access status, topic, quality, and impact factors are essential in determining the number of document citations.⁴¹

'Prevalence of musculoskeletal disorders in dentists' was the most frequently cited article and reached the top ranking with 274 citations. Written by Alexopoulos E.C., in 2004 from the Department of Public Health, Technological Educational Institute of Athens, Greece and Occupational Health Department, Hellenic Shipyards SA, Athens, Greece. The contents of this article are the results of a survey of 430 dentists in Thessaloniki, Greece, using the Nordic

questionnaire to determine the occurrence of MSD complaints in the last 12 months, chronic MSD complaints for at least one month, MSD complaints that caused them not being able to work and whether the respondents sought medical treatment. The survey results showed that 62% of dentists experienced at least one MSD complaint, 30% of dentists experienced chronic MSD complaints, 16% stated they had been absent, and 32% of dentists sought medical treatment. From these results, it is concluded that dentists are at risk of experiencing MSDs related to the physical load of their work.⁴² Ranked second is an article titled 'Preventing musculoskeletal disorders in clinical dentistry: Strategies to address the mechanisms leading to musculoskeletal disorders' written by Valachi B., a physiotherapist who is one of the founders of Posturedentics, Portland, Oregon. In this article, strategies for preventing the development of MSDs in dentistry are presented which aim to shape body posture and work ergonomically.⁴³ The third most cited article is 'Reports of the body in dental student population' by Rising D.W., from the Department of Preventive and Restorative Dental Sciences, School of Dentistry University of California, San Francisco. The research was conducted on 271 dental students in their fourth year, and the conclusion was that 70 percent of students experienced MSD complaints since their third year as dental students.⁴⁴

The application of dental ergonomics is important because dentists repeatedly assume sitting, standing, and static positions when working. Dentists often use static postures such as bending the body forward, bending the neck forward and tilting towards the patient's mouth, twisting the spine, and abducting the hands for a long time.⁴⁵ Static positions cause excessive contraction of several tissues, increasing muscle tension and causing musculoskeletal and peripheral nervous pain.⁴⁶ High visual demands result in postural adaptations. Dentists often assume a kyphotic posture, bending and turning the head to adjust their field of vision with lumbar rotation and flexion. Therefore, the prevalence of MSDs in dentists is higher compared to other professions.⁴⁷

Other risk factors for MSDs include static and awkward neck and shoulder postures, repetitive movements with force in the hands and arms, poor lighting, patient position not appropriate to the dentist's position, individual characteristics (physical condition, height, weight, general health, gender, age) and stress.⁴⁸ MSDs will reduce the range of motion grip strength, eliminate normal sensation, and even coordination of the musculoskeletal system.⁴⁹ MSDs in dentists begin with initial symptoms including pain, swelling, tenderness, numbness, and loss of strength.⁵⁰ In research in Saudi Arabia, neck and back pain were the main problems for dentists, which could start with dental education. So, dental schools need to improve dental ergonomics training for their students.⁵¹ This bibliometric analysis research has identified

various quantitative descriptive images of country citations, journals, articles, and authors related to research on ergonomics and dentistry. Limitations in this research are the possibility that the downloaded data is incomplete, data on inappropriate topics, and duplicate data.

Conclusion

The bibliometric analysis in this study provides quantitative and visual information from articles about dental ergonomics in Scopus-indexed publications from the 1990s to 2023. World research trends related to dental ergonomics revolve around ¹⁸ data on the prevalence, diagnosis, management, and evaluation of musculoskeletal disorders in ²⁷ dentists, dental students, dental assistants, and dental technicians.

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