

MAPPING THE RESEARCH LANDSCAPE OF ERGONOMICS IN DENTISTRY: A BIBLIOMETRIC ANALYSIS OF WORK-RELATED MUSCULOSKELETAL DISORDERS AND OCCUPATIONAL HEALTH

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ABSTRACT:

Background: Dentistry demands sustained static postures, fine motor precision and repetitive movements, making work-related musculoskeletal disorders (WMSDs) one of the most persistent occupational health concerns for dental professionals. Many systematic reviews have synthesised prevalence and prevention evidence, but the structure and evolution of the wider scholarly literature on dental ergonomics have not been mapped quantitatively. Objective: To present a bibliometric analysis of Scopus-indexed research on ergonomics in dentistry.

Methods: Records were retrieved from Scopus using the keywords "ergonomics" and "dentistry" (n = 477) and analysed with the bibliometrix R package (Biblioshiny) to produce descriptive indicators, source productivity, source growth over time and a keyword co-occurrence network.

Results: The analytical dataset comprised 469 documents published between 1965 and 2026 in 266 sources by 1,514 authors, with an annual growth rate of 2.86%, 3.83 co-authors per document and 11.92 citations per document on average. The European Journal of Dental Education (n = 16), Work (n = 15) and Die Quintessenz (n = 13) were the most productive sources. Keyword mapping revealed three thematic clusters: ergonomics, posture and equipment design; occupational musculoskeletal epidemiology; and dental education.

Conclusion: The field is long established but growing slowly, is widely dispersed across journals, and is increasingly connected to dental education. Priorities for future work include intervention research, multi-database mapping and citation-based analyses of the field's intellectual structure.

KEYWORDS: ergonomics; dentistry; work-related musculoskeletal disorders; occupational health; bibliometric analysis

INTRODUCTION

Dentistry is a physically demanding profession. Clinicians work in a small intraoral field that requires precise visual and manual control, they often hold constrained and asymmetrical postures for long periods, use vibrating hand instruments, and repeat similar movements throughout the working day. Awkward working posture, a high number of treated patients, administrative work, vibration and repetition have all been identified as occupational risk factors for musculoskeletal problems in dental professionals (Lietz et al., 2018), and an umbrella review identified static posture as the most frequently reported risk factor across both narrative reviews and original studies (De Sio et al., 2018). Musculoskeletal disorders are therefore recognised as one of several occupational health problems that persist in modern dental practice (Leggat et al., 2007; Valachi & Valachi, 2003a; Yamalik, 2007).

The reported burden is high. An early systematic review found that the prevalence of general musculoskeletal pain among dental professionals ranged between 64% and 93% (Hayes et al., 2009), and a later systematic review and meta-analysis of 41 studies in Western countries reported prevalence rates from 10.8% to 97.9%, with an overall pooled prevalence of about 78% (Lietz et al., 2018). Recent surveys report similar magnitudes: 92% of 450 German dentists and dental students reported symptoms over twelve months, most often in the neck, shoulders and lower back (Ohlendorf et al., 2020), and 90.2% of dentists surveyed in Riyadh reported musculoskeletal pain (Al-Mohrej et al., 2016). Beyond individual suffering, these disorders have professional and economic consequences, including health care expenditure (Lietz et al., 2020) and the need for early intervention, because problems may begin to develop during dental education (Roll et al., 2019).

Research and practice have responded with a wide range of ergonomic measures, from equipment modification, magnification loupes and saddle seats to ergonomic training and physical exercise (Plessas & Bernardes Delgado, 2018; Roll et al., 2019). Yet the evidence for prevention remains thin. A Cochrane review identified only two eligible studies of

physical ergonomic interventions and none on cognitive or organisational interventions (Mulimani et al., 2018), and education-based approaches, such as fitness courses and risk-perception training for dental students, have been examined in smaller studies (Garcia et al., 2013; Peros et al., 2011).

Systematic and narrative reviews are designed to answer focused clinical or epidemiological questions. They are not designed to show how a research field has grown, where it is published, or how its themes group together. Bibliometric analysis is suited to this task: it is a rigorous method for exploring large volumes of scientific data, unpacking the evolution of a field and revealing emerging areas (Donthu et al., 2021). Open-source tools such as the bibliometrix R package make comprehensive science-mapping analyses reproducible (Aria & Cuccurullo, 2017). Applying this approach to ergonomics in dentistry can show where research effort has concentrated, which venues carry the discussion, and which topics remain peripheral.

This study therefore maps the research landscape of ergonomics in dentistry, with particular attention to work-related musculoskeletal disorders and occupational health, using Scopus data. It addresses four research questions:

RQ1. How has research output on ergonomics in dentistry evolved, and what are the main descriptive characteristics of the literature?

RQ2. Which sources are the most productive, and how has their contribution changed over time? RQ3. Which conceptual themes structure the literature, as revealed by keyword co-occurrence? RQ4. What gaps and opportunities for future research emerge from the mapped structure?

The remainder of the paper is organised as follows. Section 2 reviews the relevant literature. Section 3 describes the research methodology. Section 4 presents the results. Section 5 discusses the findings and concludes, and Section 6 outlines the scope for future work.

2. LITERATURE REVIEW

This review draws peer-reviewed articles from journals indexed in Scopus, organised around four themes: the prevalence and burden of musculoskeletal disorders, risk factors and mechanisms, ergonomic interventions and equipment, and education and students.

2.1 Prevalence and burden of musculoskeletal disorders

The earliest comprehensive syntheses established that musculoskeletal problems are a significant burden for dentistry. Hayes et al. (2009) reviewed the literature on dentists, dental hygienists and dental students and reported general musculoskeletal pain prevalence of 64% to 93%, with the back (36.3%–60.1%) and neck (19.8%–85%) most affected among dentists and the hand and wrist (60%–69.5%) most affected among dental hygienists. Studies of students were notably limited. A companion review focused on dental hygienists reported that up to 96% experienced pain and called for longitudinal studies and standardised research techniques (Hayes et al., 2010). Survey evidence from Australian dental hygienists subsequently described the twelve-month prevalence and severity of symptoms by body region (Hayes et al., 2013).

Primary studies across countries confirm these patterns. In a questionnaire survey of 430 dentists in Thessaloniki, Greece (88% response rate), 62% reported at least one musculoskeletal complaint, 30% reported chronic complaints, 16% reported absence from work and 32% had sought medical care; physical load was associated with the number of complaints (Alexopoulos et al., 2004). Among dentists in Riyadh, 90.2% reported pain, lower back pain was the most common (68.1%), and women had roughly double the risk of shoulder pain (Al-Mohrej et al., 2016). Morse et al. (2010) examined neck and shoulder disorders specifically across the dental professions. The most recent large synthesis, a systematic review of 41 studies of which 30 were meta-analysed, reported prevalence between 10.8% and 97.9% across body regions (Lietz et al., 2018), and a German survey of 450 dentists and dental students found seven-day, twelve-month and lifetime prevalence of 65.6%, 92% and 95.8%, with women affected more often than men in almost all body regions (Ohlendorf et al., 2020).

2.2 Risk factors and mechanisms

A second group of studies explains why dental work generates musculoskeletal strain. Valachi and Valachi (2003a) described the mechanisms through which dental work leads to musculoskeletal disorders and, in a companion article, set out strategies for prevention that target those mechanisms (Valachi & Valachi, 2003b). Leggat et al. (2007) placed musculoskeletal disorders alongside infectious, radiological, dermatological, respiratory and psychological hazards in modern dentistry and noted that further studies were needed to identify causative factors. Yamalik (2007) reviewed risk factors, the magnitude of the problem, prevention and dental ergonomics. Pîrvu et al. (2014) analysed the dentist's operating posture, and Sakzewski and Naser-ud-Din (2014) reviewed work-related musculoskeletal disorders among dentists and orthodontists. At the physiological level, an electromyographic study of dental work quantified muscular load during clinical tasks (Milerad et al., 1991).

Integrative evidence points to posture as the central mechanism. An umbrella review of 29 articles, drawn from 4,188 records in PubMed, Scopus and the Cochrane Library, found static posture to be the principal risk factor, followed by repetitive movements and individual characteristics, and described characteristic awkward postures such as forward-head neck flexion and trunk inclination and rotation (De Sio et al., 2018). The meta-analysis by Lietz et al. (2018) similarly listed awkward posture, patient volume, administrative work, vibration and repetition as potential risk factors.

2.3 Ergonomic interventions and equipment

Reviews of dental ergonomics emphasise workstation design, instruments and lighting as targets for prevention (Gupta et al., 2013). Systematic evidence for specific interventions, however, is limited. Plessas and Bernardes Delgado (2018) included eight studies and concluded that ergonomic saddle seats and dental loupes improve working postures, that loupes appear to relieve shoulder, arm and hand pain, and that no included study reported the effect of saddle seats on pain. Roll et al. (2019) screened 3,571 unique abstracts and included 34 articles; evidence suggested that magnification loupes and indirect-vision techniques reduce musculoskeletal symptoms, while the main techniques evaluated were equipment modification, ergonomic training and physical exercise. Lietz et al. (2020) updated this evidence and added support for prismatic spectacles. The Cochrane review found only two eligible studies, both of physical ergonomic interventions, and none of cognitive or organisational interventions (Mulimani et al., 2018). The umbrella review additionally noted the prominence of stretching and modern ergonomic instruments in the preventive recommendations of the literature (De Sio et al., 2018).

2.4 Education and students

Because symptoms can begin during training, dental education is an important setting for prevention. Hayes et al. (2009) observed that studies of dental students were limited at that time. Since then, Peros et al. (2011) reported that dental students who attended a physical fitness course had significantly better physical fitness and that students who exercised regularly had less low back pain. Garcia et al. (2013) studied the perception of musculoskeletal risk among Brazilian dental students, and Gopinadh et al. (2013) examined ergonomics and musculoskeletal disorders as an occupational hazard in dentistry, with physiotherapy and yoga the approaches most often chosen by students to relieve pain. Roll et al. (2019) argued that, because problems may begin during education, early intervention is crucial.

2.5 Synthesis and research gap

Three observations follow from the literature. First, descriptive evidence on prevalence is abundant and consistent across countries, but is dominated by self-reported cross-sectional surveys. Second, mechanisms are well described, with static and awkward posture at the centre, yet evidence for the effectiveness of interventions is limited by small numbers of studies. Third, education has emerged as a setting for prevention. What the literature does not provide is a quantitative picture of the field as a whole: how much has been published, in which outlets, over what period, and around which concepts. The present bibliometric analysis addresses this gap.

3. Research Methodology 3.1 Research design

This study is a quantitative bibliometric analysis combining two families of techniques described in the bibliometric literature: performance analysis, which describes the output and impact of a field, and science mapping, which reveals its conceptual structure (Donthu et al., 2021). Performance analysis was used to describe publication volume, growth, authorship and citation indicators and source productivity. Science mapping was used to explore the conceptual structure of the field through keyword co-occurrence.

3.2 Data source and search strategy

Data were collected from Scopus, a multidisciplinary abstract and citation database selected for its broad coverage of dental, ergonomic and occupational health journals and its exportable bibliographic metadata. The search combined the terms "ergonomics" and "dentistry" with the Boolean operator AND, targeting research at the intersection of the two fields. The search returned 477 records in 2026. The resulting dataset spans 1965 to 2026; because 2026 was still in progress at the time of data collection, output for that year is partial.

3.3 Screening and dataset construction

Record identification, screening and inclusion were documented with a flow diagram adapted from the PRISMA reporting framework (Moher et al., 2009) for bibliometric studies (Figure 1, presented in Section 4.1). Because a bibliometric analysis maps the whole body of retrieved literature rather than appraising individual studies for quality or effect size, no methodological quality assessment was performed. The analytical dataset imported into the analysis software comprised 469 documents.

3.4 Analytical tools and indicators

The data were analysed in R using the bibliometrix package through its Biblioshiny web interface (Aria & Cuccurullo, 2017). The following outputs were generated: (a) a main- information summary reporting timespan, number of sources and documents, annual growth rate, number of authors, single-authored documents, international co-authorship, co- authors per document, number of author keywords, references, document average age and average citations per document; (b) the most relevant sources ranked by number of documents; (c) source production over time, expressed as cumulative occurrences by year; and (d) a keyword co-occurrence network.

In the co-occurrence network, each node represents a keyword and node size reflects its frequency; links represent co-occurrence in the same document, and link thickness reflects co-occurrence strength. Clusters of closely connected keywords were identified automatically by the software and are distinguished by colour. Clusters were interpreted thematically by examining the keywords they contain. Keywords in the network are dominated by indexer-assigned terms

from Scopus (for example "human", "humans", "article", "male" and "female"); these generic terms were interpreted as part of the indexing context, and thematic interpretation relied on the more specific terms in each cluster.

3.5 Ethical considerations

The study used only published bibliographic metadata and involved no human participants; ethical approval was therefore not required.

4. RESULTS

4.1 Dataset and screening

Figure 1 shows the PRISMA-style flow diagram for the study. The Scopus search for "ergonomics" and "dentistry" identified 477 records. The analytical dataset generated by the analysis software comprised 469 documents (Figure 2).

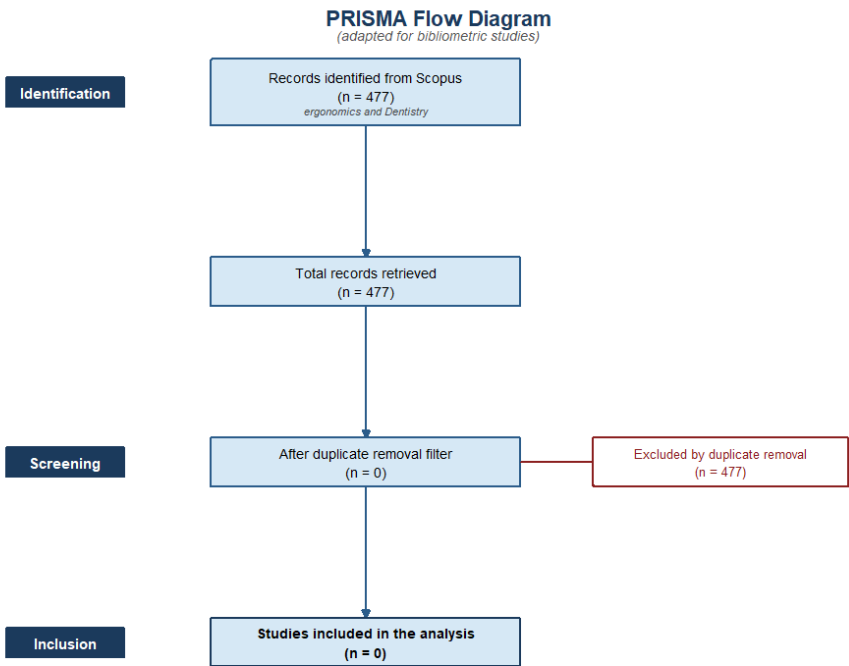


Figure 1: PRISMA Flow Diagram (Adapted for Bibliometric Studies)

Note. Records were identified in Scopus using the search terms "ergonomics and Dentistry".

4.2 Main information (RQ1)

Figure 2 and Table 1 summarise the descriptive characteristics of the dataset. The 469 documents were published between 1965 and 2026 in 266 sources and were written by 1,514 authors. Annual scientific production grew at a modest rate of 2.86%. Over the 62- year span the dataset corresponds to an average of roughly eight documents per year. The average document is 16.2 years old, indicating a relatively mature literature, and each document has received 11.92 citations on average.

Authorship patterns indicate that team-based research is the norm, with 3.83 co-authors per document, although 85 authors have produced single-authored documents. The dataset contains 763 distinct author keywords, which indicates considerable terminological diversity. Two indicators are reported as zero: international co-authorship (0%) and references (0). These values should be interpreted cautiously, as discussed in Section 5.2.

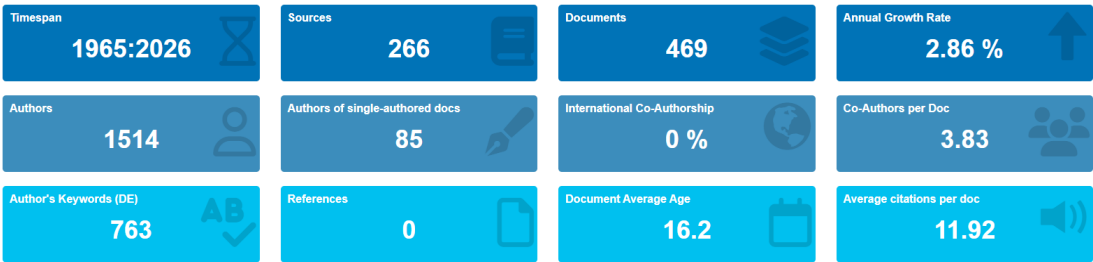


Figure 2: Main Information: Initial Analysis of the Dataset

Note. Output of the bibliometrix (Biblioshiny) summary module based on Scopus data.

Table 1: Main bibliometric indicators of the dataset

Indicator	Value	Interpretation
<u>Timespan</u>	1965–2026	More than six decades; 2026 is a partial year.
Sources	266	Wide dispersion across journals and other outlets.
<u>Documents</u>	469	<u>Analytical dataset.</u>
Annual growth rate	2.86%	Modest growth in annual output.
Authors	1,514	Unique author names.
Authors of single-authored documents	85	Solo authorship persists.
International co-authorship	0%	Probably a data-processing artefact (Section 5.2).
Co-authors per document	3.83	Collaborative research is the norm.
Author keywords (DE)	763	High terminological diversity.
References	0	Cited references were not available in the export.
Indicator	Value	Interpretation
Document average age	16.2 years	Relatively mature literature.
Average citations per document	11.92	Moderate citation impact.

4.3 Most relevant sources (RQ2)

Figure 3 and Table 2 rank the ten most productive sources. The European Journal of Dental Education leads with 16 documents, followed by Work (15) and Die Quintessenz (13). Applied Ergonomics, Dentistry Today and the Journal of Dental Education each contributed 11 documents, Ergonomics and the Journal of Contemporary Dental Practice seven each, and the International Journal of Dental Hygiene and the International Journal of Environmental Research and Public Health six each. Together these ten sources account for 103 documents, about 22% of the 469 in the dataset, so the remaining three-quarters of the literature is spread across the other 256 sources.

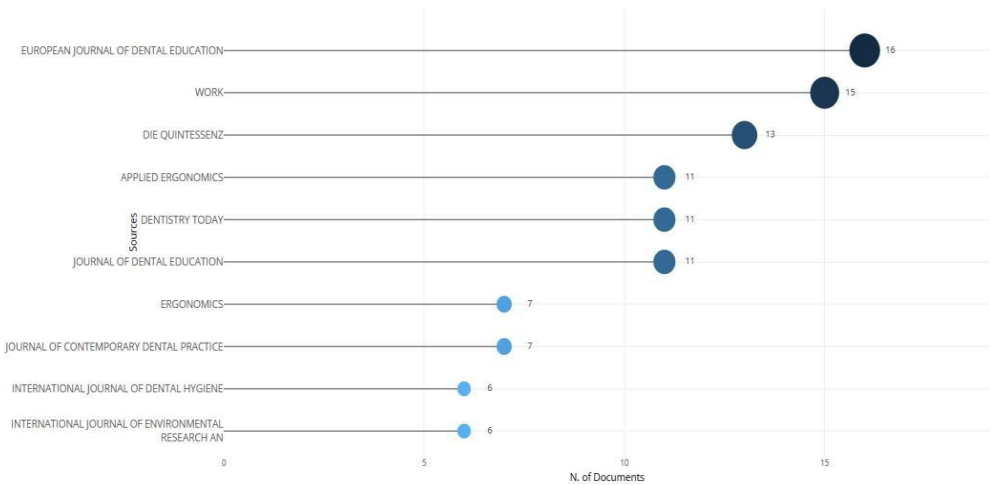


Figure 3: Most Relevant Sources

Note. The label of the last source is truncated in the software output; it corresponds to the International Journal of Environmental Research and Public Health.

Table 2: Ten most relevant sources

Rank	Source	Documents	Share (%)	Orientation†
1	European Journal of Dental Education	16	3.4	Dental education
2	Work	15	3.2	Occupational
3	Die Quintessenz	13	2.8	Clinical / practitioner
4	Applied Ergonomics	11	2.3	Ergonomics
5	Dentistry Today	11	2.3	Clinical / practitioner
6	Journal of Dental Education	11	2.3	Dental education
7	Ergonomics	7	1.5	Ergonomics
8	Journal of Contemporary Dental Practice	7	1.5	Clinical / practitioner
9	International Journal of Dental Hygiene	6	1.3	Clinical / practitioner
10	International Journal of Environmental Research and Public Health	6	1.3	Public health
<i>Total, top ten</i>		<i>103</i>	<i>22.0</i>	

Note. †Orientation is an interpretive classification by the authors, not a database field. Share is calculated against 469 documents.

Using this interpretive classification, 37 of the 103 top-ten documents (36%) appeared in clinical and practitioner-oriented outlets, 33 (32%) in ergonomics and occupational journals, 27 (26%) in dental education journals and six (6%) in a public health journal. The literature therefore sits across clinical dentistry, ergonomics and occupational health, and dental education.

4.4 Conceptual structure: keyword co-occurrence (RQ3)

Figure 4 presents the keyword co-occurrence network, and Table 3 lists the representative keywords of each cluster. Three clusters are visible. The red cluster is centred on the largest nodes, "ergonomics", "dentistry" and "human", linked by the thickest connections, and also contains "posture", "body posture", "dental equipment", "equipment design", "dental assistant", "human engineering" and "bioengineering". It represents the engineering and human-factors perspective on dental work. The blue cluster contains the epidemiological vocabulary of the field: "musculoskeletal diseases", "musculoskeletal disorders", "musculoskeletal pain", "occupational diseases", "prevalence", "risk factor", "neck pain", "questionnaire", "cross-sectional study", "workload" and "work environment", together with demographic terms such as "female", "male", "adult" and "middle aged". The green cluster, smaller and more peripheral, is built around "dental education", "dental student", "students", "education", "body position", "procedures" and "controlled study".

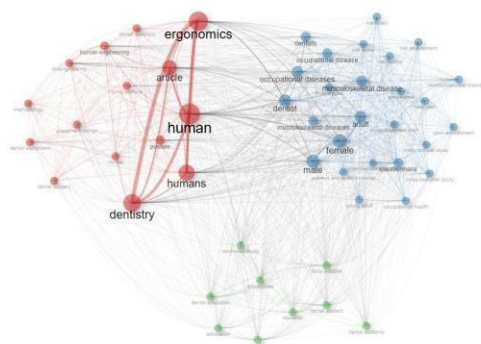


Figure 4: Keyword Co-occurrence Network

Note. Node size reflects keyword frequency; links show co-occurrence; colours denote clusters identified by the software.

Table 3: Keyword clusters and their interpretation

Cluster	Representative keywords	Interpretation
Red	ergonomics, dentistry, human, humans, article, posture, body posture, dental equipment, equipment design, dental assistant, human engineering, bioengineering, methodology, review, dental surgery	Ergonomics, posture and equipment design
Blue	musculoskeletal diseases / disorders / pain, occupational diseases, dentist(s), adult, female, male, middle aged, young adult, questionnaire, surveys and questionnaires, cross-sectional study, prevalence, neck pain, risk factor(s), risk assessment, workload, work environment, occupational health, major clinical study	Occupational musculoskeletal epidemiology
Green	dental education, dental student(s), students, education, dental, body position, procedures, controlled study	Dental education and training

4.5 Source dynamics over time (RQ2)

Figure 5 shows the cumulative number of documents for the six leading sources. Three distinct trajectories can be seen. Die Quintessenz accumulated documents very early, rising to about 11 by the late 1960s and 13 by 1973, and has remained flat since. Applied Ergonomics appears from the mid-1970s and grew steadily to about 10 documents by 2016, after which its curve is flat. Dentistry Today rose sharply in the early 2000s to about 10 by 2005 and about 11 by 2011, and has plateaued since. In contrast, Work began accumulating documents around 2005 and climbed steadily to 15 by the mid- 2020s, while the Journal of Dental Education and the European Journal of Dental Education show steep growth in the most recent years, the latter rising from about 9 documents in 2023 to 16 by 2026 and overtaking all other sources.

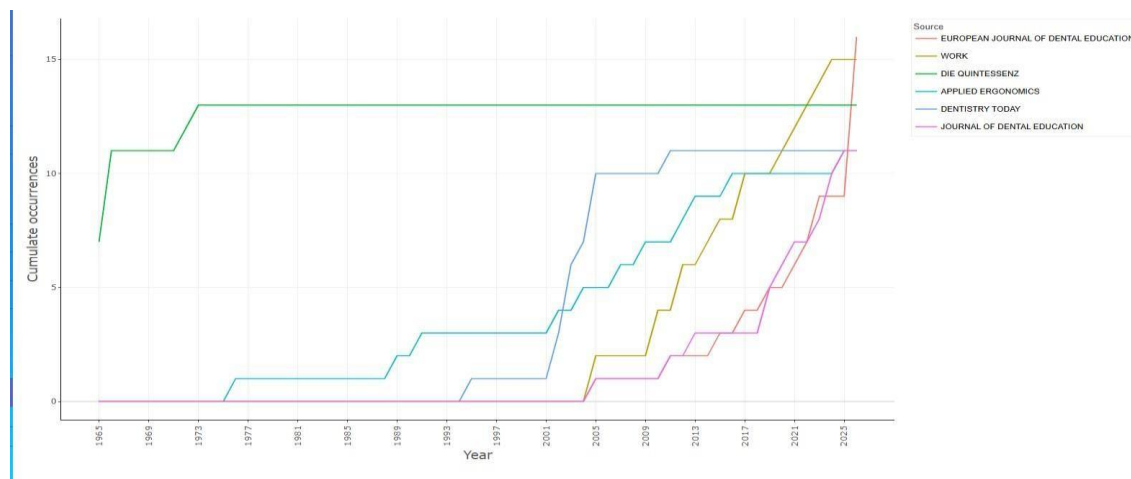


Figure 5: Source Production over Time (Cumulative Occurrences)

Note. Cumulative occurrences of the six most productive sources, 1965–2026; 2026 is a partial year.

5. FINDINGS AND CONCLUSION

5.1 Principal Findings, Discussion and Implications

The analysis of 469 Scopus documents shows that research on ergonomics in dentistry is a long-established but slowly growing field (RQ1). It spans 1965 to 2026, with an annual growth rate of 2.86%, an average of roughly eight documents per year and an average document age of 16.2 years. Authorship is predominantly collaborative, with 3.83 co-authors per document, although single-authored work persists (85 authors), and the average of 11.92 citations per document suggests steady but not exceptional citation impact. The 763 distinct author keywords point to considerable terminological diversity. The publication landscape is dispersed (RQ2). The 469 documents are spread over 266 sources, and the ten most productive sources hold only about 22% of the output, so no single outlet dominates. Leading venues fall into three kinds: dental education journals, ergonomics and occupational health journals, and clinical or practitioner-oriented outlets, which indicates that knowledge circulates among researchers, educators and practising clinicians. Centres of activity have also shifted. Die Quintessenz, Dentistry Today and Applied Ergonomics have plateaued, Work continued to grow, and the European Journal of Dental Education and the Journal of Dental Education show the steepest recent growth. The very

early accumulation of documents in *Die Quintessenz*, a German-language dental journal, suggests that ergonomic concerns were being discussed in clinical dentistry as early as the 1960s and 1970s, although this may also reflect the period for which Scopus indexes that journal.

The keyword network separates three thematic clusters (RQ3): ergonomics, posture and equipment design; occupational musculoskeletal epidemiology; and dental education. These correspond closely to the three strands of the literature review. The blue cluster mirrors the large body of prevalence research (Al-Mohrej et al., 2016; Hayes et al., 2009; Lietz et al., 2018; Ohlendorf et al., 2020), and its vocabulary of "questionnaire", "cross-sectional study" and "prevalence" reflects the dominance of self-reported survey designs noted in Section 2.5. The red cluster corresponds to work on posture, workstations and equipment (Pirvu et al., 2014; Plessas & Bernardes Delgado, 2018; Valachi & Valachi, 2003a), and the green cluster to education-centred studies (Garcia et al., 2013; Peros et al., 2011). That "controlled study" appears only in the small, peripheral green cluster is consistent with the scarcity of controlled evidence on interventions found by Mulimani et al. (2018) and Roll et al. (2019), although keyword frequency alone cannot establish this.

The rapid recent growth of the education journals suggests that ergonomics is increasingly treated as a curricular topic. This is consistent with arguments that preventive measures should be taught during undergraduate training (De Sio et al., 2018) and that early intervention is crucial (Roll et al., 2019). The continued growth of Work indicates sustained interest from the occupational health and rehabilitation community. Two observations deserve caution. First, the largest nodes in the network ("human", "humans", "article", "male", "female") are generic indexer terms and say little about content. Second, dental hygienists and dental assistants are prominent in the literature reviewed (Hayes et al., 2009, 2010, 2013), yet only "dental assistant" is visible among the keywords displayed and "dental hygienist" is absent. This may reflect the frequency threshold used for display, or different terminology, rather than a true absence of research on these groups, and it merits follow-up.

These findings carry implications for several audiences (RQ4). For researchers, the maps show a well-developed epidemiological core and a thinner experimental periphery, so rigorously designed intervention studies would add the most value. For educators, the growth of education-oriented journals provides a platform for disseminating ergonomic curricula. For journal editors and research funders, the dispersion of the literature across 266 sources makes relevant evidence difficult to locate, which strengthens the case for dedicated syntheses and special issues. For practitioners and professional bodies, the presence of clinical and trade journals among the leading sources confirms that these outlets are a route for translating research into practice.

5.2 LIMITATIONS

Several limitations should be acknowledged. First, only Scopus was searched, so relevant documents indexed elsewhere may be missing. Second, the search used only the keywords "ergonomics" and "dentistry"; studies of musculoskeletal disorders in dental professionals that do not use the term "ergonomics" may not have been retrieved, so the dataset represents the ergonomics-labelled portion of the literature. Third, the indicators for international co-authorship (0%) and references (0) are most likely artefacts of the data export and processing, since the exported file evidently did not contain cited references and the affiliation data may not have been processed; they should not be read as evidence that no international collaboration or citing occurred. Fourth, the dataset includes a partial year (2026), which affects cumulative curves and the annual growth rate. Fifth, the analysis dataset (469 documents) is smaller than the number of records retrieved (477), and the reason for the difference is not documented in the software outputs. Sixth, keyword clusters are descriptive and depend on the software's clustering settings. Finally, bibliometric indicators describe the quantity and structure of research, not its quality.

5.3 CONCLUSION

This bibliometric analysis mapped 469 Scopus documents on ergonomics in dentistry published between 1965 and 2026. The field is long-established, collaborative and widely dispersed across journals; it grows slowly but is currently being energised by dental education journals. Its conceptual structure has three interlocking parts: ergonomics, posture and equipment design; occupational musculoskeletal epidemiology; and dental education. The picture complements the evidence from systematic reviews, which consistently report a high burden of musculoskeletal disorders among dental professionals and limited evidence on prevention. By showing where the research effort has concentrated and where it is sparse, the study offers a basis for directing future research towards intervention studies, underrepresented professional groups and the integration of ergonomics into dental education.

6. Scope for Future Work

The limitations above and the patterns in the maps suggest several directions for future research. The most immediate concerns the data and search strategy. Repeating the analysis with Web of Science, PubMed/MEDLINE and other databases, and merging de-duplicated records, would test the robustness of the clusters and source rankings. The search itself could also be broadened with terms such as "musculoskeletal", "posture", "dental hygienist" and "dental assistant", and with field-restricted queries, to capture work that does not use the term "ergonomics".

A second direction is to deepen the bibliometric analysis itself. Re-exporting the data with affiliation fields would resolve the 0% international co-authorship value and allow reporting of the most productive and most cited authors, institutions and countries, together with collaboration networks. Re-exporting with cited references would enable co-citation and bibliographic-coupling analyses, which would reveal the intellectual foundations and research fronts of the field. Trend-

topic, thematic-evolution and burst-detection techniques applied across time slices could then identify rising themes and compare the periods before and after the recent growth of dental education journals.

A third direction concerns who is studied. Future work could examine research coverage of dental hygienists, dental assistants and technicians, whose visibility in the keyword network was limited, and could analyse sex-specific findings, because women reported higher prevalence in several surveys (Al-Mohrej et al., 2016; Ohlendorf et al., 2020).

Finally, the maps can serve as a baseline for evidence-gap analysis in primary research. Randomised and controlled trials with long follow-up of equipment, training and exercise interventions are still needed (Mulimani et al., 2018; Roll et al., 2019), as are longitudinal studies (Hayes et al., 2010). Combining bibliometric mapping with content analysis of studies that use objective exposure measures, such as electromyography (Milerad et al., 1991), would show how far the field has moved beyond self-reported outcomes.

REFERENCE

1. Alexopoulos, E. C., Stathi, I.-C., & Charizani, F. (2004). Prevalence of musculoskeletal disorders in dentists. *BMC Musculoskeletal Disorders*, 5, Article 16. <https://doi.org/10.1186/1471-2474-5-16>
2. Al-Mohrej, O. A., AlShaalani, N. S., Al-Bani, W. M., Masuadi, E. M., & Almodaimegh, H. S. (2016). Prevalence of musculoskeletal pain of the neck, upper extremities and lower back among dental practitioners working in Riyadh, Saudi Arabia: A cross-sectional study. *BMJ Open*, 6(6), Article e011100. <https://doi.org/10.1136/bmjopen-2016-011100>
3. Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959–975. <https://doi.org/10.1016/j.joi.2017.08.007>
4. De Sio, S., Traversini, V., Rinaldo, F., Colasanti, V., Buomprisco, G., Perri, R., Mormone, F., La Torre, G., & Guerra, F. (2018). Ergonomic risk and preventive measures of musculoskeletal disorders in the dentistry environment: An umbrella review. *PeerJ*, 6, Article e4154. <https://doi.org/10.7717/peerj.4154>
5. Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
6. Garcia, P. P., Presoto, C. D., & Campos, J. A. (2013). Perception of the risk of musculoskeletal disorders among Brazilian dental students. *Journal of Dental Education*, 77(11), 1543–1548.
7. Gopinadh, A., Devi, K. N., Chiramana, S., Manne, P., Sampath, A., & Babu, M. S. (2013). Ergonomics and musculoskeletal disorders: As an occupational hazard in dentistry. *The Journal of Contemporary Dental Practice*, 14(2), 299–303. <https://doi.org/10.5005/jp-journals-10024-1317>
8. Gupta, A., Ankola, A. V., & Hebbal, M. (2013). Dental ergonomics to combat musculoskeletal disorders: A review. *International Journal of Occupational Safety and Ergonomics*, 19(4), 561–571. <https://doi.org/10.1080/10803548.2013.11077005>
9. Hayes, M., Cockrell, D., & Smith, D. R. (2009). A systematic review of musculoskeletal disorders among dental professionals. *International Journal of Dental Hygiene*, 7(3), 159–165. <https://doi.org/10.1111/j.1601-5037.2009.00395.x>
10. Hayes, M. J., Smith, D. R., & Cockrell, D. (2010). An international review of musculoskeletal disorders in the dental hygiene profession. *International Dental Journal*, 60(5), 343–352.
11. Hayes, M. J., Smith, D. R., & Taylor, J. A. (2013). Musculoskeletal disorders and symptom severity among Australian dental hygienists. *BMC Research Notes*, 6, Article 250. <https://doi.org/10.1186/1756-0500-6-250>
12. Leggat, P. A., Kedjarune, U., & Smith, D. R. (2007). Occupational health problems in modern dentistry: A review. *Industrial Health*, 45(5), 611–621. <https://doi.org/10.2486/indhealth.45.611>
13. Lietz, J., Kozak, A., & Nienhaus, A. (2018). Prevalence and occupational risk factors of musculoskeletal diseases and pain among dental professionals in Western countries: A systematic literature review and meta-analysis. *PLoS ONE*, 13(12), Article e0208628. <https://doi.org/10.1371/journal.pone.0208628>
14. Lietz, J., Ulusoy, N., & Nienhaus, A. (2020). Prevention of musculoskeletal diseases and pain among dental professionals through ergonomic interventions: A systematic literature review. *International Journal of Environmental Research and Public Health*, 17(10), Article 3482. <https://doi.org/10.3390/ijerph17103482>
15. Milerad, E., Ericson, M. O., Nisell, R., & Kilbom, Å. (1991). An electromyographic study of dental work. *Ergonomics*, 34(7), 953–962. <https://doi.org/10.1080/00140139108964837>
16. Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ*, 339, Article b2535. <https://doi.org/10.1136/bmj.b2535>
17. Morse, T., Bruneau, H., & Dussetschleger, J. (2010). Musculoskeletal disorders of the neck and shoulder in the dental professions. *Work*, 35(4), 419–429. <https://doi.org/10.3233/WOR-2010-0979>
18. Mulimani, P., Hoe, V. C. W., Hayes, M. J., Idiculla, J. J., Abas, A. B. L., & Karanth, L. (2018). Ergonomic interventions for preventing musculoskeletal disorders in dental care practitioners. *Cochrane Database of Systematic Reviews*, 2018(10), Article CD011261. <https://doi.org/10.1002/14651858.CD011261.pub2>
19. Ohlendorf, D., Naser, A., Haas, Y., Haenel, J., Fraeulin, L., Holzgreve, F., Erbe, C., Betz, W., Wanke, E. M., Brueggmann, D., Nienhaus, A., & Groneberg, D. A. (2020). Prevalence of musculoskeletal disorders among dentists and dental students in Germany. *International Journal of Environmental Research and Public Health*, 17(23), Article 8740. <https://doi.org/10.3390/ijerph17238740>

24. Peros, K., Vodanovic, M., Mestrovic, S., Rosin-Grget, K., & Valic, M. (2011). Physical fitness course in the dental curriculum and prevention of low back pain. *Journal of Dental Education*, 75(6), 761–767.
25. Pîrvu, C., Pătraşcu, I., Pîrvu, D., & Ionescu, C. (2014). The dentist's operating posture – Ergonomic aspects. *Journal of Medicine and Life*, 7(2), 177–182.
26. Plessas, A., & Bernardes Delgado, M. (2018). The role of ergonomic saddle seats and magnification loupes in the prevention of musculoskeletal disorders. A systematic review. *International Journal of Dental Hygiene*, 16(4), 430–440.
27. Roll, S. C., Tung, K. D., Chang, H., Sehremelis, T. A., Fukumura, Y. E., Randolph, S., & Forrest, J. L. (2019). Prevention and rehabilitation of musculoskeletal disorders in oral health care professionals: A systematic review. *The Journal of the American Dental Association*, 150(6), 489–502.
28. Sakzewski, L., & Naser-ud-Din, S. (2014). Work-related musculoskeletal disorders in dentists and orthodontists: A review of the literature. *Work*, 48(1), 37–45. <https://doi.org/10.3233/WOR-131712>
29. Valachi, B., & Valachi, K. (2003a). Mechanisms leading to musculoskeletal disorders in dentistry. *The Journal of the American Dental Association*, 134(10), 1344–1350. <https://doi.org/10.14219/jada.archive.2003.0048>
30. Valachi, B., & Valachi, K. (2003b). Preventing musculoskeletal disorders in clinical dentistry: Strategies to address the mechanisms leading to musculoskeletal disorders. *The Journal of the American Dental Association*, 134(12), 1604–1612. <https://doi.org/10.14219/jada.archive.2003.0106>
31. Yamalik, N. (2007). Musculoskeletal disorders and dental practice Part 2. Risk factors for dentistry, magnitude of the problem, prevention and dental ergonomics.
32. *International Dental Journal*, 57(1), 45–54. <https://doi.org/10.1111/j.1875-595X.2007.tb00117.x>