



Review

Multidisciplinary Applications of AI in Dentistry: Bibliometric Review

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Abstract: This review explores the impact of Artificial Intelligence (AI) in dentistry, reflecting on its potential to reshape traditional practices and meet the increasing demands for high-quality dental care. The aim of this research is to examine how AI has evolved in dentistry over the past two decades, driven by two pivotal questions: “What are the current emerging trends and developments in AI in dentistry?” and “What implications do these trends have for the future of AI in the dental field?”. Utilizing the Scopus database, a bibliometric analysis of the literature from 2000 to 2023 was conducted to address these inquiries. The findings reveal a significant increase in AI-related publications, especially between 2018 and 2023, underscoring a rapid expansion in AI applications that enhance diagnostic precision and treatment planning. Techniques such as Deep Learning (DL) and Neural Networks (NN) have transformed dental practices by enhancing diagnostic precision and reducing workload. AI technologies, particularly Convolutional Neural Networks (CNNs) and Artificial Neural Networks (ANNs), have improved the accuracy of radiographic analysis, from detecting dental pathologies to automating cephalometric evaluations, thereby optimizing treatment outcomes. This advocacy is underpinned by the need for AI applications in dentistry to be both efficacious and ethically sound, ensuring that they not only improve clinical outcomes but also adhere to the highest standards of patient care.

Keywords: dentistry; diagnostics; artificial intelligence; deep learning; bibliometrics



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1. Introduction

Artificial Intelligence (AI) has significantly reshaped modern healthcare, introducing groundbreaking enhancements in patient care and medical practice [1]. Its integration into diverse medical fields has not only extended human capabilities but also improved efficiency and accuracy in clinical settings [1]. In this technological surge, the field of dentistry has not remained untouched by the AI wave, witnessing transformative changes in various aspects of dental practice [2]. The integration of digital technologies in dentistry is advancing the frontiers of precision medicine at an unprecedented pace [3].

While the field of dentistry has made considerable strides with the adoption of AI, certain challenges persist. Variability in diagnostic precision and the subjectivity inherent in treatment planning are prominent concerns that require attention [4]. AI stands as a robust solution to these issues, promising to strengthen decision-making processes, bring uniformity to clinical practices, and improve the quality of patient care outcomes.

The growing volume of academic literature underscores the significant advancements in the theoretical and practical utilization of AI within dentistry. AI's applications are extensive and profound. This includes not only diagnosing oral pathologies, such as cancerous lesions, periodontal and periapical diseases, and caries, but also the conception of individualized treatment strategies in orthodontics, and the enhancement of precision in oral surgeries through guidance and positioning techniques [5–7].

The goal of this study is to thoroughly review and synthesize a broad spectrum of literature from 2000 to 2023, applying a bibliometric approach to provide a comprehensive overview of AI's applications and impact in dentistry. The focus extends to understanding emerging trends and pinpointing significant contributions and advancements in the field; additionally, to showcase how AI technologies are effectively being utilized to enhance diagnostic accuracy, treatment planning, and prediction of treatment outcomes.

The expected outcome of our work was to provide a comprehensive overview of AI applications within dentistry, offer valuable contributions to the scientific discourse, and inform further research and developments in this transformative field.

2. Materials and Methods

2.1. Data Collection

To collect data for the article, a Boolean search strategy was deployed on Scopus in December 2023. Scopus has become a substantial collection of peer-reviewed literature consisting of books, scientific journals, and conference papers since it was established in 2004 [8]. It spans a wide range of research topics, spanning from scientific and technical fields to medicine and community studies, and even arts and humanities [9]. It operates as a prominently curated abstract and citation database, boasting an expansive reach at both the global and regional levels [10]. Our strategy involves identifying articles with “dentistry” and “artificial intelligence” mentioned in their title, keywords, or abstract, and restricted to publications between 2000 and 2023 (see Figure 1). By closing our search window in 2023, we strategically aimed to capture the most updated collection of records, coinciding with the apex of interest in AI. Additionally, a rigorous filtering process was instituted to eliminate content forms such as books, book chapters, editorials, letters, retracted articles, non-English articles, those not directly pertinent to AI in dentistry, and any duplicates. Subsequently, these articles were classified according to their primary focus areas, which may encompass diagnostics, treatment planning, or the utilization of AI within specific dental specialties like endodontics, conservative dentistry, prosthodontics, oral pathology, orthodontics, and periodontics.

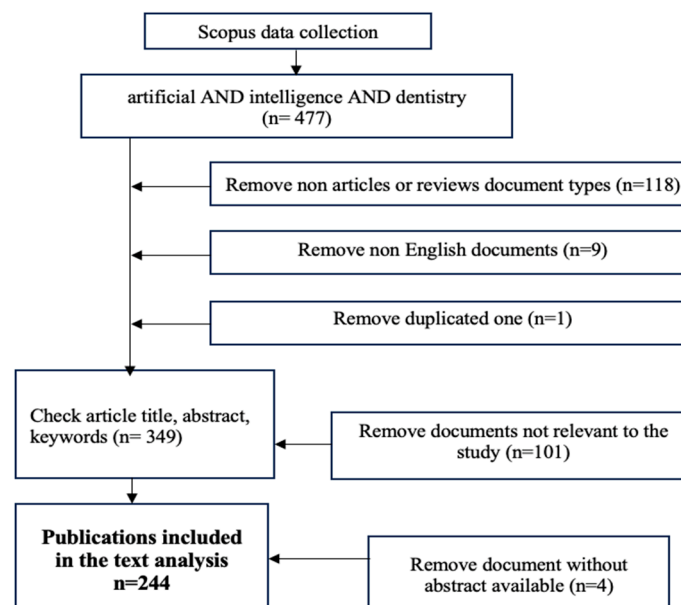


Figure 1. Flowchart of the literature identification and selection for this study.

2.2. Methodology

Bibliometrics is an invaluable method for both qualitative and quantitative analysis of scientific literature, offering an organized framework for assessing study outcomes and their implications and identifying emerging patterns of a specific topic [11]. It enables the

exploration of contributions from various countries, institutions, journals, and individual scholars within a particular field. These analyses typically involve the use of specialized software tools and visual assessments, designed to systematically scrutinize the knowledge base and trace the evolutionary trends of a given discipline. In the field of dentistry, bibliometric analyses have proven to be effective in assessing trends and guiding research, as evidenced by the work of Chen et al. [12] and Qasim et al. [13]. It has been widely used, such as in prosthodontics, endodontics, implantology, orthodontics, pediatric dentistry, and periodontology, which concisely delivered valuable information for future advancement [14]. In this study, we applied bibliometric methodologies to conduct an in-depth review of AI applications in dentistry, aiming to identify current trends in this field [7].

This bibliometric analysis follows the BIBLIO framework's guidelines for methodological transparency and quantitative approaches [15], as well as detailed guidance on scientific mapping [16,17] and inclusive bibliometric indicator selection [18]. This allowed us to present our data transparently, promoting replication and comprehension of the review's breadth, while also ensuring that the analysis remained responsible and indicative of the diverse character of this study subject.

3. Results

3.1. The Scientific Discourse

3.1.1. The Development of the Field

The evolution of AI in dentistry from 2000 to 2023 has been marked by a gradual but accelerating interest, culminating in a significant surge in recent years. The early years, particularly from 2000 to 2017, saw a limited number of publications, indicating that AI's application in dentistry was a relatively unexplored area. However, this trend shifted notably in 2019, with an increase in research output. The period from 2020 to 2021 marked a substantial growth phase, reflecting advancements in AI technology and its applicability in dental research and practice [19]. This growth trajectory peaked in 2022 and 2023 is illustrated in Figure 2, with an explosive increase in publications, underscoring a robust and widespread academic and practical interest in AI within the dental field.

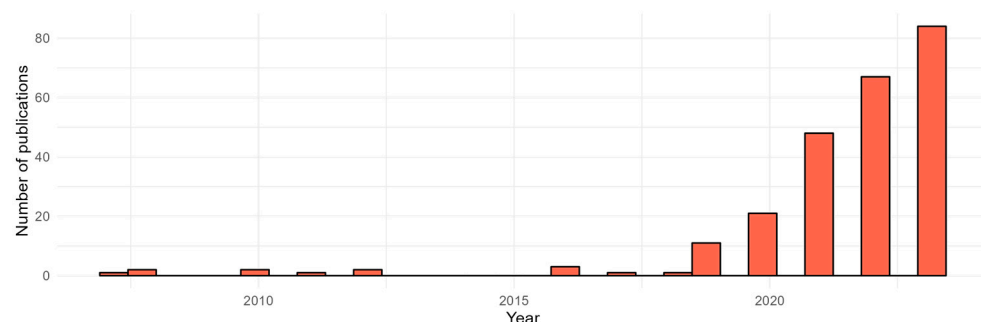


Figure 2. The number of papers published per year between 2000 and 2023.

3.1.2. Publications Outlets

From 2000 to 2023, our analysis uncovered 137 journals that have published 244 articles related to the use of AI in dental specialties; precisely, a significant portion of these sources have published at least one article over the past 4 years. The top 19 journals in terms of the number of published articles are listed in Figure 3. They were responsible for publishing 104 articles, around 42.6% of the whole sample. Throughout the years, the forefront of publishing AI in dentistry has been led by a select few journals. *Diagnostics* emerges as the top publisher with a total of 14 manuscripts, followed closely by the *Journal of Dental Research* with 12 articles. Equally impactful, *Applied Sciences (Switzerland)* and *Journal of Dentistry* have each contributed ($n = 8$), illustrating their significant roles in advancing the field. Other notable contributors include *Dentomaxillofacial Radiology* and *Oral Radiology*, each adding a substantial number of articles to the growing body of knowledge. This varied

landscape of publication venues showcases the multidisciplinary nature of AI research in dentistry, reflecting a widespread academic interest.

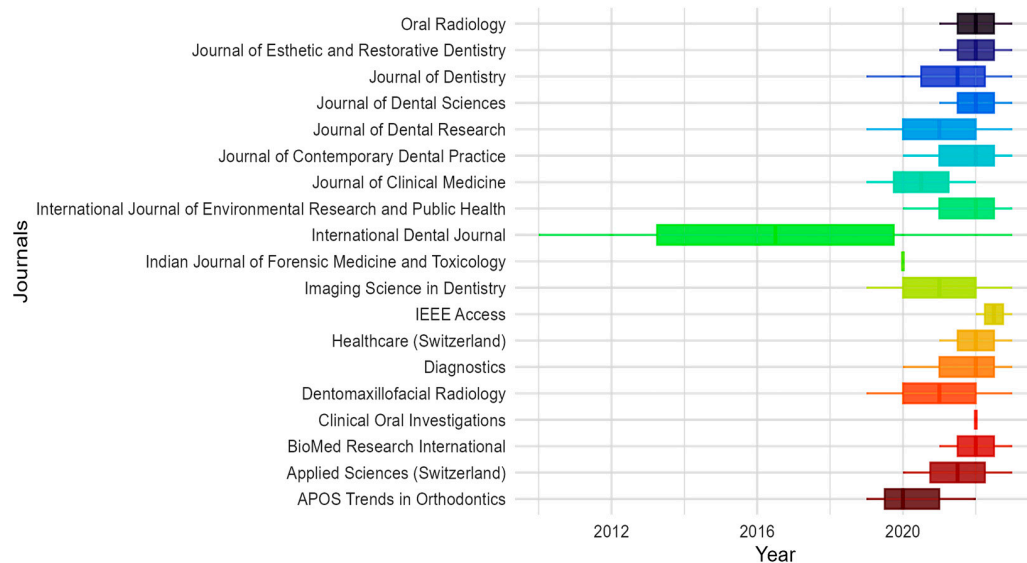


Figure 3. Publication Trends of Top 19 Journals.

3.1.3. Producers’ Locations

Regarding the number of countries represented in the authors list, we reviewed all affiliations provided and discovered writers in 54 countries/territories. Figure 4 below shows the distribution of authorships by continent and nation. The darker the color, the larger the number of authors linked with national institutions. The grey color identifies the countries where no authors were found affiliated.

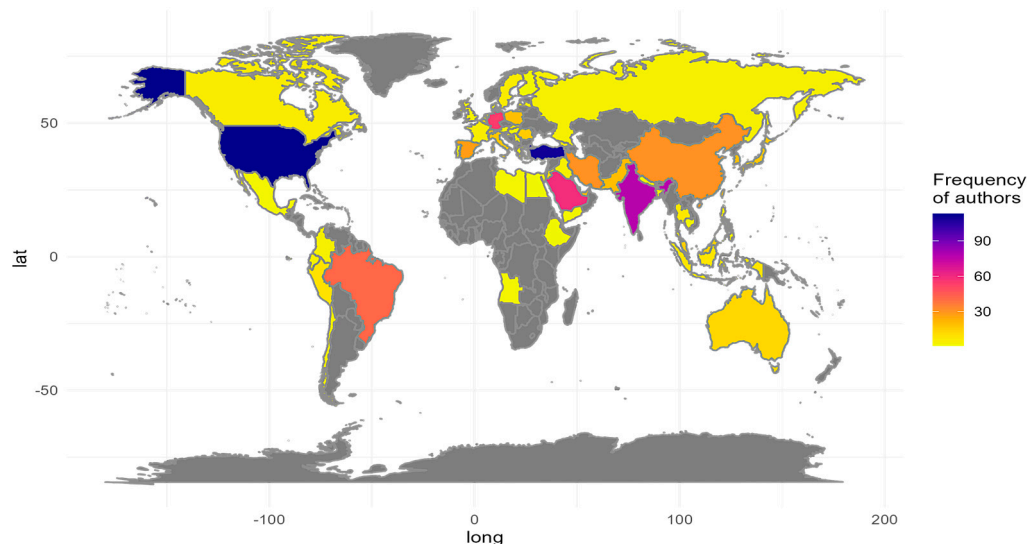


Figure 4. Global distribution of publications (2000–2023).

The United States stands out as the country hosting the highest number of co-authors, with Turkey coming in second place. On the other hand, Africa has the lowest representation among the authors, a trend that mirrors observations in various other fields. For instance, this pattern is evident in geoscience research, as detailed in a comprehensive review [20], and in studies focusing on climate change research within the African continent [21]. The disparity in author representation underscores broader regional imbalances in academic contributions and research outputs across different scientific disciplines.

Upon analyzing publication frequency, India emerges as the leading nation with the highest number of publications ($n = 30$, 12.30%). The United States follows closely with 27 publications (11.07%), and Turkey ranks third with 24 publications (9.84%). Germany holds the fourth position ($n = 19$, 7.79%), followed by Saudi Arabia ($n = 16$, 6.56%). India's prominence in research output has been increasingly recognized since 2022, when it surpassed the United Kingdom and ranked third globally, following only China and the United States.

When examining the contributions of various institutions, the two most prolific are located in Turkey: the University of Ankara with the highest number of publications ($n = 16$), followed by Eskisehir Osmangazi University ($n = 11$). The third position is held by Charité-Universitätsmedizin Berlin ($n = 8$) from Germany. The notable productivity of these institutions underscores their pivotal role in advancing scientific knowledge and the prominence of Turkish and German research outputs in the global academic landscape.

3.2. Thematic Focus

3.2.1. Extraction from Keywords

We investigated research publications about the use of AI in dental specialties to identify prevailing themes within this domain. After pre-processing the data, 1061 different keywords were found, but we set a minimum occurrence of two times for each keyword to analyze which ones occurred the most. In total, 58 keywords met this criteria. Both "dentistry" and "artificial intelligence" were removed as these were the words used in the search criteria. These can be seen through a word cloud methodology. Words with darker and larger fonts are more frequent topics.

The most frequently used words, as shown in Figure 5, are "deep learning" and "machine learning" which are both types of AI (Although both systems have the capacity for advanced problem-solving, "deep learning" is a "machine learning" sub-field which employs artificial neural networks with multiple layers to analyze data and make intelligent decisions (see [22])). Each one appears 64 times in the articles selected. Their notable occurrences in the literature are revolutionizing diagnosis and treatment planning, significantly in areas like periodontal disease, orthodontics, and prosthodontics [23]. They are followed by "neural networks", "diagnosis", and "digital dentistry", with frequencies of 21, 18, and 17 times, respectively, which underscore a shift towards more accessible, efficient, and technologically integrated dental care. The integration of robotics, such as for computer-assisted surgery or crown preparation, into dental practices, although less frequent than other topics, still represents a significant trend toward automating and enhancing dental procedures [24]. The existing literature confirms the potential of robotics to improve dental procedure outcomes, but they are understudied due to their limited availability and the technical expertise required for their operation. Thus, progress in dental robotics hinges on collaborations between engineers and dentists [25].

3.2.2. Extraction from Abstracts

In order to gain a broader overview of the context and approaches followed in each article considered, we analyzed the abstracts as short pieces of text, which is seen as a succinct summary of the entire paper. For this purpose, we applied four pivotal steps: text segmentation, purgation of numbers and punctuation, conversion to lowercase, and removal of stop words. Each step aims to guarantee the data quality and accuracy by reducing the noise (irrelevant or redundant information) and the dimensionality of the data, making it more manageable and computationally efficient to process.

The first step developed was the text segmentation, synonymously known as tokenization, pertaining to the fragmentation of the primary text into discrete words based on delineated word boundaries such as white spaces, a process corroborated by Hinterberger et al. [26]. We followed by converting the entire corpus to lowercase and eliminated elements such as numbers, punctuation, and running heads, streamlining the texts to facilitate analytical precision. At the end, words deemed trivial or auxiliary at the terminus of word

segments were purged. Recognized as “stop words”, these constituents were removed as they have a negligible contribution to the analytical purpose, and their omission does not compromise the integrity of the text analysis outcomes [27]. Finally, the most frequent words, which occurred more than 70 times in the abstracts, were plotted in Figure 6.



Figure 5. Word cloud visualization of frequently and repeatedly used keywords.



Figure 6. Word cloud visualization of frequently and repeatedly used keywords in articles' abstract.

As expected, the most frequently occurring word was “dental”, appearing 556 times, which aligns with the focus of our study. This term is prominent in discussions about the impact of AI on dental implant procedures [28,29], replacing dental personnel [29,30] and providing appropriate dental care [31]. The words “data” and “learning” occurred 236 times in articles exploring AI applications, such as models for assessing and classifying periodontal defects [32] and for caries detection [33]. These findings are consistent with the most frequent keywords identified, pointing out the substantial body of literature focused on the integration of new AI techniques in the field of dentistry.

3.3. The Evolving Discussion

3.3.1. Longitudinal Development of Keywords

In order to analyze the longitudinal development of the field, a panel plot was prepared to illustrate the evolution of specific keywords in dentistry as reflected in scientific publications from 2000 to 2023. Figure 7 shows the keywords that experienced the greatest

shift in frequency over this period. For most of them, the first appearance occurred in recent years, as did the repetitions.

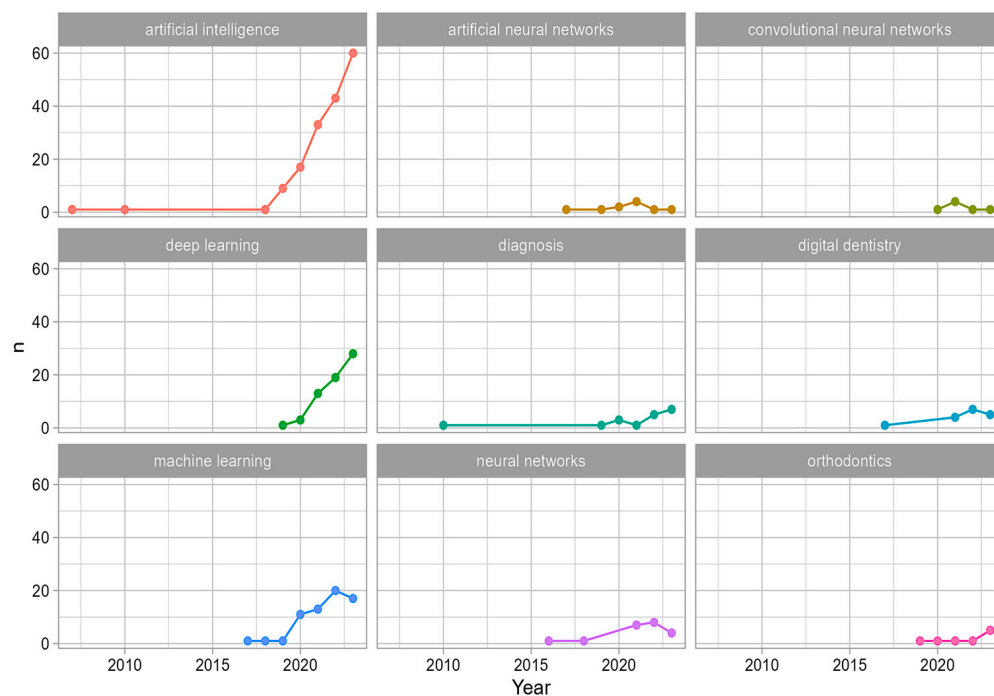


Figure 7. Featuring keyword patterns.

During the early years of the study period (2000–2018), keywords like “artificial intelligence” and “diagnosis” showed a modest consistent presence in dentistry research. More recently, from 2019 to 2023, there has been a notable increase in the frequency of keywords including “Artificial Intelligence”, “Deep Learning”, “Machine Learning”, and “Neural Networks” (see, for example, [34]), indicating a shift toward more sophisticated AI methodologies. This is followed by the increase, although discrete, of keywords related to specific AI techniques, such as “Artificial Neural Networks” and “convolutional neural networks”.

Concurrently with the increased usage of technical keywords in recent years, there has also been a marked rise in the frequency of keywords pertinent to the dentistry field, such as “orthodontics”, “digital dentistry”, and “diagnosis”. This trend suggests that the emerging techniques are being mainly applied to these areas within dentistry. The growing prevalence of these keywords underscores the targeted application of advanced methodologies to enhance specific domains within dental research and practice.

3.3.2. Trending Topics in the Abstracts

Considering that abstracts serve as concise representations of complete papers and can provide more information about the context, we conducted a longitudinal analysis to identify the words that exhibited the most significant changes over the studied period. The twelve words with the greatest variation in frequency are illustrated in Figure 8. All those words seem to increase in the last years following the increasing number of articles published.

By far, “model” is the most frequent word with an exponential growth in its usage from 2020 onwards. It has been applied in articles aiming to develop tools to determine automatic tooth numbering, frenulum attachments, gingival overgrowth areas, and gingival inflammation signs on intraoral photographs [35], classifying periodontal defects [32] and assessing the performance of AI models [28].

The second word achieving the highest frequencies is “learning”, associated with Deep and Machine learning models, which underscores a shift toward advanced, complex data processing capabilities, particularly in image analysis. These terms surged as the

dental field recognized the potential of AI for deep analysis of images and radiographs, using sophisticated techniques like image segmentation for enhanced detection and diagnosis [36]. Simultaneously, “Machine Learning” steadily gained momentum, reflecting its integral role in predictive analytics and individualized treatment planning. The focused emergence of “Dental Implants” as a significant term marks AI’s increasing practical application in dental treatments, with AI assisting in precision and accuracy, especially in implantology [28,37,38].

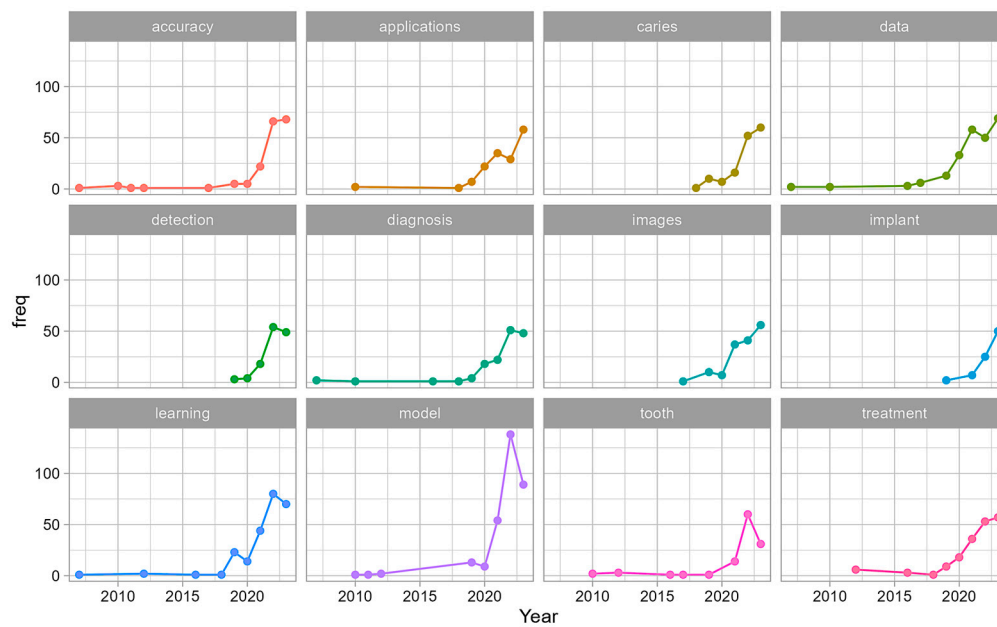


Figure 8. Longitudinal development of specific words in abstracts.

The term “data” emerges as a prominent and fundamental element in the realm of learning models, serving as the cornerstone for the processes of training, testing, and validation. This foundational element underpins the development and refinement of algorithms, providing the required input for models to learn, adapt, and improve. Its growth was accompanied by the term “accuracy” as a performance criterion for classification ensuring the reliability of models. Additionally, terms such as “diagnosis”, “detection”, and “treatment” have become more prevalent, suggesting the application of these complex techniques (see [37,39]).

3.3.3. Most Relevant Discussion

All the trending topics identified in the abstracts were accompanied by words that contextualize them in countless directions. To explore the subject matters addressed in relation to each topic, we analyzed the co-occurring words within the abstracts, regardless of their proximity to each other. For this purpose, we applied a method that analyzes word occurrence correlations and identifies words commonly associated with previously identified trending topics such as “caries”, “learning”, and “tooth”. The five words with higher correlation to these three are illustrated in Figure 9. Higher correlations indicate more simultaneous occurrences.

It is quite interesting to see some common words being shared between the three topics such as “deep” and “detection”, although with different degrees of correlation. In the context of “caries”, the term “detection” exhibits the highest correlation, indicating that the interest in identifying this pathology is a frequent topic of discussion. Additionally, the occurrence of the term “machine” suggests that machine learning techniques are being considered for the detection of caries (see [7,30,33]).

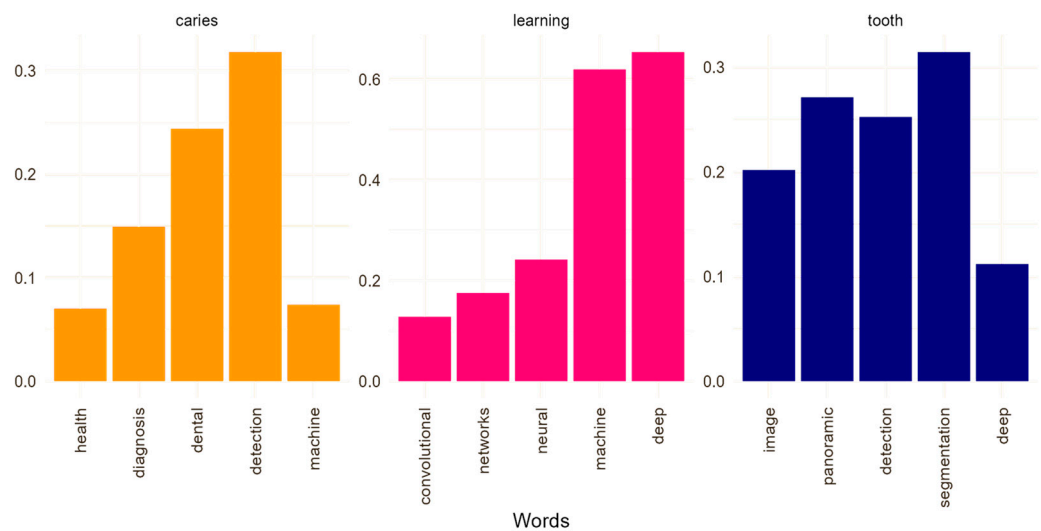


Figure 9. Words co-occurrence correlation.

Regarding “learning”, both “deep” and “machine” are the most correlated topics because of the techniques being discussed. However, other methods are also being addressed simultaneously, such as neural networks and convolutional.

About tooth, “segmentation” has the first position as teeth segmentation is a prerequisite for computer-aided dental diagnosis and treatment. It is followed by the word “panoramic” as it is a common diagnostic tool for dentists and oral surgeons for being a quick and non-invasive procedure that enables an accurate assessment of oral health needs.

4. Discussion

The analysis of our study indicated that, between 2000 and 2023, a diverse group of 647 authors from 63 countries and 478 institutions contributed to 244 publications on the application of AI in the dentistry field. These publications emphasize the extensive reach and diverse perspectives in this area of research. Notably, there was a marked escalation in the volume of publications between 2018 and 2023. We observed a significant rise in the number of publications, a trend that aligns with findings in broader literature [7]. This surge can be linked to a variety of crucial factors. Thurzo et al. [40] conducted a comprehensive review, revealing a remarkable and unparalleled increase in research activity in AI dental publications, with an average annual growth of 21.6% over the last decade and a 34.9% increase per year over the last 5 years, particularly in digital diagnostic methods like radiology. Ahmed et al. [41] further supported this trend, highlighting the improvement in AI techniques and their outcomes in dentistry, emphasizing AI’s role in accurate patient management, dental diagnosis, prediction, and decision-making. Moreover, another research on dental esthetics indicates a growing interest in research trends and global productivity [42].

Notably, India and the United States have emerged as forefront leaders in this domain. Among these contributions, the University of Ankara, Eskisehir Osmangazi University, and Charité Universitätsmedizin Berlin stand out for their significant impact and leadership in the field. Additionally, the work of highly cited authors like Schwendicke F. and Krois J. has been influential in shaping the current and future directions of AI applications in dentistry [43]. These findings align closely with those reported in a similar study by Xie et al. [7], reinforcing the global relevance and consistency in AI dentistry research trends.

The transformative potential of AI in dentistry, as previously highlighted in our literature review, has been empirically validated by our bibliometric analysis. Between 2018 and 2023, there has been a pronounced surge in publications focusing on advanced AI techniques such as Deep Learning (DL) and Neural Networks (NNs). These methods

have transitioned from experimental to core tools in dental AI applications, especially in the areas of diagnosis and treatment planning.

Our findings indicate a significant emphasis on the use of CNNs (Convolutional Neural Networks) and ANNs (Artificial Neural Networks) for critical diagnostic tasks. CNNs, for example, have been increasingly applied to enhance the accuracy of diagnosing periapical lesions and identifying root anatomies from radiographic images, often producing results that surpass the diagnostic capabilities of experienced practitioners [44]. Similarly, ANNs have shown quite high accuracy in predicting post-operative pain and accurately placing cephalometric points on lateral cephalograms and CBCT [44,45]. Studies have highlighted that an ANN not only simplifies the process but also eases the workload for dentists [46]. This correlates strongly with the trends identified in our bibliometric analysis, where these technologies have been employed to analyze a variety of radiographic data including bitewings, periapical and panoramic radiographs, and CBCT scans. Radiographic data are essential for AI use in dentistry, as they serve as a critical resource for training AI models, enhancing accuracy in diagnostics, standardizing interpretations, and facilitating predictive analysis [47].

Notably, the literature underscores AI's capacity for improving image classification and segmentation. Segmentation allows AI systems to isolate specific areas within radiographs, such as distinguishing healthy tissue from pathological areas [48]. Once segmented, these images are classified, enabling detailed diagnostics. For instance, in the literature in periodontics, CNNs are used for segmenting images to identify periodontal cysts and then classifying them as either having cysts or no cysts [49]. Similarly, CNNs are employed to detect approximal dental caries in bitewing radiographic images and classify them according to the severity of the lesion [50]. This aligns with the observed bibliometric trends where AI's role in image segmentation and classification has markedly contributed to enhancing diagnostic precision and optimizing treatment outcomes.

Such advancements reflect a concerted effort within the dental research community to leverage AI not merely as a supplementary tool but as an integral component of modern dental practice, significantly influencing both current methodologies and future directions in dental care.

Future research should explore integrating AI with widely used digital tools, like smartphone applications and daily use software. For instance, combining AI with smartphone apps could make AI-driven diagnostics more accessible and practical in daily practice [51]. Similarly, using AI with software for pediatric dental radiographs could further validate its reliability and ease of use in clinical settings [52]. Addressing these areas will enable the dental research community to more easily test the reliability of AI-based programs in daily clinical practice, ensuring that they are both effective and user-friendly in real-world environments, which is crucial for enhancing dental care.

By synthesizing the empirical data from our bibliometric analysis with the theoretical insights from the literature, it is evident that AI's capabilities in dental diagnostics are both evolving rapidly and proving indispensable. This dual approach not only supports but also enhances our understanding of AI's critical role in advancing dental diagnostics and treatment planning, paving the way for further innovation and application in the field.

However, several limitations should be acknowledged. At the study and outcome levels, there is a potential risk of bias in the selection of studies, possibly leading to an over-representation of positive outcomes, especially those involving advanced AI techniques. Methodological differences across studies may also affect result comparability.

At the review level, incomplete retrieval of research is a concern. Despite an extensive search, some studies may have been missed due to language barriers, publication delays, or access issues. Additionally, reporting bias may have skewed the analysis toward studies with significant or favorable results.

5. Conclusions

This bibliometric study highlights the progressive integration of digital technology in oral health from 2000 to 2023, showcasing a significant transformation in dental practices and patient care. The evolution of AI during this period reflects a shift from basic data management to advanced implementations like the use of Deep Learning (DL) and Neural Networks (NNs). This technological advancement has revolutionized diagnostic methods, treatment planning, and outcomes prediction in dentistry, significantly enhancing the efficiency, accuracy, and personalization of treatments across various specialties.

Moreover, this study presents an opportunity for policymakers to understand and leverage these technological trends, types, and applications to improve access, literacy, knowledge, and services in oral health. It emphasizes that technology types and classifications vary over time and across dental areas, underscoring the importance of context-specific applications.

However, it is important to recognize that while AI-developed algorithms have shown promising results, they are still in need of further development and refinement. Challenges like data security, ethical considerations, and maintaining the human element in patient care are crucial. These considerations call for a balanced and cautious approach to the integration of AI in dentistry. The study suggests that continuous evaluation, adaptation, and development are essential for AI to further integrate effectively into the dental field, guiding the future toward an informed, precise, and patient-centered approach in dental healthcare. Additionally, it is important to acknowledge the long learning curve associated with AI, which necessitates ongoing attention and effort as we move forward.

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