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# A bibliometric analysis of the literature from the past to the present on the use of artificial intelligence in orthodontics and orthognathic surgery

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## ABSTRACT

**Aims:** This study aims to investigate the publication characteristics of academic work centred around artificial intelligence (AI) in orthodontics and orthognathic surgery in detail.

**Methods:** In this analysis, the VOSviewer software and the Bibliometrix Biblioshiny R-package were employed for the purposes of bibliometric investigation and data visualisation.

**Results:** Between 1991 and 2024, 842 articles were published, averaging 12.33 citations per article. China topped the list with 200 articles, succeeded by the U.S. with 183 and South Korea with 121. Seoul National University authored the highest number of publications (47), succeeded by Peking University (36) and the University of North Carolina (34). Seoul National University (807) and the Catholic University of Leuven (567) ranked highest in citation impact. Jacobs Reinhilde was the most prolific author, with 22 publications, and alongside Dinggang Shen and Adriaan Van Gerven, had the greatest citation counts of 544, 491, and 476, respectively. The most used keywords were "artificial intelligence," "deep learning," "machine learning," "orthodontics," "convolutional neural network," "orthognathic surgery," "dentistry," "cephalometry," "CBCT," and "cephalometric analysis."

**Conclusion:** This bibliometric analysis illustrates that AI has swiftly become an expanding research subject in orthodontics and orthognathic surgery, attracting considerable interest from the scientific community. The thorough investigation indicates that AI is essential, especially in cephalometric evaluations, diagnostic procedures, and treatment strategies.

**Keywords:** Artificial intelligence, bibliometrics, orthodontics, orthognathic surgery

## INTRODUCTION

Artificial intelligence (AI) refers to the capacity of machines to perform tasks that typically require human intelligence, such as learning, reasoning, and decision-making. First introduced as a concept in 1956, AI has since evolved into a transformative technology across a wide range of fields, including healthcare and dentistry.[1,2] One of AI's most powerful attributes is its ability to process and analyze vast datasets with exceptional speed and consistency.[3] In recent years, AI applications have emerged as promising tools for enhancing diagnostic accuracy, streamlining clinical workflows, and supporting decision-making in dental specialties.[4]

In orthodontics, AI has been applied to patient monitoring, skeletal age assessment, temporomandibular joint (TMJ) diagnostics, automated cephalometric landmark detection, treatment planning, and outcome evaluation.[5] These applications suggest that AI may significantly improve clinical efficiency and accuracy while reducing practitioners' administrative burdens.[6] Given the irreversible nature of many orthodontic and orthognathic procedures, which require high standards of diagnostic precision and individualized planning, AI can play a valuable role in consolidating clinical and radiographic data for more reliable assessment and treatment planning.[7,8]

Orthognathic surgery, in particular, demands comprehensive preoperative analysis due to the anatomical complexity and functional implications of the procedures involved. AI models have recently been employed in a variety of related tasks, including prediction of facial profile changes following orthognathic surgery,[9] estimation of intraoperative blood loss,[10] automated surgical planning using CBCT and intraoral scanning,[11] skeletal maturation assessment,[12] and detection of maxillofacial anomalies.[13]

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The increasing integration of AI into orthodontics and orthognathic surgery reflects the broader technological evolution across healthcare disciplines. As AI-driven research expands within these fields, there is a growing need to systematically evaluate the academic literature to understand the scope and trajectory of this emerging domain. A bibliometric study offers a rigorous method for analyzing publication trends, identifying key research themes, mapping citation patterns, and highlighting influential authors and institutions. Such an approach provides valuable insights into the current state and future directions of AI applications in orthodontics and orthognathic surgery.[14] Prior bibliometric studies in orthodontics have examined topics such as cleft lip and palate,[15] lingual orthodontics,[16] temporary anchorage devices,[17] and clear aligner treatments.[18] Alternatively, they have concentrated on the most-cited papers.[19]

The objective of the present study is to conduct a comprehensive bibliometric analysis of the literature concerning the use of AI in orthodontics and orthognathic surgery. We hypothesize that while both fields demonstrate increasing engagement with AI, orthodontics has received more research attention and integration of AI methodologies than orthognathic surgery. Through this analysis, we aim to identify publication trends, prominent contributors, and thematic developments to inform future research directions and support the clinical advancement of AI-assisted interventions in these domains.

## METHODS

In accordance with the ethical standards governing research and the principles of the Declaration of Helsinki, no approval was required, as the study did not involve clinical studies or the use of patient data. That is why clinical trial number is not applicable.

In August 2024, a comprehensive literature search was conducted using the Web of Science (WoS) Core Collection database, originally established by the Institute for Scientific Information (ISI) and currently maintained by Clarivate Analytics. Prior to the final search on 1 August 2024, a screening process and a series of pilot searches were performed to optimize the search strategy. These initial searches were broadened and led to the identification of 3,069 records. The "all fields" option was selected during the electronic search to retrieve the maximum number of relevant entries. To ensure completeness, manual screening was also performed to enhance accuracy.

As a result of these pilot searches, a total of 3069 studies were found when ''artificial intelligen*'' OR ''deep learn*'' OR ''machine learn*'' OR ''convolutional neural network*'' OR ''CNN*'' OR ''Recurrent neural network*'' OR ''RNN*'' OR ''Fully Convolutional Network*'' OR ''FCN*'' OR ''artificial neural network*'' (all fields) and "orthod*" OR "cephal*" OR "craniofacial*" OR "maxillo*" OR "orthogn*" (all fields) was typed in the search bar to determine the publications to be included in the study. The document types were filtered to include "article," "proceeding paper," "review," and "early access."

Only English-language publications were considered. Titles and abstracts were screened first to assess eligibility. If eligibility could not be determined at this stage, full texts were reviewed. A single reviewer conducted article selection. Although this ensured consistency, the potential for selection bias is acknowledged. In future studies, inclusion of multiple independent reviewers is recommended.

Following the filtering and screening process, a total of 842 articles were selected for analysis. The VOSviewer software (developed by Leiden University's Centre for Science and Technology Studies) and the Bibliometrix Biblioshiny R-package (available via https://www.bibliometrix.org/home/index.php/layout/biblioshiny) were employed in this analysis for the purposes of bibliometric investigation and data visualisation.

The VOSviewer software (version 1.6.20) was downloaded on 30 September 2023 and has since been used by our team in multiple bibliometric studies. For the purposes of this particular study, the literature search and article selection were carried out in August 2024. Although the software installation predates the current study, all visualizations and analyses included in this manuscript were generated using data from the August 2024 search. This clarification is provided to address any potential confusion about the timeline of data collection and analysis.

The VOSviewer enables the production of maps of authors or journals based on co-citation data, as well as maps of keywords based on co-occurrence data. The software provides an extensive viewer for the detailed examination of bibliometric maps.[20] Bibliographic data exported in ".txt" format using a marked list were opened in Microsoft Excel (Microsoft, Inc., Redmond, Washington). We cleaned the dataset to resolve formatting issues and inconsistencies. For example, variations in author names such as "Cevidanes, Lucia," "Cevidanes, Lucia H.S.," and "Cevidanes, Lucia Soares" were merged to ensure accurate representation. Author data were cross-verified using the Web of Science and, when needed, Scopus or general web searches. Similarly, inconsistent country names-e.g., "Turkey" vs. "Turkiye"-were standardized. After these corrections, the cleaned dataset was exported again and visualized in VOSviewer.

An innovative open-source tool for the comprehensive examination of scientific networks is the Biblioshiny R-pack. The program facilitates the implementation of a proposed workflow for bibliometric analysis. The suggested tool is flexible, amenable to improvement, and compatible with other statistical R packages, given that it was created with the R programming language. Consequently, it constitutes an invaluable instrument in an ever-changing discipline such as bibliometrics.[21] The data was exported in the '.bib' file format and then subjected to processing by the program, which yielded the generation of visuals.

The Microsoft Excel program was employed for the purpose of data tabulation.

# RESULTS

## Growth in Publications

A total of 842 articles were obtained for review concerning the application of AI in the domains of orthodontics and orthognathic surgery. The annual growth rate of publications was relatively stable from 1991 to 2016. Nevertheless, there was an appreciable surge in the volume of publications from 2017 to 2024. From January 1 to August 1, 2024, a total of 114 articles were published (Figure 1). The articles in question have been referenced a total of 10,381 times, of which 6,029 were not self-citations. The average number of citations per article was 12.33.

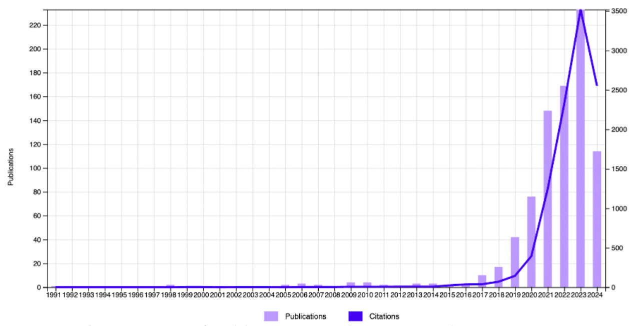


**Figure 1.** The quantity of publications and corresponding citations, organized by year

## Countries/Regions and Institutions

A total of 73 countries or regions published at least one article on the topic of AI in orthodontics and orthognathic surgery between the years 1991 and 2024. China has published the greatest number of articles on the subject, with 200 articles, followed by the United States and South Korea, which have published 183 and 121 articles, respectively. Moreover, these countries were the recipients of the greatest number of citations. A collaboration map of countries on this subject, together with a list of the five most prolific countries, is provided in Figure 2. In terms of institutional affiliations, there were notable examples of robust collaborative relationships, including those with Seoul National University, Ulsan University, and Kyungpook National University (Figure 3A). Seoul National University published the greatest number of papers, with a total of 47, followed by Peking University and the University of North Carolina, which published 36 and 34 papers, respectively. With regard to the analysis of citation figures, Seoul National University and the Catholic University of Leuven were the most highly cited universities, with respective figures of 807 and 567. Although Seoul National University and the Catholic University of Leuven are among the most influential institutions in their respective fields, it has been observed that they do not engage in collaboration (Figure 3B). The top five most prolific institutions are represented in Figure 3C.

## Authors

The author profiles extracted from the publications were subjected to analysis with the aim of identifying the most influential scholars in the field of AI in orthodontics and

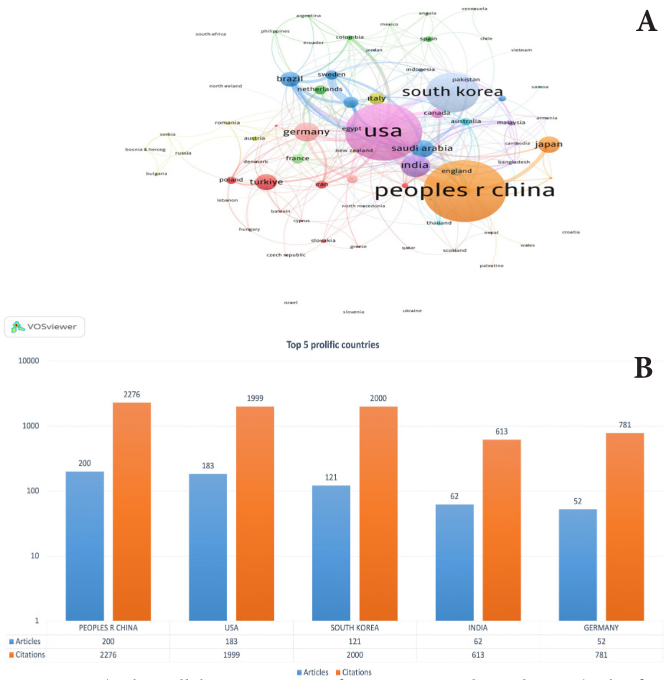


**Figure 2.** A) The collaboration map of countries on this subject B) The five countries with the highest rates of productivity

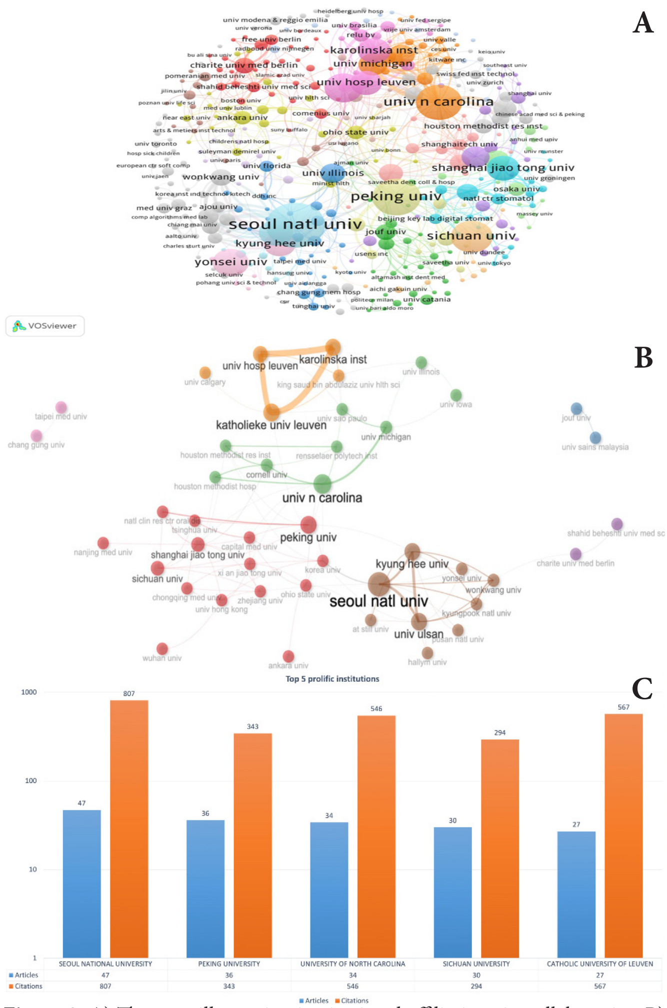


**Figure 3.** A) The map illustrating institutional affiliations in collaboration B) Visualization of collaborative networks among different affiliations, including Seoul National University and the Catholic University of Leuven C) The five most productive institutions

orthognathic surgery. The seven most prolific authors are presented in Figure 4A. The most prolific author was Jacobs, Reinhilde (Belgium, n. 22), followed by Xia, James J. (USA, n. 20), and Xu, Tianmin (China, n. 20). With regard to the attention paid to their work by other authors, Jacobs, Reinhilde; Shen, Dinggang; and Van Gerven, Adriaan, have had the most significant impact on this field, having been cited 544, 491, and 476 times, respectively. The findings suggest that the majority of collaborating authors were from the same country or region. A notable degree of collaboration in Figure 4B was evident between the following research teams: Xia, James J., and Deng, Hannah H; Xu, Tianmin, and Pei, Yuru; and Lucia, Cevidanes, and Jonas, Bianchi.

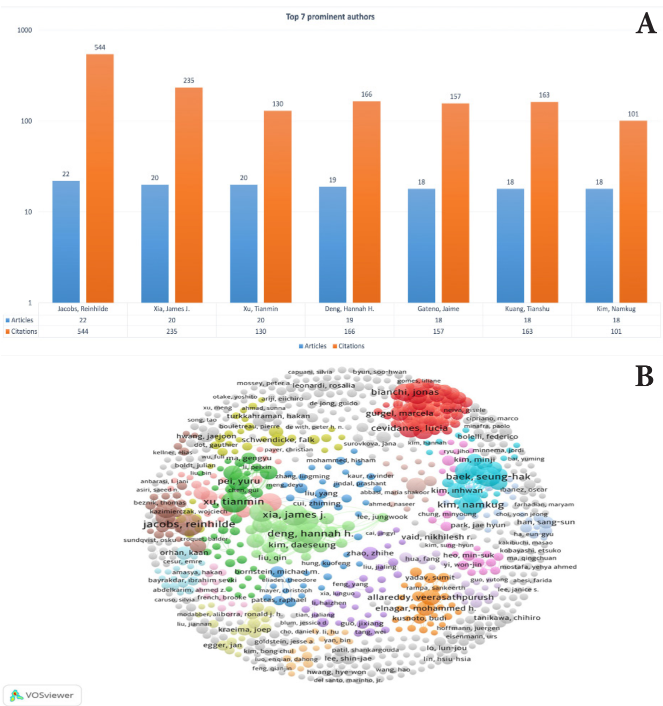


Figure 4. A) The seven top-producing authors B) The map of the author collaboration on this topic

## Articles

The most highly cited publications provide readers with a comprehensive overview of the development and current status of a field of study, offering guidance to subsequent investigators and influencing the direction of ongoing research. Table presents the 25 most frequently cited papers in this context.

## Journals

Figure 5 depicts the five most prolific journals, as determined by the number of publications and citations. The three journals with the highest number of publications were Scientific Reports, Orthodontics & Craniofacial Research, and Diagnostics, with respective publication numbers of 42, 40, and 30. With regard to the number of citations, the most influential journals were Medical Image Analysis, Scientific Reports, and the Journal of Dentistry, with 647, 554, and 552 citations, respectively.

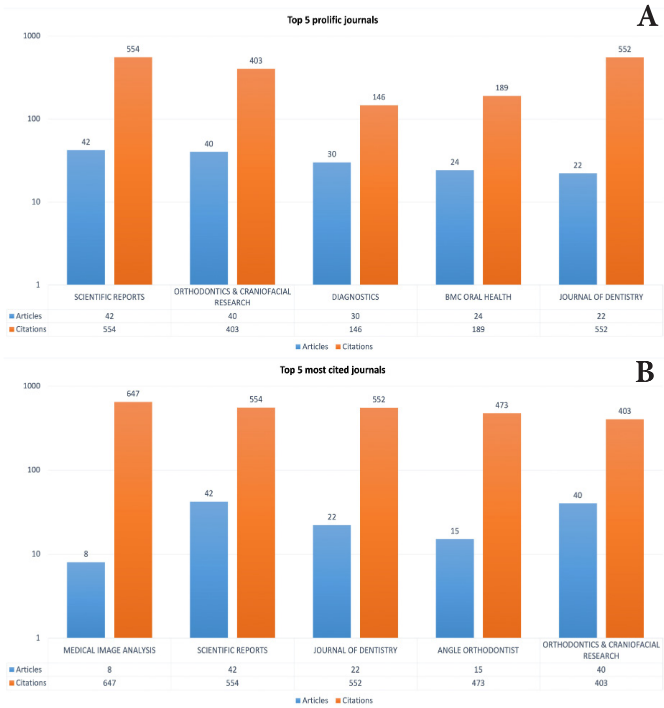


Figure 5. A) The five most prolific journals based on publication figures B) The five most prolific journals considering citation counts

## Co-citation References

The co-citation network in Figure 6 displays references cited together at least 30 times. This analysis revealed key studies that have shaped interdisciplinary links between orthodontics, radiology, and AI applications. Central nodes represent foundational works frequently co-cited in the literature, highlighting their continued relevance to the field.

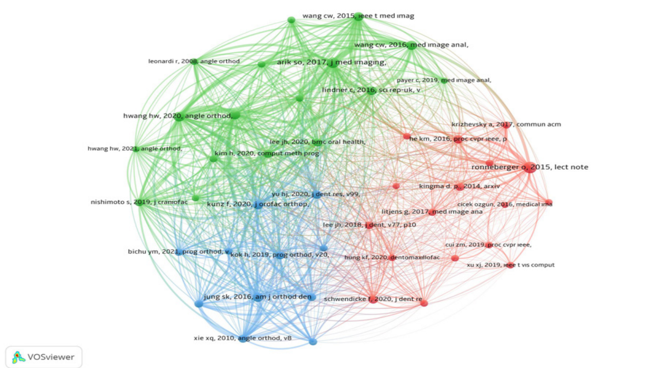


Figure 6. The co-citation reference network map of citations cited a minimum of thirty times

## Keywords

The most frequently occurring keywords were "artificial intelligence," "deep learning," "machine learning," "orthodontics," "convolutional neural network," "orthognatic surgery," "dentistry," "cephalometry," "cbct," and "cephalometric analysis" (Figure 7). The results revealed that AI exhibited the highest occurrence and total link strength. In light of the recent proliferation of publications on the subject of AI in orthodontics and orthognathic surgery, particularly in the period following 2019, we present in Figure 8 a map of

**Table. Top 25 most frequently cited articles**

| Title | Author | Sources | Publication year | Total citations | Average per year | Type of study |
|---|---|---|---|---|---|---|
| Deep learning for automated skeletal bone age assessment in X-Ray images | Spampinato et al.[32] | Medical Image Analysis | 2017 | 264 | 33 | Article |
| Convolutional neural networks for dental image diagnostics: a scoping review | Schwendicke et al.[33] | Journal of Dentistry | 2019 | 192 | 32 | Review |
| Integrating spatial configuration into heatmap regression based CNNs for landmark localization | Payer et al.[34] | Medical Image Analysis | 2019 | 185 | 30.83 | Article |
| Developments, application, and performance of artificial intelligence in dentistry-a systematic revie | Khanagar et al.[35] | Journal of Dental Sciences | 2021 | 180 | 45 | Review |
| Fully automated quantitative cephalometry using convolutional neural networks | Arik et al.[36] | Journal of Medical Imaging | 2017 | 157 | 19.63 | Article |
| The use and performance of artificial intelligence applications in dental and maxillofacial radiology: a systematic review | Hung et al.[37] | Dentomaxillofacial Radiology | 2020 | 149 | 29.8 | Review |
| Deep learning in medical image analysis: a third eye for doctors | Fourcade A, Khonsari RH.[38] | Journal of Stomatology Oral and Maxillofacial Surgery | 2019 | 129 | 21.5 | Article; Proceedings Paper |
| Automated identification of cephalometric landmarks: part 1-comparisons between the latest deep-learning methods YOLOV3 and SSD | Park et al.[39] | Angle Orthodontist | 2019 | 114 | 19 | Article |
| Automated identification of cephalometric landmarks: part 2- might it be better than human? | Hwang et al.[40] | Angle Orthodontist | 2020 | 108 | 21.6 | Article |
| Artificial intelligence in orthodontics evaluation of a fully automated cephalometric analysis using a customized convolutional neural network | Kunz et al.[41] | Journal of Orofacial Orthopedics | 2020 | 106 | 21.2 | Article |
| 3D tooth segmentation and labeling using deep convolutional neural networks | Xu et al.[42] | IEEE Transactions on Visualization and Computer Graphics | 2019 | 101 | 16.83 | Article |
| Artificial neural network modeling for deciding if extractions are necessary prior to orthodontic treatment | Xie et al.[43] | Angle Orthodontist | 2010 | 92 | 6.13 | Article |
| Automated skeletal classification with lateral cephalometry based on artificial intelligence | Yu et al.[44] | Journal of Dental Research | 2020 | 87 | 17.4 | Article |
| A fully automatic AI system for tooth and alveolar bone segmentation from cone-beam CT images | Cui et al.[45] | Nature Communications | 2022 | 86 | 28.67 | Article |
| Automated cephalometric landmark detection with confidence regions using Bayesian convolutional neural networks | Lee et al.[46] | BMC Oral Health | 2020 | 80 | 16 | Article |
| Deep geodesic learning for segmentation and anatomical landmarking | Torosdagli et al.[47] | IEEE Transactions on Medical Imaging | 2019 | 80 | 13.33 | Article |
| Applying artificial intelligence to assess the impact of orthognathic treatment on facial attractiveness and estimated age | Patcas et al.[48] | International Journal of Oral and Maxillofacial Surgery | 2019 | 78 | 13 | Article |
| Impact of artificial intelligence on dental education: a review and guide for curriculum update | Thurzo et al.[49] | Education Sciences | 2023 | 77 | 38.5 | Review |
| Towards a fully automated diagnostic system for orthodontic treatment in dentistry | Murata et al.[50] | 2017 IEEE 13th International Conference on E-Science (E-Science) | 2017 | 77 | 9.63 | Proceedings Paper |
| Bone age assessment with various machine learning techniques: a systematic literature review and meta-analysis | Dallora et al.[51] | PloS One | 2019 | 76 | 12.67 | Review |
| Deep multi-scale mesh feature learning for automated labeling of raw dental surfaces from 3D intraoral scanners | Lian et al.[52] | IEEE Transactions on Medical Imaging | 2020 | 74 | 14.8 | Article |
| Usage and comparison of artificial intelligence algorithms for determination of growth and development by cervical vertebrae stages in orthodontics | Kök et al.[53] | Progress in Orthodontics | 2019 | 74 | 12.33 | Article |
| Automatic classification and segmentation of teeth on 3D dental model using hierarchical deep learning networks | Tian et al[5]4 | IEEE Access | 2019 | 74 | 12.33 | Article |
| Orthodontic treatment planning based on artificial neural networks | Li et al.[55] | Scientific Reports | 2019 | 73 | 12.17 | Article |
| TSegNet: an efficient and accurate tooth segmentation network on 3D dental model | Cui et al.[56] | Medical Image Analysis | 2021 | 72 | 18 | Article |

CNNs: Convolutional neural networks, YOLOV3: You only look once version 3, SSD: Solid state disk, AI: Artificial intelligence, CT: Computed tomography

the co-occurrence network of keywords used on this topic, as well as a word cloud of keywords. Additionally, we utilized a longitudinal visual associated with the keywords in **Figure 9**, as evaluating trend topics related to keywords is crucial in identifying potential research gaps or areas for future exploration.

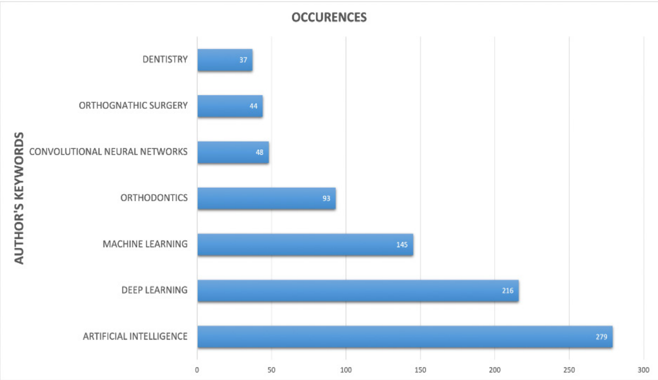


**Figure 7.** The most commonly utilized keywords

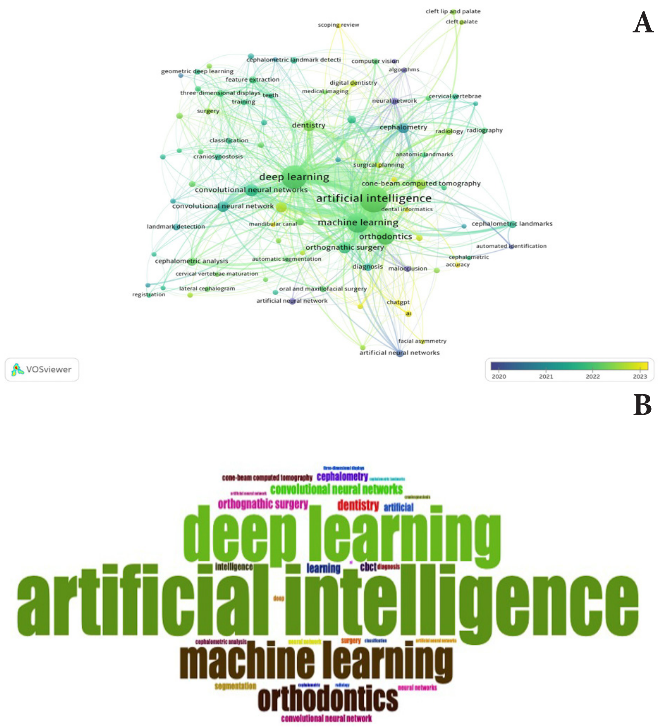


**Figure 8.** A) The co-occurrence network map of keywords B) The word cloud of keywords

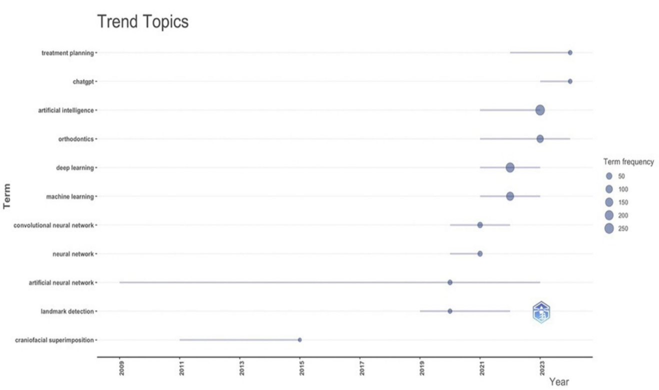


**Figure 9.** A longitudinal visualization of keyword trends

## Thematic Map

Thematic mapping, shown in **Figure 10**, identified the main conceptual clusters within the literature. These clusters reflect core research areas such as diagnostic imaging, treatment planning, and cephalometric analysis.

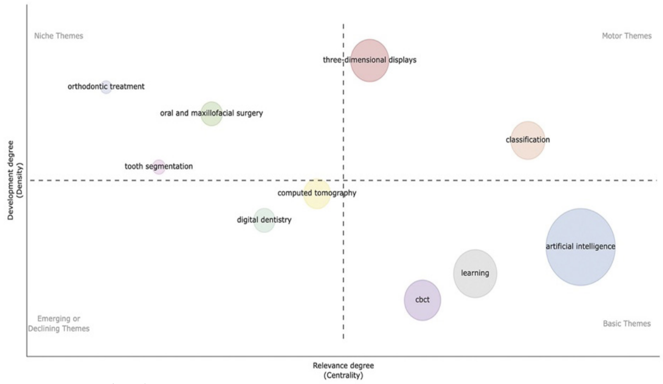


**Figure 10.** The thematic map

## DISCUSSION

This bibliometric study provides meaningful insights into the expanding role of AI in orthodontics and orthognathic surgery. The marked increase in AI-related publications after 2017 suggests a shift from theoretical exploration to more mature, clinically focused applications. AI systems-particularly those using machine learning algorithms-have been employed in various tasks such as automatic cephalometric analysis, dental segmentation, and three-dimensional (3D) imaging.[22] In addition, they support automated anatomical landmark detection and growth and development assessment,[23] as well as evaluations of upper airway obstruction, decision-making for extractions, remote consultations, and clinical documentation.[24] More recent applications involve treatment outcome prediction, including postoperative facial profile and symmetry, determination of surgical necessity, perioperative blood loss estimation, and surgical simulation.[25]

By evaluating the publication patterns, research focuses, and methodological approaches in the literature, this bibliometric study contributes to a better understanding of how AI technologies are shaping clinical workflows and advancing treatment planning in orthodontics and orthognathic surgery.

This bibliometric analysis reveals notable shifts in the trajectory of research on AI in orthodontics and orthognathic surgery. Between 1991 and 2016, the relatively modest growth in publications suggests that AI applications in these fields were largely in an exploratory phase. However, the surge in research output from 2017 onward signals a transition toward clinically oriented and evidence-driven investigations. This increased scholarly interest parallels broader advancements in AI capabilities, including improvements in diagnostic precision, treatment simulation, and prognosis prediction.[26-28] These developments underscore AI's growing status as a supportive tool in dental practice, capable of transforming traditional workflows and enhancing clinical efficiency.

Several factors likely contributed to this post-2017 escalation in publications. First, technological innovations-particularly in deep learning and big data processing-have made AI tools more accessible and adaptable for dental professionals.[29] Second, the increasing availability of large-scale annotated datasets and high-performance computing has enabled the development of more sophisticated and generalizable models. Finally, the widespread integration of AI across other medical disciplines may have encouraged researchers in dentistry to explore its utility in orthodontic and surgical contexts.

The citation analysis reinforces the scientific impact of this body of work. With a total of 10,381 citations and an average of 12.33 citations per article, the literature demonstrates both depth and influence. Notably, 6,029 of these were non-self-citations, suggesting that AI-focused studies are being actively referenced by independent researchers, further affirming their contribution to the advancement of knowledge and practice.[30] These findings reflect a growing consensus within the dental community regarding the value of AI not only in research but also in real-world clinical integration.

The distribution of publications from 1991 to 2024 in the field of AI in orthodontics and orthognathic surgery highlights important geographical and institutional patterns. Contributions from 73 countries demonstrate the global reach and growing international relevance of AI in dental research. Among them, China, the United States, and South Korea stand out as the most prolific, publishing 200, 183, and 121 articles, respectively. This productivity reflects not only their scientific infrastructure but also strategic investments in AI-driven healthcare innovation. China's leadership may be attributed to national policy initiatives, public-private collaboration networks, and a strong emphasis on digital transformation in healthcare.[31] The United States has similarly benefited from robust research ecosystems and sustained federal and private funding. South Korea's position reinforces its commitment to integrating AI technologies across healthcare sectors through coordinated efforts among academia, government, and industry.

Institutional analysis reveals that Seoul National University is the most productive institution, with 47 publications. It is followed by Peking University (36 publications) and the University of North Carolina (34 publications). These institutions have distinguished themselves not only through output but also through influence, as seen in high citation counts-807 for Seoul National University and 567 for the Catholic University of Leuven. The prominence of these institutions suggests their central role in shaping the research agenda and advancing methodological innovations in the use of AI within orthodontics and orthognathic surgery. However, the findings also highlight limited cross-institutional collaboration, which represents an opportunity for greater knowledge exchange and interdisciplinary synergy on a global scale.

Among the most influential studies identified in this bibliometric analysis, several have significantly shaped the application of AI in orthodontics and orthognathic surgery. One of the top-cited works by Spampinato et al.[32] applied deep learning techniques for skeletal bone age assessment in radiographic images. The study demonstrated that AI could improve diagnostic accuracy and reproducibility in growth evaluation, a key consideration in pediatric orthodontics.

Another important contribution is the scoping review by Schwendicke et al.,[33] which synthesized research on convolutional neural networks (CNNs) for dental image diagnostics across multiple domains, including endodontics, periodontology, and radiology. The review highlighted the versatility of CNNs and their growing role in image interpretation and clinical decision-making.

Additionally, the work by Payer et al.[34] introduced a heatmap-based CNN architecture for anatomical landmark localization using small datasets. This approach demonstrated strong performance in cephalometric applications, suggesting that AI can achieve high accuracy even under data constraints-a common challenge in medical image analysis.

Several high-impact studies identified in this analysis further illustrate the expanding scope of AI applications in dentistry and orthodontics. Khanagar et al.[35] conducted a comprehensive systematic review of AI technologies in dental practice, highlighting their use in diagnosis, treatment planning, and outcome prediction across diverse specialties. This study emphasized that AI has become a central component of clinical decision support systems, particularly due to its accuracy and reproducibility.

Arık et al.[36] explored the use of deep CNNs for fully automated cephalometric analysis. Their findings underscore the utility of CNNs in identifying anatomical landmarks and performing quantitative assessments of craniofacial structures, a crucial task in both orthodontics and orthognathic surgery.

In another systematic review, Hung et al.[37] examined AI applications in dental and maxillofacial radiology. Their work summarized evidence from 50 studies covering tasks such as osteoporosis detection, cephalometric landmark localization, and the segmentation of cysts and tumors. The review reinforced AI's potential to streamline diagnostic workflows and enhance radiological precision.

Further contributions to the field underscore the evolving precision and clinical utility of AI-driven diagnostic tools. Fourcade and Khonsari[38] emphasized the transformative role of deep learning in medical imaging, presenting it as a "third eye" that enhances visual diagnosis, particularly in complex fields such as radiology and pathology. Their work highlights how CNNs can augment diagnostic accuracy and support clinicians in visually intensive tasks.

In the domain of cephalometric analysis, Park et al.[39] compared two advanced object detection algorithms, YOLOv3 and SSD, for automated landmark identification. Their study demonstrated that both models could perform cephalometric landmark detection with a high degree of accuracy, offering a fast and reproducible alternative to manual tracing. Expanding on this, Hwang et al.[40] evaluated whether these AI systems could outperform human experts. Their results showed that the YOLOv3 model achieved performance levels comparable to experienced clinicians, suggesting AI's strong potential as a reliable assistant in orthodontic diagnostics.

Moreover, Kunz et al.[41] developed a fully automated cephalometric analysis tool using a customized CNN architecture. The model's performance was benchmarked against that of human specialists, revealing comparable levels of precision. Their findings support the feasibility of integrating AI-driven tools into routine orthodontic workflows, offering efficiency gains without compromising diagnostic quality.

Together, these studies illustrate the significant strides made in AI-assisted imaging, particularly in cephalometric assessment-an area that demands high anatomical precision. As accuracy, reliability, and speed continue to improve, AI systems are poised to become indispensable components of modern orthodontic and surgical planning processes.

In evaluating the dissemination of AI-related research within orthodontics and orthognathic surgery, journal analysis reveals key publication and citation trends. Among these, Medical Image Analysis emerged as the most highly cited journal, amassing 647 citations from only 8 publications. This suggests a high citation density and reflects the journal's strong influence, particularly in areas such as medical imaging and AI-based diagnostic systems. In contrast, Scientific Reports was the most prolific journal by output, publishing 42 articles on the topic. While its total number of publications is higher, the average citations per article are notably lower compared to medical image analysis, indicating that while scientific reports plays a critical role in quantity, medical image analysis holds a greater qualitative impact in terms of scholarly recognition. These findings highlight the importance of both high-volume and high-impact publication venues in shaping the discourse around AI in dental specialties.

**Figure 9** illustrates the longitudinal evolution of thematic trends in AI research within orthodontics and orthognathic surgery, offering insight into how publication focus has shifted alongside technological developments. Between 2009 and 2015, dominant keywords such as "artificial neural network" and "craniofacial superimposition" reflect early foundational efforts focused on digital image processing and craniofacial mapping-paving the way for AI's entrance into dental diagnostics.

From 2016 to 2020, the emergence of terms like "deep learning," "convolutional neural network," and "landmark detection" highlights a shift toward more advanced computational methods. This period coincides with major breakthroughs in CNN architectures, enabling automated and precise identification of cephalometric landmarks-crucial for treatment planning and outcome assessment in orthodontics.

Since 2021, the focus has increasingly turned to clinical applicability. Keywords such as "treatment planning," "artificial intelligence," and "orthodontics" suggest growing efforts to translate algorithmic models into real-world workflows. The rise of "transfer learning" underscores efforts to overcome limitations in labeled datasets by adapting pre-trained models to dental tasks. Notably, the appearance of "ChatGPT" in 2023 signals a nascent but rapidly growing interest in conversational AI, particularly for enhancing patient communication, education, and clinical decision support.

This longitudinal keyword analysis also uncovers emerging research frontiers and critical gaps. One particularly promising area is predictive modeling, reflected by recurring terms such as "deep learning" and "treatment planning." These applications highlight AI's growing role in forecasting clinical outcomes and tailoring personalized treatment strategies in orthodontics. However, despite its promise, predictive modeling remains largely theoretical. Few studies have validated these models in real-world clinical settings, limiting their current applicability. Expanding external validation efforts across diverse patient populations is essential to ensure their generalizability and clinical relevance.

An equally important observation is the relative underrepresentation of orthognathic surgical planning in AI literature. The lack of domain-specific keywords or clusters points to a significant gap in research. Given the complexity and irreversible nature of orthognathic procedures, AI-based simulation tools and outcome prediction models could offer valuable decision support. Future studies should prioritize this area to balance the orthodontics-dominant focus observed in current literature.

Finally, the parallel rise of key technologies-particularly CNNs and transfer learning-correlates strongly with the accelerated growth of AI research in dental specialties. These innovations have enabled automated diagnostics and robust model development even with limited datasets. Moving forward, the integration of generative AI, multimodal models, and real-time feedback systems may further enhance clinical workflows, offering not only precision but also adaptability across diagnostic and treatment contexts.

### Limitations

This study has several limitations that should be considered when interpreting the results. The bibliometric analysis was limited to the Web of Science Core Collection (WoSCC), which may have excluded relevant studies indexed in other major databases such as Scopus or PubMed. As a result, the overall representation of global research output may be incomplete. Additionally, while the article selection process was carefully conducted, the involvement of a single reviewer, as noted in the methodology, may introduce a degree of selection bias. Furthermore, the analysis relied on author affiliations and keyword metadata, which may not fully capture the nuances of interdisciplinary contributions or evolving terminologies in the field.

## CONCLUSION

This bibliometric study highlights the significant and accelerating role of AI in orthodontics and orthognathic surgery. Technological advancements-particularly in deep learning and transfer learning-have driven a surge in publications, especially after 2017, marking a shift from foundational research to clinical application. Orthodontics has received the bulk of AI-related attention, while orthognathic surgery remains an underrepresented but promising frontier. Institutions such as Seoul National University and high-impact journals like medical image analysis have shaped the discourse through influential contributions. Moving forward, expanding AI research into orthognathic surgical planning, improving interdisciplinary collaboration, and validating AI tools in real-world settings will be crucial. Emerging technologies such as generative AI and multimodal models offer exciting opportunities to enhance diagnosis, treatment planning, and patient care. These developments signal a paradigm shift, positioning AI as a core component of future clinical and academic practice in dental specialties.

## ETHICAL DECLARATIONS

### Ethics Committee Approval

This study is a bibliometric analysis based on publicly available scientific literature and does not involve human participants, clinical trials, patient data, or any interventions requiring ethical approval.

### Informed Consent

Since this research is a bibliometric study, it did not require informed consent.

### Referee Evaluation Process

Externally peer-reviewed.

### Conflict of Interest Statement

The authors have no conflicts of interest to declare.

### Financial Disclosure

The authors declared that this study has received no financial support.

### Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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