BIBLIOMETRIC ANALYSIS OF FRACTAL ANALYSIS STUDIES IN PANORAMIC RADIOGRAPHY.

Abstract:

This study presents a bibliometric analysis of fractal analysis studies in panoramic radiographs. In this context, 226 articles published between 1995 and 2025 in the Web of Science Core Collection database were analyzed. The findings indicate a marked increase in scientific publications after 2019. Keyword and thematic map analyses reveal that fractal analysis and panoramic radiography are positioned within the basic themes, indicating their central role in the literature. In conclusion, this field represents an increasingly important research area with considerable potential for further development.

Key words: Fractal analysis,Panoramic radiography,Bibliometric analysis,Fractal dimension, Trabecular bone,Osteoporosis.

.....

Introduction: Fractal analysis is an analytical method used to evaluate complex body structures. The resulting number is called a fractal dimension (1, 2). The term "fractal" has been used to describe objects that resemble each other when viewed at different scales, employing an approach different from standard geometry. Fractal analysis was first explored by researchers in the 1970s. Over time, this method has been used to study complex geometric structures. Fractal analysis evaluates structures that show approximate self-similarity across different scales rather than true infinite repetition (2-4). This method, used in evaluating geometric structures, has also begun to be used in dentistry to examine the structure of bone trabeculae. Fractal analysis can evaluate bone trabeculae from digital radiographs. Although trabecular bone is not a perfect fractal structure, it exhibits fractal-like properties that allow quantitative analysis using fractal methods. With the widespread use of fractal analysis in dentistry, studies measuring bone density have utilized fractal analysis to provide numerical data on the trabecular evaluation of bone (2, 5).

Panoramic radiography is an imaging method in dentistry that allows examination of both jaws, teeth, surrounding anatomical structures, and condyles in a single image. It is routinely used in dentistry (6, 7). Panoramic radiography is also a very suitable method for examining the complexity of trabeculae in the bone, and therefore the bone quality, through fractal analysis (8). For this reason, bone quality has been examined in many studies using fractal analysis in panoramic radiographs (2, 9, 10). Fractal analysis in panoramic radiographs is a currently studied topic, and there is a knowledge gap regarding the evolution of research in this field, key research themes, and contributing institutions or individuals. Acquiring this information will summarize the history of fractal analysis on panoramic radiographs and shed light on its future. Bibliometric analysis is a method currently used for this purpose. Through bibliometric analysis, research patterns in the literature can be revealed, and indicators such as Annual Scientific Output, Average Citations per Year, and Most Relevant Sources can be analyzed. (11, 12). The aim of

this study is to examine the citation patterns and trends of fractal analysis studies performed on panoramic radiographs, to analyze the literature bibliometrically, and to make predictions about the future by examining the impact, thematic structure, and evolution of current research on the subject.

Materials and Methods: This research is designed as a bibliometric analysis focusing on studies related to fractal analysis on panoramic radiography. The aim of our study is to examine the impact, thematic structure, and evolution of fractal analysis-based approaches on panoramic radiography, which are frequently used in dentistry, and to make predictions about the future. Due to the nature of bibliometric analysis, no human or animal subjects were included in our study, therefore ethical approval was not obtained. Our study was conducted using the Web of Science Core Collection (WoSCC) database to identify studies in the field of dentistry that apply fractal analysis on panoramic radiography. In WoSCC, the advanced search option was selected and the command ("fractal analysis" OR "fractal dimension") AND ("panoramic" OR orthopantomogram OR OPG) was entered. Only articles were evaluated in our analysis; editorial letters, studies not related to fractal analysis in panoramic radiography, conference proceedings, and non-English publications were excluded to ensure the accuracy of the dataset.

Bibliometric analyses were performed using the bibliometrix package (version 5.3.0) via R (version 4.6.0) and the web interface Biblioshiny. Annual Scientific Production, Average Citations per Year, and Most Relevant Sources were used as descriptive indicators. In addition to traditional bibliometric indicators, network-based clustering approaches were used to examine the conceptual structure of the literature. Keyword co-occurrence analysis was performed using author-provided keywords to investigate the conceptual structure of the literature. A network-based clustering algorithm was applied to identify dominant research themes associated with fractal analysis and panoramic radiography. In the resulting network, node size represents keyword frequency, edge thickness represents concurrency strength, and colors represent different thematic clusters.Thematic map analysis was performed to evaluate the thematic structure of the literature. This analysis identified engine themes, core themes, emerging themes, and niche themes in the research area.

Results: The bibliometric analysis in our study included 226 fractal analysis studies on panoramic radiography indexed in the Web of Science database from 1995 to 2025. Scientific publications focusing on fractal analysis in panoramic radiography remained relatively low until 2019 and showed an increasing trend thereafter. 2025 appears to have the highest number of scientific publications so far (Figure 1).

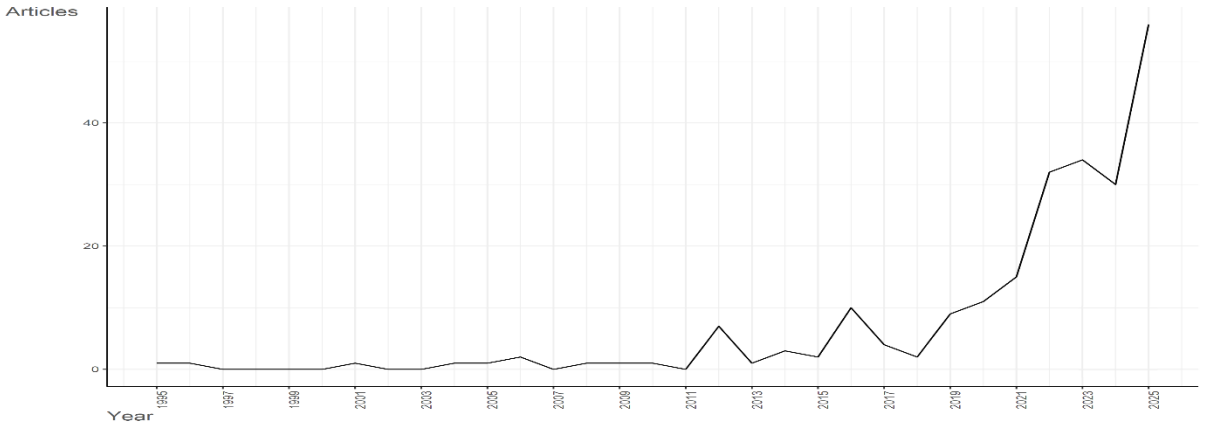

Figure 1. Distribution of scientific output on fractal analysis in panoramic radiography by year (1995–2025).

The decrease in the average number of citations for publications on fractal analysis on panoramic radiography in recent years may be due to the fact that new publications have not yet reached a sufficient citation period (Figure 2).

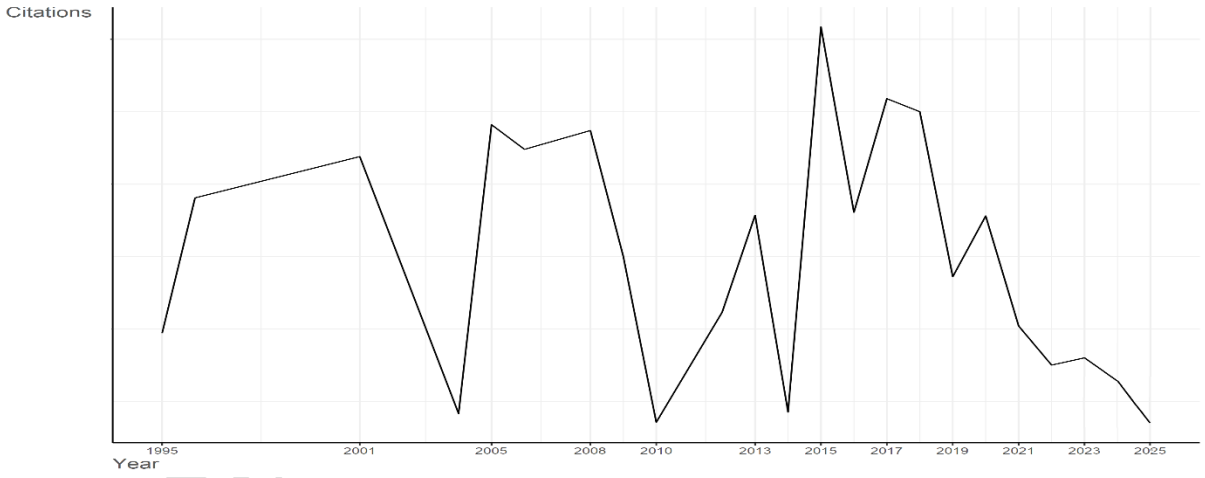

Figure 2. Distribution of average citation counts over the years for studies related to fractal analysis on panoramic radiography.

When examining the journals with the most publications on fractal analysis in panoramic radiography, “Oral Radiology”, “BMC Oral Health”, and “Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology” were identified as the journals with the most publications, and these journals are given in Figure 3.

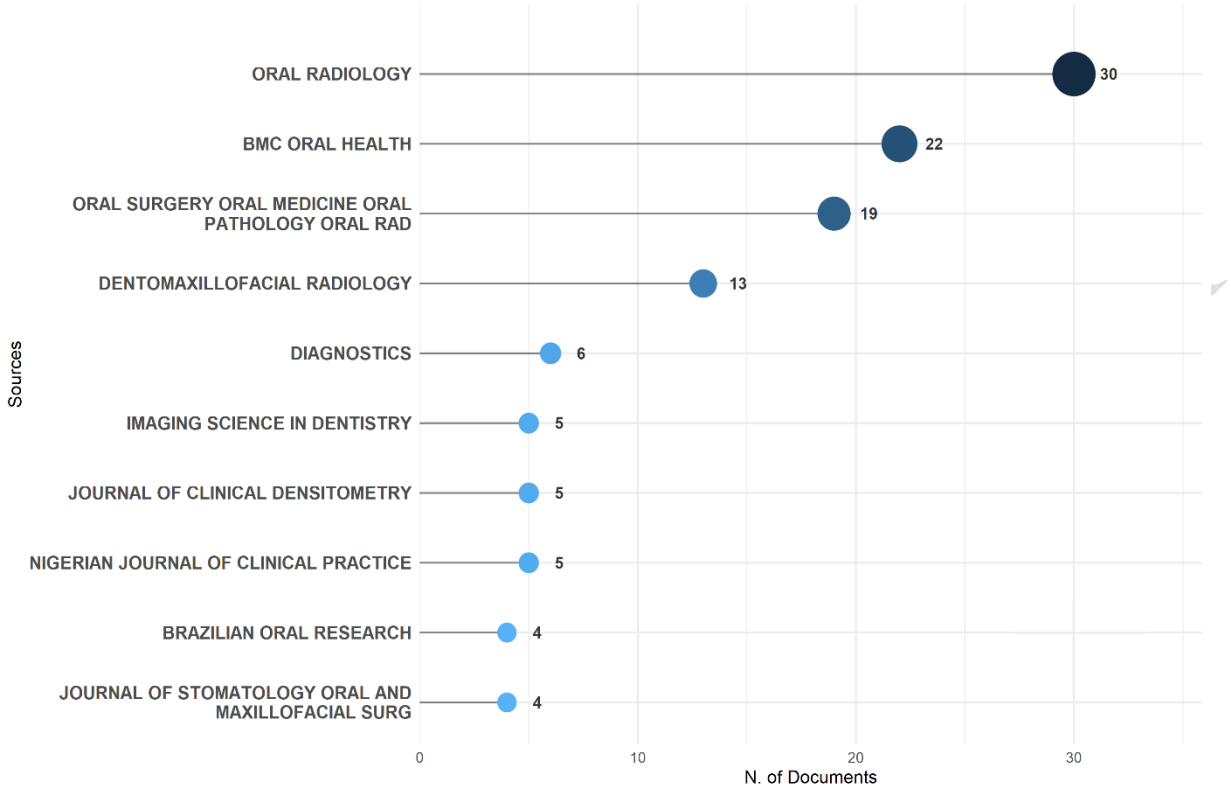

Figure 3. Distribution of journals with the most publications in the field of fractal analysis on panoramic radiography.

Keyword co-occurrence analysis, conducted to understand the conceptual structure of the literature, identified several different clusters. These included fractal analysis, panoramic radiography, mandible, and trabecular bone (Figure 4).

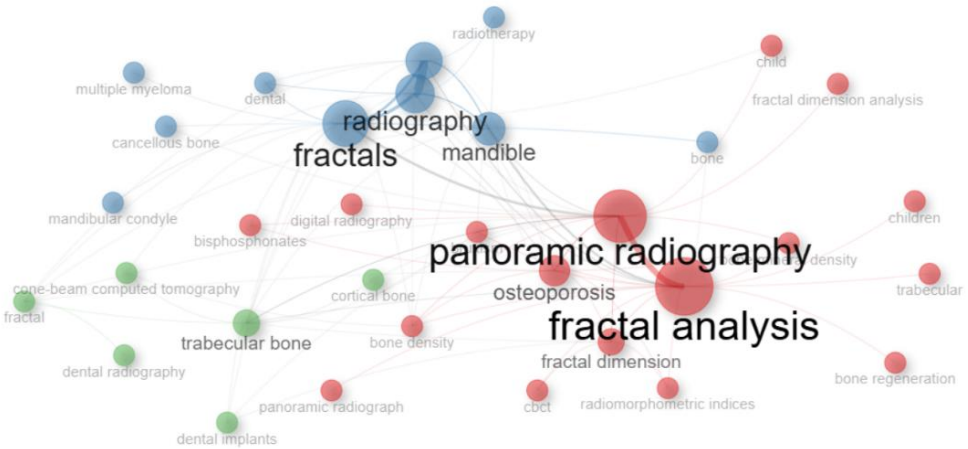

Figure 4. Keyword co-occurrence network related to panoramic radiography and fractal analysis.

Thematic map analysis revealed that panoramic radiography, osteoporosis, and fractal analysis are located within the basic themes, indicating that these topics are fundamental to the field and widely studied, yet still require further development. These themes are characterized by high centrality but relatively low development. The terms “fractal” and “children” are located near the motor themes region, indicating that they are well-developed and play a driving role in the field. Hypodontia and ectodermal dysplasia are located within the niche themes, reflecting well-developed but specialized research areas. Overall, these findings indicate that the field is supported by fundamental themes while continuing to evolve through specialized and emerging research areas (Figure 5).

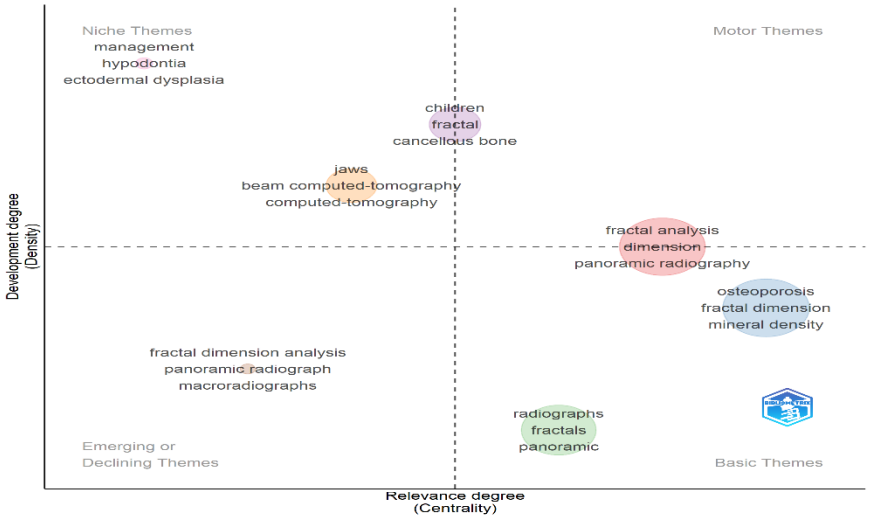

Figure 5. Thematic map analysis of fractal analysis studies on panoramic radiography.

Discussion: This study examines the bibliometric structure of the dental literature related to fractal analysis on panoramic radiography. It reveals significant data regarding publication trends, leading journals, citation patterns, thematic development, and conceptual structure related to this topic.According to the data in our study, the increase in the number of scientific studies on this subject in recent years indicates a growing interest in fractal analysis on panoramic radiography, which is a non-invasive imaging method. The fact that panoramic imaging is frequently used by clinicians in routine practice due to its advantages such as low cost, easy accessibility, and relatively low radiation dose indicates that it is a suitable method for fractal analysis studies(13-15). The increasing number of publications, particularly in recent years, suggests that this field remains an active area of research.

When the average number of citations is examined, it is found that older publications have a higher number of citations compared to publications in recent years. This is likely due to the citation window effect rather than a decrease in interest in the subject. However, the reason

for this decrease in citation numbers in recent years will become clearer in the coming years.When considering the most prolific journals in this field, such as Oral Radiology and BMC Oral Health, the focus of their publications on imaging and jaw structure analysis in dentistry has led to a greater publication rate on fractal analysis in these journals. This demonstrates that fractal analysis is not merely a mathematical calculation, but is also used by clinicians as a diagnostic method (16-18).When the main research area was examined using keyword analysis, it was observed that the terms fractal analysis, panoramic radiograph, mandible, and trabecular bone were frequently used. It is understood that fractal analysis plays an important role in evaluating osteoporosis-related changes in bone trabeculae due to causes such as temporomandibular joint diseases and systemic diseases (19-21). The frequent performance of fractal analysis studies on the mandible may be related to the clearer visualization of this region in panoramic radiography (22).

Thematic map analysis revealed that panoramic radiography, osteoporosis, and fractal analysis are positioned within the basic themes, indicating that these topics are fundamental to the field and widely studied, yet still require further development. The terms “fractal” and “children” are located near the motor themes region, suggesting that these areas are both well-developed and play a driving role in current research. In contrast, hypodontia and ectodermal dysplasia are situated within the niche themes, reflecting well-developed but more specialized and limited areas of investigation. Overall, these findings demonstrate that while the field is supported by strong foundational themes, it continues to evolve through emerging and specialized research directions.

This study has several limitations. First, the analysis was restricted to the WoSCC database, which may have excluded relevant studies indexed in other databases. Second, only English-language publications were included, potentially introducing language bias. Additionally, citation-based analyses may be influenced by citation bias and the time-dependent nature of citation accumulation.

Conclusion: Research on fractal analysis in panoramic radiography has increased significantly in recent years. This topic is increasingly recognized as an important area of research. The potential for applying fractal analysis in panoramic radiographs in osteoporosis assessment and pediatric patient groups is particularly interesting. Future research encompassing larger databases will contribute to the scientific advancement of this field.

References

1. Güngör E, Yildirim D, Çevik R. Evaluation of osteoporosis in jaw bones using cone beam CT and dual-energy X-ray absorptiometry. Journal of oral science. 2016;58(2):185-94.
2. Kato CN, Barra SG, Tavares NP, Amaral TM, Brasileiro CB, Mesquita RA, et al. Use of fractal analysis in dental images: a systematic review. Dentomaxillofacial Radiology. 2020;49(2):20180457.

3. Güleç M, Taşsöker M, Şener S. Fractal Analysis in Medicine and Dentistry. INTERNATIONAL ARCHIVES OF DENTAL SCIENCES. 2019;40(1):17-31.
4. Zhou W, Cao Y, Zhao H, Li Z, Feng P, Feng F. Fractal analysis on surface topography of thin films: A review. Fractal and fractional. 2022;6(3):135.
5. Epsilawati L, Wulansari DP, Asykarie INA. Fractal dimension approach for quantitative analysis radiograph in periapical inflammation: A systematic review. Acta Medica Philippina. 2025;59(3):125.
6. Nur S. Panoramik Radyografi. Radyasyon Uygulamaları ve Radyasyondan Korunma. 2024:41.
7. Ertuğrul ZM, Şendişçi R, Alkış HT. Diş Hekimlerinin Panoramik Radyografi Üzerinde Anatomik Noktaları Değerlendirmedeki Bilgi Düzeylerinin Araştırılması. Akdeniz Diş Hekimliği Dergisi. 2023;2(1):29-33.
8. Eninanç İ, Yeler DY, Çınar Z. Investigation of mandibular fractal dimension on digital panoramic radiographs in bruxist individuals. Oral surgery, oral medicine, oral pathology and oral radiology. 2021;131(5):600-9.
9. Colaco LSL, Chhaparwal Y, Patil V, Smriti K. Decoding dental images: a comprehensive review of fractal analysis. BDJ open. 2025;11(1):74.
10. Kumar SS, Nagi R, Chacko R, Khan J. The effectiveness of fractal analysis in diagnosing temporomandibular joint disorders: a systematic review of clinical studies. Oral Radiology. 2025;41(2):153-68.
11. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. Journal of business research. 2021;133:285-96.
12. Passas I. Bibliometric analysis: the main steps. Encyclopedia. 2024;4(2).
13. Gledhill D, Tian GY, Taylor D, Clarke D. Panoramic imaging—a review. Computers & Graphics. 2003;27(3):435-45.
14. Demiralp KÖ, Kurşun-Çakmak EŞ, Bayrak S, Akbulut N, Atakan C, Orhan K. Trabecular structure designation using fractal analysis technique on panoramic radiographs of patients with bisphosphonate intake: a preliminary study. Oral Radiology. 2019;35(1):23-8.
15. Koca H, Ergün S, Güneri P, Boyacıoglu H. Evaluation of trabecular bone healing by fractal analysis and digital subtraction radiography on digitized panoramic radiographs: a preliminary study. Oral Radiology. 2010;26(1):1-8.
16. Ozturk EMA, Artas A. Evaluation of bone mineral changes in panoramic radiographs of hypothyroid and hyperthyroid patients using fractal dimension analysis. Journal of Clinical Densitometry. 2024;27(1):101443.
17. İncebeyaz B, Eberliköse H, Öztürk C, Karasu HA. Fractal and Morphometric Analysis of Mandibular Bone in Individuals With Bruxism: A Retrospective Cross-Sectional Study Using Panoramic Radiographs. Journal of Oral Rehabilitation. 2026.
18. Yavuz E, Yardimci Tunc S, Tercanli H. Fractal analysis of mandibular condyles in patients with temporomandibular disorder. Journal of Imaging Informatics in Medicine. 2025:1-10.
19. Yeşiltepe S, Yılmaz AB, Kurtuldu E, Sarıca İ. Fractal analysis of temporomandibular joint trabecular bone structure in patients with rheumatoid arthritis on cone beam computed tomography images. Meandros Medical and Dental Journal. 2018;19(4):345-51.
20. Canturk F, Miloglu O, Gumussoy I, Dayanan R. The investigation of radiographic findings of mandibles on panoramic radiographs of patients with primary hyperparathyroidism using fractal analysis. The Eurasian Journal of Medicine. 2021;53(3):185.

21. Mulyani SWM, Savitri Y, Asymal A, Saputra D, Laksanti PAM, Ibrahim N. Assessing Osteoporosis Risk on Panoramic Radiography through Fractal Dimension Analysis of Mandibular Condyles in Postmenopausal Women. European Journal of Dentistry. 2026.
22. Sevimay MA, Gürsu M, Çege MA, Çankal DA, Akarslan Z, Çetiner S. Fractal dimension analysis of mandibular trabecular bone in patients receiving antiresorptive therapy for osteoporosis and oncologic conditions. Diagnostics. 2025;15(6):748.