



# Digital behavior management in pediatric dentistry: a bibliometric analysis (2000–2025)

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## Abstract

This study aimed to analyze global scientific trends in digital behavior management strategies in pediatric dentistry between 2000 and 2025. A bibliometric analysis was conducted using the Web of Science Core Collection, including English-language articles and reviews published between 2000 and 2025. Performance indicators, collaboration networks, Bradford's Law, Lotka's Law, keyword co-occurrence, and thematic mapping were evaluated using Bibliometrix and VOSviewer. A total of 150 publications were identified, with scientific output increasing markedly after 2018. Audiovisual distraction, anxiety, and pain emerged as central themes, while virtual reality was identified as a motor theme with high centrality and density. India, the United States, and Saudi Arabia were the most productive countries. Research output was concentrated in leading pediatric dentistry journals, and author productivity suggested a fragmented but growing field. Overall, digital behavior management research has expanded substantially, with immersive technologies such as virtual reality becoming increasingly prominent. Future multicenter collaborations and standardized outcome measures may facilitate clinical translation.

**Keywords** Pediatric dentistry · Behavior management · Dental anxiety · Virtual reality · Audiovisual distraction · Digital health · Bibliometric analysis · Science mapping

## 1 Introduction

Behavior management has long been a fundamental aspect of pediatric dentistry. Building trust, alleviating fear and fostering cooperation are crucial for providing safe and effective dental care to children (American Academy of Pediatric Dentistry 2024; Akşit-Bıçak et al. 2024). For many years, traditional non-pharmacological techniques such as Tell–Show–Do have been widely used as standard behavioral guidance methods to reduce uncertainty and encourage adaptive coping during dental visits (American Academy of Pediatric Dentistry 2024). Despite the clinical importance

of these conventional behavioral strategies, dental fear and anxiety continue to be common and have significant clinical impacts in pediatric populations (Grisolia et al. 2021; Sun et al. 2024). Childhood dental anxiety has consistently been associated with avoidance of dental care, increased perception of pain, poorer cooperation during treatment and negative attitudes toward oral health that can persist into adolescence and adulthood (Grisolia et al. 2021; Hegazi et al. 2024). Recent evidence also indicates that dental fear and anxiety are linked to broader oral health outcomes and psychosocial factors, including family-related influences and quality-of-life measures (Besiroglu-Turgut et al. 2024; Hegazi et al. 2024). Therefore, pediatric dentists are increasingly exploring additional non-pharmacological methods to enhance comfort and promote positive treatment experiences beyond traditional chairside communication (Dhaliwal et al. 2025).

Over the past twenty years, rapid technological advances have transformed many aspects of healthcare and have begun to influence behavior management in pediatric dentistry. Digital and technology-supported interventions—such as audiovisual distraction, immersive virtual reality

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(VR), gamified preparation tools, biofeedback-supported relaxation, and mobile health applications—have emerged as promising methods to reduce anxiety and pain-related distress during dental procedures (Prado et al. 2019; Padminee et al. 2022; Del Carmen et al. 2023; Karkoutly et al. 2024; Dhaliwal et al. 2025). Audiovisual distraction has been one of the earliest and most extensively studied techniques, with controlled trials and systematic reviews demonstrating positive effects on fear and anxiety during pediatric dental care (Prado et al. 2019). More recently, immersive VR has gained increasing attention due to its capacity to provide multisensory engagement, capture attention, and divert focus from threatening stimuli within the dental environment (Jamil et al. 2023; Truşculescu et al. 2025; Aly et al. 2025; Kasımoğlu et al. 2025). In parallel, gamified “serious games” and smartphone-based preparatory applications have been investigated as experiential learning tools to improve cooperation and reduce anticipatory anxiety (Zhu et al. 2020; Del Carmen et al. 2023; Karkoutly et al. 2024), while biofeedback-supported relaxation has been proposed as a physiologically targeted method to modulate anxiety responses during procedures such as local anesthesia administration (Padminee et al. 2022). This apparent transition from conventional behavior guidance techniques to digitally supported interventions reflects broader digitalization trends in healthcare and pediatric patient engagement. However, although clinical trials and systematic reviews have evaluated the effectiveness of specific techniques (Prado et al. 2019; Dhaliwal et al. 2025), the overall scientific landscape of digital behavior management in pediatric dentistry has not yet been comprehensively mapped. A structured understanding of publication growth, intellectual foundations, thematic development and international collaboration patterns is essential to identify research gaps, minimise redundancy and guide the next generation of clinically meaningful and methodologically robust studies.

Bibliometric analysis provides a quantitative framework to examine the intellectual structure and evolution of a research field by assessing publication output, citation patterns, source dispersion, collaboration networks, and thematic clustering. Through science-mapping approaches and network analysis, bibliometric methods enable visualization of scientific growth and conceptual transitions over time (Aria and Cuccurullo 2017; van Eck and Waltman 2010). When transparently reported, such analyses can complement evidence syntheses by clarifying how, where and by whom knowledge is generated and how research topics consolidate into mature, emerging or niche thematic domains (Aria and Cuccurullo 2017; Page et al. 2021).

Therefore, the aim of the present study was to conduct a comprehensive bibliometric analysis of digital behavior management strategies in paediatric dentistry between 2000

and 2025. Specifically, this study aimed to (i) analyse temporal publication trends, (ii) identify core journals and productive countries, (iii) explore collaboration networks and (iv) map thematic evolution from traditional approaches to immersive digital technologies.

## 2 Materials and methods

### 2.1 Study design

This study was designed as a retrospective, descriptive bibliometric analysis to systematically map the scientific landscape of digital behavior management strategies in pediatric dentistry. The investigation focused on evaluating global research productivity, collaboration structures, intellectual organization, and thematic evolution between 2000 and 2025. The methodological framework adhered to established bibliometric principles and was reported in accordance with the PRISMA 2020 statement, adapted for bibliometric studies.

### 2.2 Data source and search strategy

A comprehensive literature search was conducted in the Web of Science Core Collection (WoSCC) database. WoS was selected due to its standardized indexing system, citation tracking capabilities, and suitability for advanced bibliometric mapping. The search was performed in February 2026 and included publications indexed between January 2000 and December 2025. The query was applied to the Topic field (TS), encompassing title, abstract, author keywords, and Keywords Plus.

The final Boolean search strategy was:

TS=((“pediatric dentistry” OR “paediatric dentistry” OR pedodontic\* OR “child dental\*” OR “children dentistry”) AND (“virtual reality” OR VR OR “audio-visual distraction” OR audiovisual OR gamification OR “serious game\*” OR biofeedback OR “digital intervention\*” OR “mobile application\*” OR “mobile app\*” OR “immersive technology\*”)) NOT TS=(sedation OR “general anesthesia” OR “nitrous oxide”).

The search was limited to publications between 2000 and 2025, including only articles and reviews indexed in the Science Citation Index Expanded (SCI-Expanded). Only English-language publications were included to ensure consistency in data interpretation and comparability of bibliometric indicators; however, this restriction may have introduced language bias, which is acknowledged as a limitation of the study.

The search yielded 150 records, which constituted the final dataset for bibliometric evaluation.

### 2.3 Eligibility criteria study selection process

The study selection process followed established bibliometric methodological frameworks and reporting recommendations rather than conventional systematic review guidelines. Specifically, the study design was aligned with recent guidance for bibliometric analyses, including the BIBLIO guideline and the methodological framework proposed by Donthu et al. (Donthu et al. 2021; Montazeri et al. 2023; de Oliveira Rocha et al. 2025). Structured elements were adopted to enhance the transparency and reproducibility of the selection process.

As all records were retrieved from a single database (WoSCC) using a unified search strategy, duplicate removal was not expected; however, the dataset was screened to confirm the absence of duplicate records.

#### Inclusion criteria:

1. Studies focusing on pediatric dentistry or child dental populations.
2. Investigations addressing behavior management or guidance supported by digital or technology-based interventions.
3. Original research articles and review papers indexed in WoSCC between 2000 and 2025.

#### Exclusion criteria:

1. Studies exclusively addressing pharmacological sedation without a behavioral component.
2. Studies involving only adult populations.
3. Simulation-based dental education studies without clinical patient behavior relevance.
4. Editorials, letters, conference abstracts, or non-indexed material.

All 150 records met the predefined eligibility criteria and were included in the final analysis.

### 2.4 Data extraction and preprocessing

Full records and cited references were exported in plain text format from WoSCC. Bibliographic data were converted using the Bibliometrix R-package (v4.x).

Extracted variables included:

- Publication year.
- Authors and affiliations.
- Country of origin.
- Source title.
- Author keywords (DE) and Keywords Plus (ID).

- Citation counts.
- Funding information.

Data preprocessing involved keyword harmonization to reduce semantic fragmentation (e.g., unifying “virtual reality” and “VR,” “audio-visual” and “audiovisual,” and British/American spelling variations). This standardization minimized artificial inflation of network nodes and improved clustering reliability.

### 2.5 Bibliometric and network analysis

Bibliometric analyses were conducted using Bibliometrix (Biblioshiny interface) and VOSviewer.

#### 2.5.1 Performance analysis

Descriptive performance indicators were calculated to evaluate the field’s scientific output and structural characteristics. These included annual scientific output, identification of the most productive authors, determination of the most relevant journals, analysis of the most-cited documents, and assessment of the most productive countries. Source concentration was further evaluated using Bradford’s Law to identify core journals, while author productivity distribution was analyzed using Lotka’s Law by examining the proportions of single- and multi-publication contributors.

#### 2.5.2 Science mapping and network construction

Co-authorship and co-occurrence networks were constructed using association strength normalization. Networks were visualized using the Fruchterman–Reingold layout algorithm.

The following analyses were performed:

1. **Country Collaboration Network.**
2. Evaluating international research cooperation patterns.
3. **Keyword Co-occurrence Analysis.**
4. Based primarily on Author Keywords (DE) to capture thematic structures. Minimum occurrence thresholds were applied to ensure network interpretability.
5. **Thematic Mapping.**
6. A two-dimensional strategic diagram was generated based on Callon’s centrality and density measures, classifying themes into:
  - Motor themes (high centrality, high density).
  - Basic themes (high centrality, low density).
  - Niche themes (low centrality, high density).
  - Emerging or declining themes (low centrality, low density).

## 7. Thematic Evolution Analysis.

8. Temporal segmentation was performed across three periods:

- 2000–2009.
- 2010–2017.
- 2018–2025.

This approach enabled visualization of conceptual transitions from traditional behavioral techniques toward immersive digital technologies.

### 2.5.3 Visualization and threshold parameters

Network inclusion thresholds were determined based on dataset distribution to optimize clarity and prevent over-fragmentation. Nodes with low occurrence frequency were excluded to reduce noise and enhance cluster interpretability.

All network maps were normalized using the association strength method to account for frequency bias and ensure proportional edge weighting.

## 2.6 Ethical considerations

This study analyzed publicly available bibliographic meta-data and did not involve human participants, patient data, or identifiable information. Therefore, ethical approval was not required.

## 3 Results

### 3.1 Annual scientific production

A total of 150 publications met the inclusion criteria. The temporal distribution of scientific output is presented in Fig. 1. Research activity remained limited between 2008 and 2013, with sporadic publications per year. A noticeable growth phase began after 2014, followed by a sustained upward trajectory from 2018 onward. The most pronounced increase was observed between 2021 and 2025, peaking in 2025 with the highest annual production.

This trend indicates an accelerating scholarly interest in digital and technology-assisted behavioral management approaches in pediatric dentistry over the last decade.

### 3.2 Core sources according to Bradford's law

Bradford's Law analysis identified a limited number of highly productive core journals contributing disproportionately to the literature (Fig. 2). The nucleus zone comprised leading journals such as the International Journal of Pediatric Dentistry, European Archives of Pediatric Dentistry, European Journal of Pediatric Dentistry, and the Journal of Clinical Pediatric Dentistry. These journals were identified algorithmically based on publication productivity within the dataset, rather than through subjective selection.

These core sources account for the majority of publications, while subsequent Bradford zones demonstrate progressively dispersed productivity across a larger number of

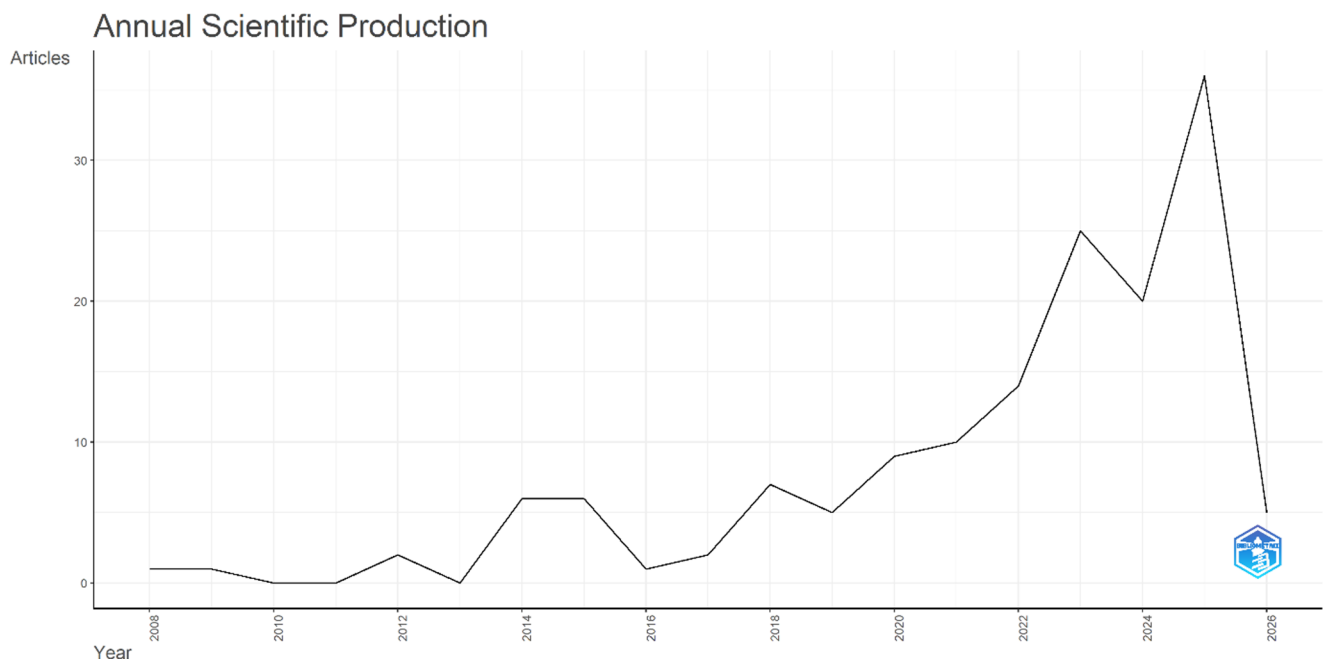


**Fig. 1** Annual scientific production. Year-by-year distribution of publications on digital/technology-assisted behavior management interventions in pediatric dentistry within the analyzed Web of Science Core Collection dataset

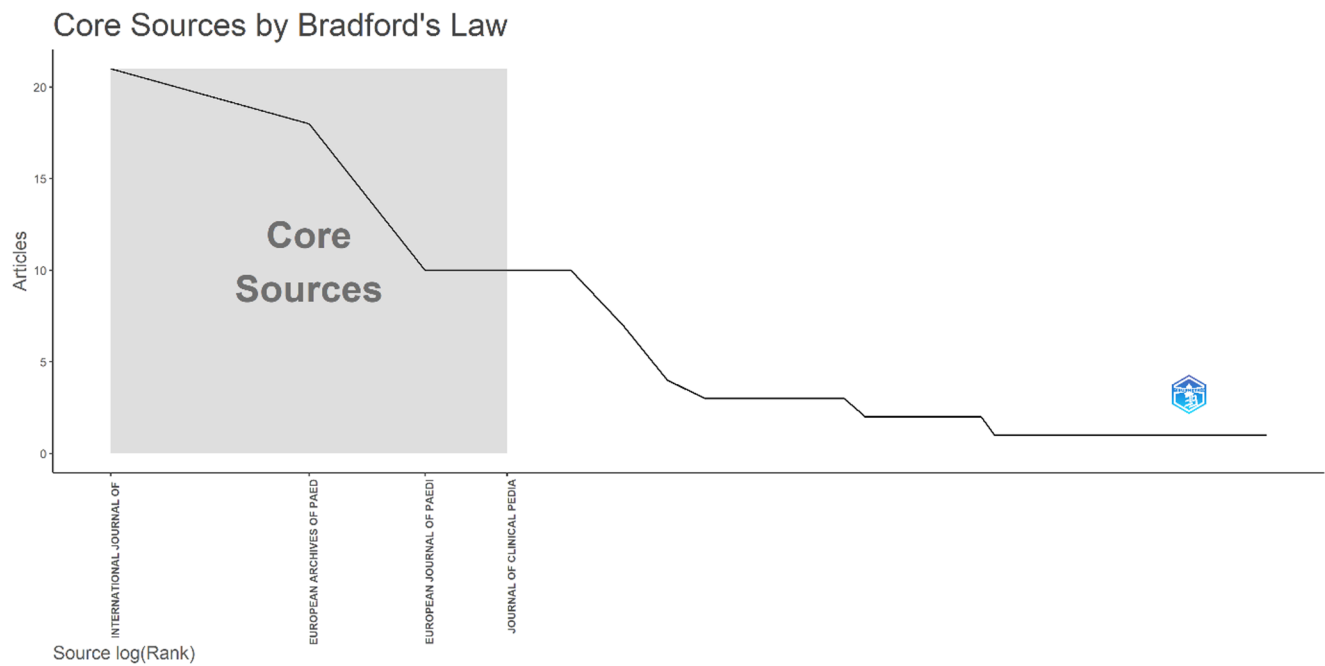


**Fig. 2** Core sources by Bradford's law. Bradford dispersion plot highlighting the set of core journals concentrating the highest number of publications in the field

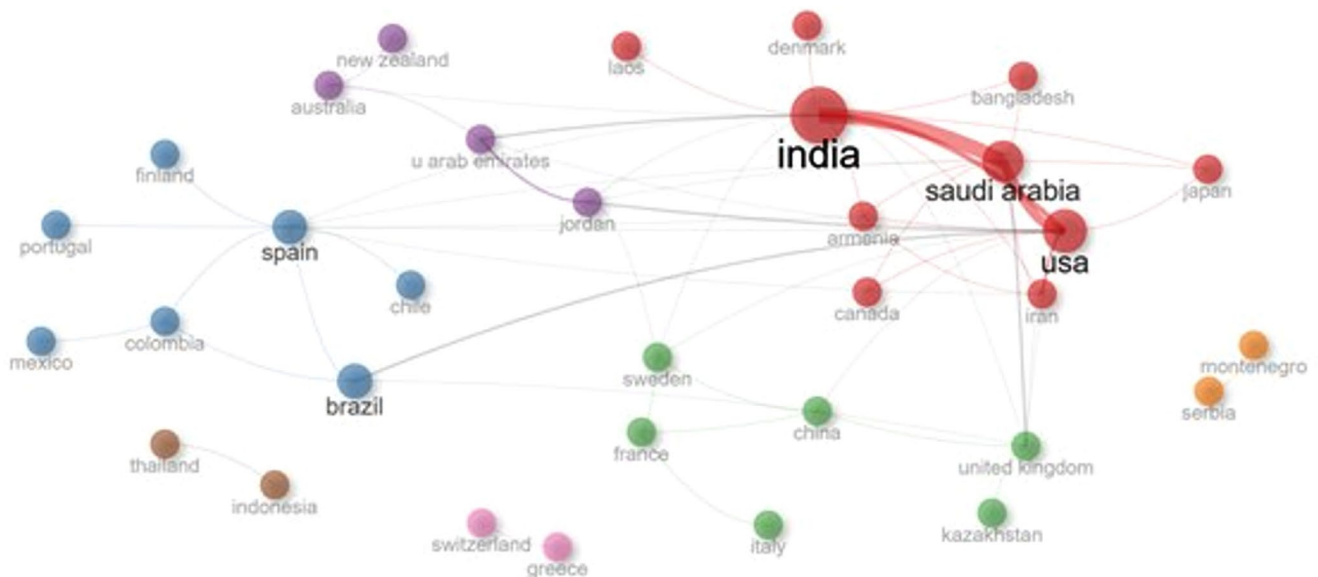


**Fig. 3** Country collaboration network. International co-authorship network map displaying the strongest collaborative ties among contributing countries; node size reflects productivity and edge thickness indicates collaboration strength

journals. This concentration pattern indicates that research on digital behavior management in pediatric dentistry is strongly anchored within specialized pediatric dental journals.

### 3.3 International collaboration network

The country collaboration network is illustrated in Fig. 3. The most prominent contributors include India, the United

States, and Saudi Arabia, forming a dense cluster of collaboration. Emerging participation is observed from European countries and selected Asian regions. The network structure demonstrates regional clustering with limited but increasing intercontinental connections. India appears as a central node within the global network, with multiple collaborative links to other countries.



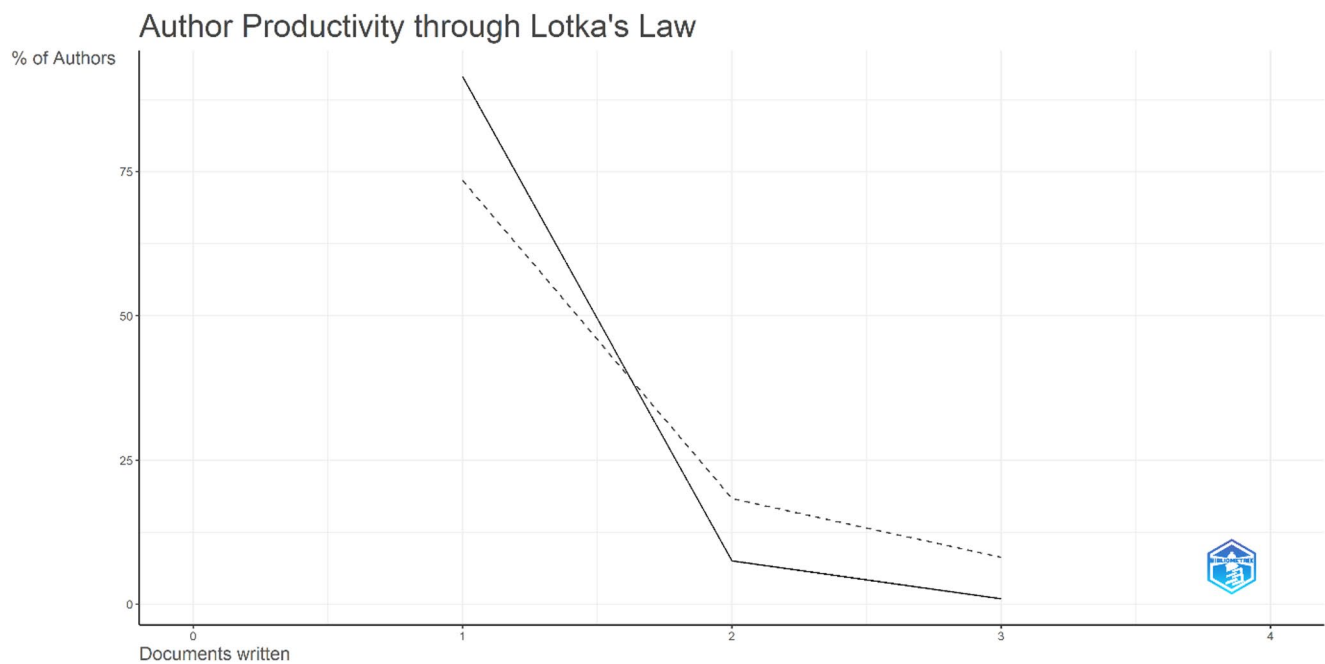


**Fig. 5** Author productivity through Lotka's law. Distribution of author productivity in relation to Lotka's theoretical expectation, illustrating concentration of output among a smaller subset of contributors

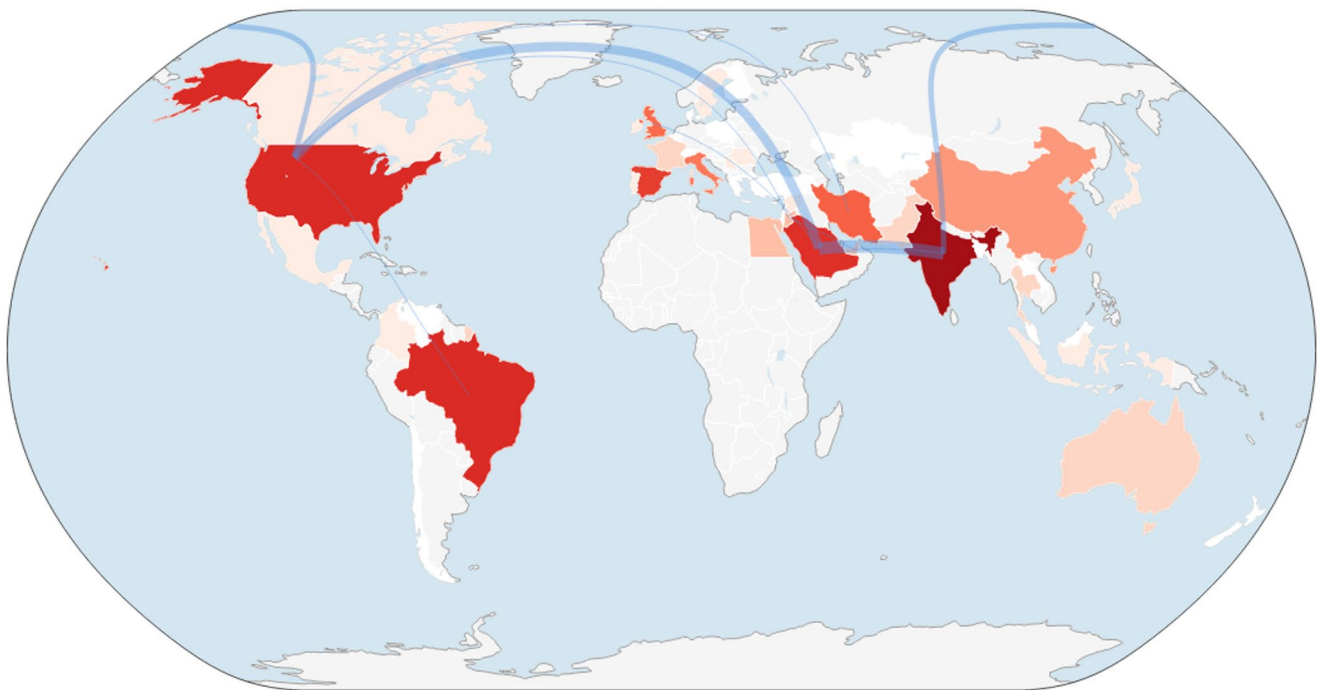


**Fig. 6** Global scientific collaboration map. World map of international collaborations visualizing geographic distribution of contributions and cross-country scientific linkages

## 4 Discussion

This bibliometric analysis, based on the methodological framework described in Sect. 2, offers an overview of the development of digital and technology-assisted behavior

management in pediatric dentistry and shows a clear increase in research output over time. The rise in publications, particularly from the mid-2010s onwards, appears to coincide with broader developments in healthcare technologies. During this period, immersive tools such as virtual reality (VR)

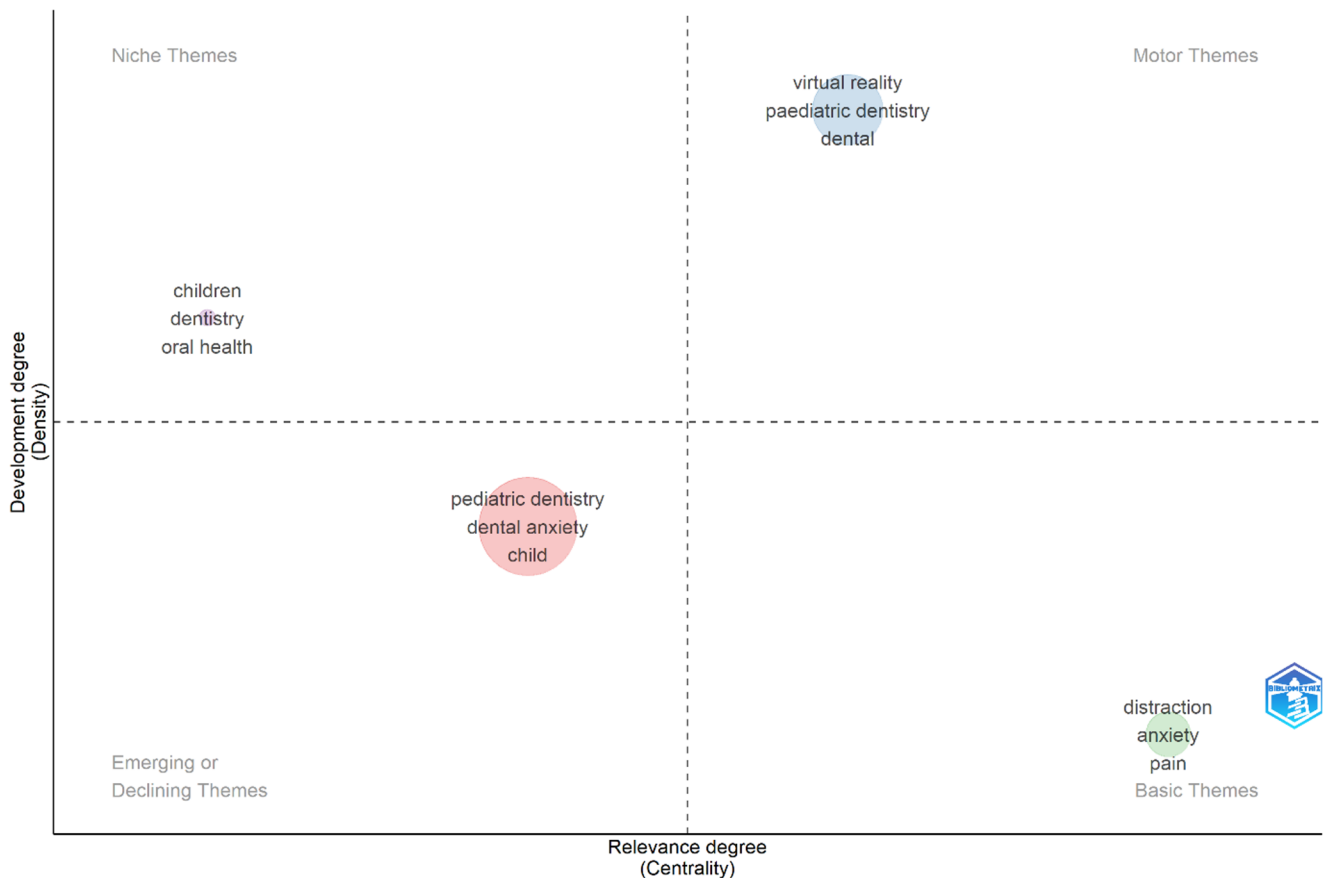


**Fig. 7** Thematic map (centrality–density). Thematic evolution map categorizing clusters into motor, basic, niche, and emerging/declining themes based on centrality (relevance) and density (development)

became more accessible and were explored more widely in clinical contexts. At the same time, there has been a growing emphasis on non-pharmacological approaches to managing dental anxiety in children, which may also have contributed to the expansion of research activity in this area (Snoswell et al. 2019; Helou et al. 2023; Grisolia et al. 2021; Sun et al. 2024).

The distribution of author productivity follows a pattern consistent with Lotka’s law, where a relatively small group of authors contributes a large proportion of the publications. This likely reflects the specialized and interdisciplinary nature of the field. Research in digital behavior management often requires collaboration across clinical dentistry, behavioral sciences, and technological development, which may limit participation to research groups with access to these combined resources. Similar patterns have been reported in the broader dental literature (Kawamura et al. 1999).

Analysis of journal sources, based on Bradford’s law, shows that publications are concentrated in a limited number of core pediatric dentistry journals. This concentration can be advantageous for accessibility, as it allows clinicians and researchers to follow key developments in a defined set of journals. At the same time, it may also indicate that

findings are not consistently reaching related fields such as digital health or behavioral sciences. Given the interdisciplinary nature of the topic, wider dissemination across different research areas may support further development and application.

Consistent with the thematic mapping results presented in Sect. 3.7, the thematic analysis highlights that terms such as “distraction”, “anxiety”, and “pain” remain central to the literature, reflecting the primary clinical focus on managing children’s immediate responses during dental procedures. In contrast, technology-related terms, particularly “virtual reality”, appear as well-developed and increasingly prominent themes. This is consistent with recent systematic reviews and meta-analyses indicating that VR-based interventions can reduce anxiety, perceived pain, and physiological stress in pediatric dental settings (Yan et al. 2023; Dhaliwal et al. 2025).

At the same time, the thematic structure suggests that broader oral health concepts are less central and tend to appear in more specific or contextual clusters. This may indicate that current research remains largely focused on short-term, procedure-based outcomes rather than on longer-term oral health or behavioral changes. Previous studies in

this area have also noted that digital interventions are often evaluated primarily on immediate effects, with less attention to long-term outcomes such as treatment adherence or oral health improvement (Bleyen et al. 2025). Addressing this gap may help strengthen the clinical relevance of future research.

The collaboration analysis shows that international co-authorship exists but is concentrated among a relatively small number of countries. This suggests that research activity is driven by a limited number of established groups. Considering that digital interventions can be influenced by factors such as cultural context, technological infrastructure and content design, broader international collaboration may improve the generalisability of findings. Expanding multicentre and cross-cultural studies could also support the development of more consistent and widely applicable intervention protocols.

Finally, differences in study design and reporting remain an important issue in this field. Variations in outcome measures, including the use of different anxiety scales, pain assessment tools, and timing of evaluations, make it difficult to compare findings across studies. In addition, characteristics of the interventions themselves—such as duration, type of content, and level of interactivity—are not always reported in a consistent way. Greater standardization in these areas would support more reliable comparisons and facilitate the translation of research into clinical practice.

Several limitations should be acknowledged. First, this bibliometric analysis was limited to the Web of Science Core Collection database; therefore, relevant publications indexed in other databases such as Scopus, PubMed, or Google Scholar may not have been captured, potentially introducing selection bias. In addition, the findings depend on the selected search strategy, which may have influenced the scope of the retrieved records. Second, rapid technological development may introduce temporal bias, whereby newer interventions (e.g., immersive virtual reality) appear disproportionately prominent due to recent publication trends. Finally, variations in terminology across studies may influence thematic mapping, particularly in a field where digital tools are described using evolving and sometimes overlapping labels.

Despite these limitations, the present analysis provides a structured overview of the development of digital behavior management research in pediatric dentistry and highlights key areas for future research.

## 5 Conclusion

This bibliometric analysis demonstrates a marked increase in research on digital behavior management in pediatric dentistry over the past two decades. The findings indicate that audiovisual distraction and anxiety-related themes form the conceptual core of the field, while immersive technologies, particularly virtual reality, have emerged as prominent and evolving research areas. Scientific output is concentrated within specialized pediatric dentistry journals, with collaboration patterns reflecting a limited number of interconnected research groups. These results highlight the growing role of digital interventions and the need for more standardized and collaborative research to support clinical translation.

**Author contributions** H.Ç.A. conceived the study and supervised all stages; E.S. collected and organized the data; H.Ç.A. performed data extraction and preliminary coding; H.Ç.A. conducted the statistical analyses and led the manuscript writing; all authors reviewed and approved the final manuscript.

**Data availability** The datasets analysed during the current study are available from the corresponding author upon reasonable request.

## Declarations

**Competing interests** The authors declare no competing interests.

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