






## ORIGINAL RESEARCH OPEN ACCESS

# Mapping Global Scientific Production on Human Immunodeficiency Virus and Monkeypox: A Scientometric Study

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## ABSTRACT

**Background and Aim:** HIV attacks the immune system, leading to AIDS if untreated. Mpox, a zoonotic disease like smallpox, is less severe but poses higher risks for immuno-compromised individuals, especially those with HIV. Effective prevention and treatment are crucial. This study aims to assess the global academic output on Monkeypox (MPVX) and HIV during 2018–2023.

**Methods:** This descriptive, bibliometric study reviewed the published literature on “monkeypox” and “HIV” during the period 2018–2023. The search was conducted on February 11, 2024, using a systematic formula. We identified 366 potential articles, including various types of papers. When exporting metadata to SciVal for the period 2018–2023, 8 metadata could not be exported. The remaining data were analyzed using SciVal and Bibliometrix in R Studio, providing an overview of research productivity, collaborations, and citation impact.

**Results:** During the period 2018–2023, 366 papers on “monkeypox” and “HIV” were published in 183 different sources, with an annual growth rate of 208.18%. These papers had an average of 14.78 citations per paper. An additional 2522 keywords and 638 author keywords were identified. The “*Journal of Medical Virology*” led the academic output with 20 papers, followed by “*The Lancet Infectious Diseases*” with 11 papers. The “*Institut national de la santé et de la recherche médicale*” in France led the academic output. These data are specific to papers dealing with “monkeypox” and “HIV.”

**Conclusion:** Research on Monkeypox and HIV has grown significantly during the period studied, with remarkable international collaboration. These findings underscore the importance and global impact of Monkeypox and HIV research.

## 1 | Introduction

Monkeypox (MPXV) is a viral zoonosis, first identified in 1970 whose symptoms are similar, but less severe, to those caused by smallpox and its development is usually endemic to areas such as Central and West Africa [1]. However, in 2003 it had a first

outbreak in a nonendemic area such as the United States; in 2018 in Israel, in the United Kingdom in 2019 [2].

Recently, there has been an abrupt increase in the number of outbreaks in the United States spreading to the rest of the world reaching more than 66,000 cases in more than 100 nonendemic

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countries [1], representing approximately 4% of all global infections especially in male patients who have sex with men (MSM) and being declared by WHO as a public health emergency on July 23, 2022 [3]. This spread is also conditioned by various risk factors such as the immunological status of the patient.

Approximately a total of 30.18% of patients with MPXV are patients with human immunodeficiency virus (HIV) [3]. In cases of MPXV patients with uncontrolled advanced HIV infection, there is an inadequate immune response and consequently a weak prognosis, a longer period of illness and a delayed cure [4]; although the association between the two diseases is not entirely clear, the cause may lie in the similar modes of transmission (sexual route) [5].

Co-infection of these two viruses can be particularly dangerous because it can exacerbate the symptoms of both diseases [6]. This is why it is necessary to systematically compare HIV and MPXV data to get a clear picture of the status of coinfection in all regions of the world because the mode of transmission of the two diseases may vary in different countries. To achieve this, bibliometric studies are a good option to perform a quantitative analysis of the current medical literature on a given topic [7].

The results of this study will serve as a basis for a clear and current overview of MPXV coinfection in patients with HIV and vice versa, emphasizing important topics to promote the improvement of medical practice and public health policies. Despite the great extension and impact of MPXV in the world and in the research area, bibliometric analyses have only focused on the disease in general [8] or evaluating the various therapies and vaccines it presents [9], without analyzing this coinfection.

Thus, the aim of this study was to conduct a scientometric study of the world literature on HIV and MPXV coinfection.

## 2 | Methods

### 2.1 | Study Design

The study had a descriptive design with a scientometric approach. A review of the literature published on “monkeypox” and “HIV” during the period 2018–2023 was conducted using Scopus.

### 2.2 | Search Process

The search was conducted on February 11, 2024 using the following formula: TITLE-ABS (“monkeypox” OR “mpox” OR “simianpox” OR “primatepox” OR “apepox” OR “macaquepox” OR “saimiripox” OR “baboonpox” OR “chimpox” OR “gorillapox”) AND TITLE-ABS (“HIV” OR “human immunodeficiency virus” OR “acquired immune deficiency syndrome” OR “hiv-positive” OR “retrovirus” OR “human immunodeficiency syndrome virus” OR “acquired immunodeficiency syndrome virus”) AND PUBYEAR > 2017 AND PUBYEAR < 2024.

### 2.3 | Article Selection

We found 366 potential articles on “monkeypox” and “HIV.” These include 271 articles, 50 reviews, 22 letters, 12 notes, 4 editorials, 3 errata, 3 book chapters, and 1 conference article.

### 2.4 | Criteria Selection

The inclusion criteria for this study were articles published between 2018 and 2023 that included the terms “monkeypox” in the title or abstract, focusing on both “monkeypox” and “HIV.” The exclusion criteria involved articles that did not meet the search terms, were published outside the specified timeframe (before 2018 or after 2023), did not focus on both “monkeypox” and “HIV,” or had metadata that could not be exported to SciVal for analysis.

### 2.5 | Data Export

When exporting metadata to SciVal for 2018–2023, 8 metadata could not be exported. The remaining data were used for bibliometric analysis. Data analysis was performed using SciVal and Bibliometrix in R Studio. In SciVal, metadata of selected papers were imported for detailed bibliometric analysis. SciVal provided an overview of research productivity, collaborations, and citation impact. On the other hand, Bibliometrix, an R package designed for bibliometric and scientometric analysis, was used for additional data processing. With Bibliometrix, a keyword co-occurrence analysis was performed to identify the main research areas. It was also used to visualize the collaboration network between authors and countries.

### 2.6 | Data Analysis

Data were analyzed using standard bibliometric techniques to identify trends in scholarly output, collaborations, author productivity, and keyword distribution. Academic output, measured by number of publications, CiteScore 2022, Field Weighted Citation Impact, citations per publication, and views per publication were used.

## 3 | Results

In the period 2018–2023, 366 papers were published on “monkeypox” and “HIV” in 183 different sources, with an annual growth rate of 208.18%. These papers have an average of 14.78 citations per paper. An additional 2522 keywords and 638 author keywords were identified. The papers were written by 3362 authors, of which 19 wrote single-authored papers. The average number of coauthors per paper is 10.9, with 19.4% international coauthorships. Paper types include articles (271), book chapters (3), conference papers (1), editorials (4), errata (3), letters (22), notes (12), and reviews (50) (Table 1).

The “Journal of Medical Virology” led the academic output with 20 papers, followed by “The Lancet Infectious Diseases” with 11 papers and “International Journal of STD and AIDS” and “Travel Medicine and Infectious Disease” with 10 papers each. “The

Lancet” has the highest CiteScore in 2022 with 133.2 and also led in citations per publication with 72.7. However, “The Lancet Infectious Diseases” had the highest field-weighted citation impact with 34.3. It is important to note that these data are specific to papers dealing with “monkeypox” and “HIV” (Table 2).

**TABLE 1** | Descriptive characteristics of scientific production.

Description	Results
Perior	2018:2023
Sources	183
Documents	366
Annual growth (%)	208.18
Document average age	1.28
Average citations per doc	14.78
References	9001
Keywords plus	2522
Author's keywords	638
Authors	3362
Authors of single-authored docs	19
Single-authored docs	22
Co-authors per doc	10.9
International co-authorships %	19.4
Article	271
Book chapter	3
Conference paper	1
Editorial	4
Erratum	3
Letter	22
Note	12
Review	50

The “Institut national de la santé et de la recherche médicale” in France led the academic production with 15 papers, followed by the “Centro de Investigación Biomédica en Red” and the “Instituto de Salud Carlos III” in Spain with 14 papers each. The Université Paris Cité in France produced 13 papers. In the United States, the University of Miami and Emory University published 12 and 11 papers respectively. The “Assistance publique - Hôpitaux de Paris” in France and the “CNRS” in France, together with the “Centers for Disease Control and Prevention” in the United States and the “IRCCS Istituto per le Malattie Infettive Lazzaro Spallanzani - Roma” in Italy, produced 11 and 10 papers respectively (Table 3).

Most authors (2925, representing 87% of the total) wrote only one paper. A smaller number of authors (328, or 9.8% of the total) wrote two papers. As the number of papers written per author increases, the proportion of authors decreases. For example, only 66 authors (2% of the total) wrote three papers, and only 21 authors (0.6% of the total) wrote four papers. Very few authors wrote more than five papers. These data reflect the typical distribution of academic productivity, where most authors publish few papers and only a few publish many (Figure 1).

According to Bradford's law, monkeypox and HIV publications were distributed into three zones. Zone 1, which includes the most productive journals, comprised 15 journals, from the Journal of Medical Virology to Frontiers in Public Health. Zone 2, with moderate productivity, included 46 journals, from HIV Medicine to Sexual Health. Zone 3, which includes journals with only one publication, started with “Abdominal Radiology” and continued with journals such as “Acta Oto-Laryngologica,” “Advanced Emergency Nursing Journal,” and “Advances in Experimental Medicine and Biology” (Figure 2).

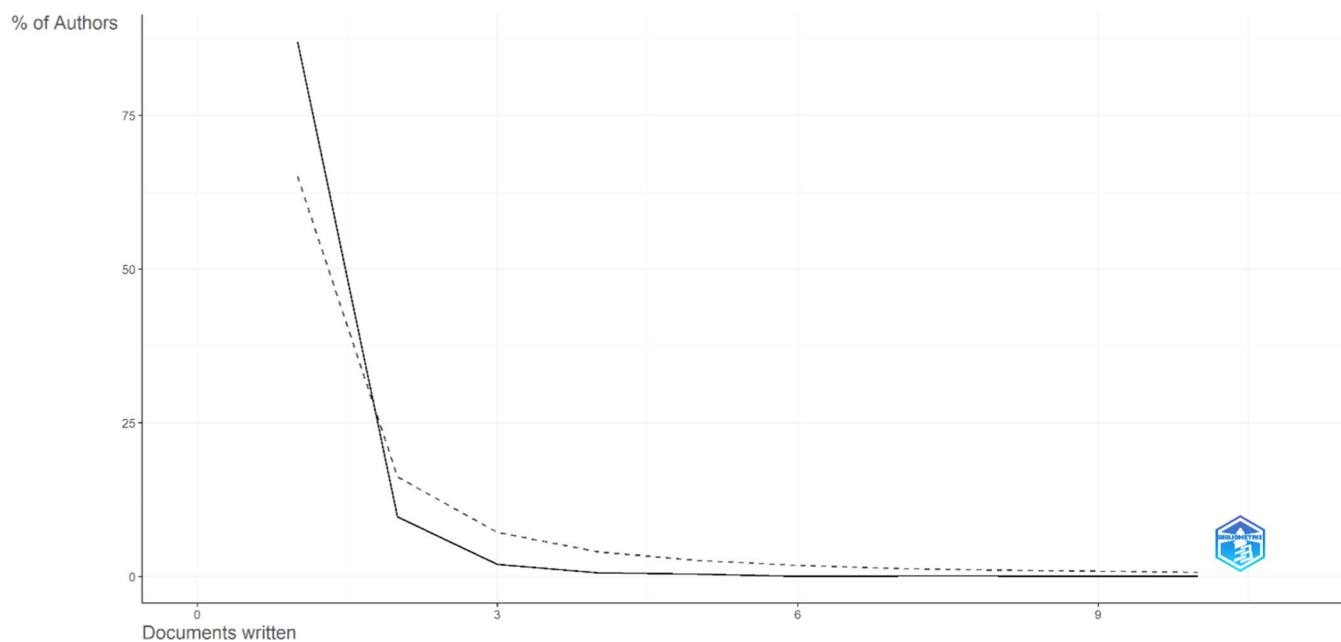
The map of collaboration between countries shows several interactions. France has the most collaborations, with six with Germany, five with Canada and Switzerland, and three with Belgium, Brazil, Denmark, Israel, Mexico, Nigeria, Portugal, Romania and Sweden. Germany also shows a strong network of

**TABLE 2** | Top-10 scientific journals.

Source	Scholarly output	CiteScore 2022	Field-weighted citation impact	Citations per publication
<i>Journal of Medical Virology</i>	20	23.4	6.28	9.6
<i>The Lancet Infectious Diseases</i>	11	55.6	34.3	49.8
<i>International Journal of STD and AIDS</i>	10	2.3	5.28	10.2
<i>Travel Medicine and Infectious Disease</i>	10	17.1	3.43	11.8
<i>AIDS</i>	8	6.3	2.43	2.8
<i>AIDS Research and Human Retroviruses</i>	7	3.2	0.66	0.7
<i>The Lancet</i>	7	133.2	45.91	72.7
<i>Vaccines</i>	7	7	4.25	10
<i>Clinical Microbiology and Infection</i>	6	21.5	14.75	17.7
<i>Infectious Disease Reports</i>	6	3.2	1.74	5.7

**TABLE 3** | Top-10 institutions.

Institution	Country	Scholarly output	Views per publication	Field-weighted citation impact	Citations per publication
Institut national de la santé et de la recherche médicale	France	15	13.9	27.6	34.7
Centro de Investigación Biomédica en Red	Spain	14	16.3	44.55	89.2
Instituto de Salud Carlos III	Spain	14	16.3	44.55	89.2
Université Paris Cité	France	13	17.4	65.77	111.2
University of Miami	United States	12	5.4	3.63	10.7
Assistance publique—Hôpitaux de Paris	France	11	16.3	78.69	128.5
CNRS	France	11	17.5	30.21	39.3
Emory University	United States	11	12.6	17.56	30.5
Centers for Disease Control and Prevention	United States	10	6.9	12.45	10.4
IRCCS Istituto per le Malattie Infettive Lazzaro Spallanzani—Roma	Italy	10	18.1	58.55	116.7

**FIGURE 1** | Most relevant authors.

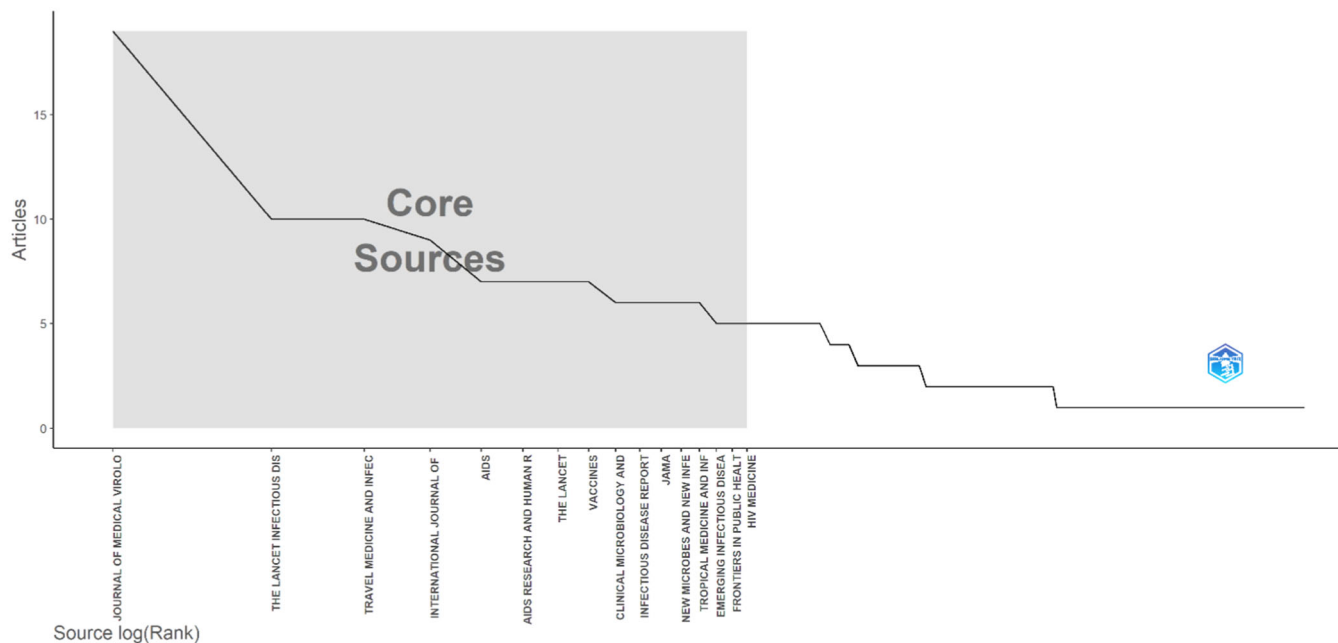
collaborations, with four with Canada, Denmark, Mexico and Sweden. Canada and Denmark have three collaborations with Belgium. Brazil has three collaborations with Nigeria. These data highlight the global connections and collaboration between these countries (Figure 3).

#### 4 | Discussion

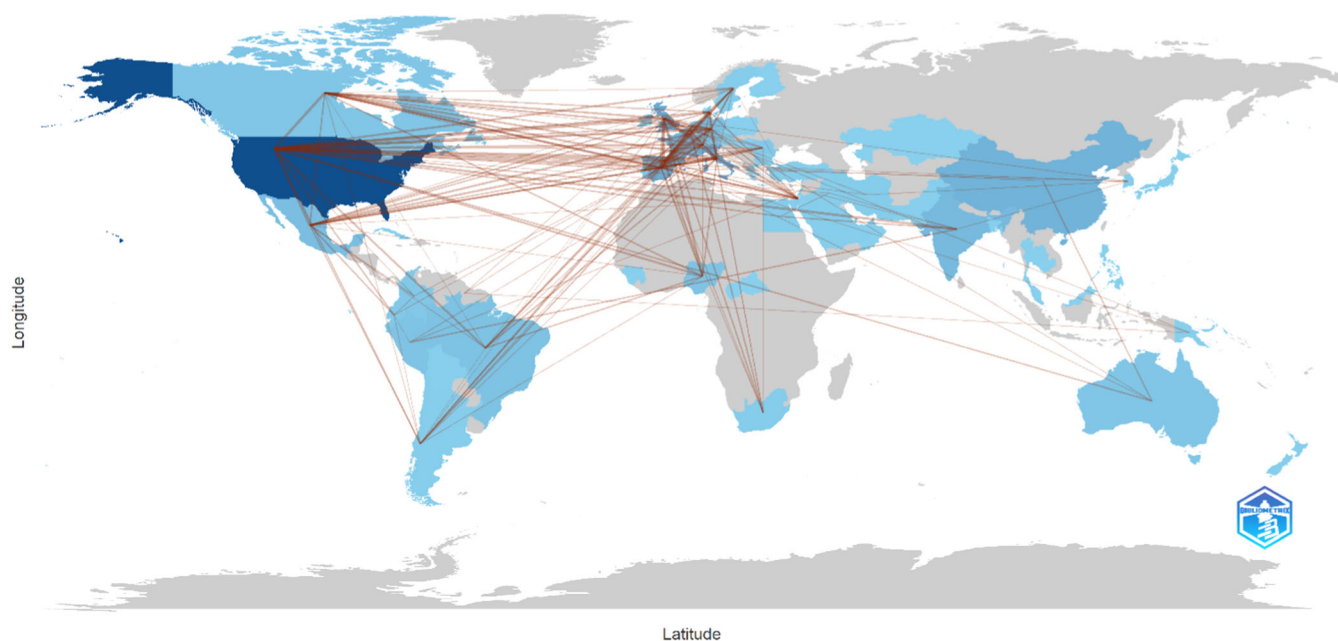
In the present study, 366 documents were found, most of which were articles and reviews with an annual growth rate of 208.18% and an average of 14.78 citations per article. In

addition, 19.4% of international collaboration was found, especially from European countries such as France or Germany.

Co-infection with HIV and Mpox can significantly worsen the progression of both diseases, leading to more severe clinical outcomes. Individuals with advanced HIV and low CD4 cell counts are especially susceptible to severe Mpox complications, such as necrotizing skin lesions, pulmonary involvement, and secondary infections. The co-infection can trigger a state of CD4+ T cell activation, which facilitates HIV infection. Overall, HIV co-infection tends to exacerbate the prognosis of Mpox, increasing both mortality and the severity of complications [10–12].



**FIGURE 2** | Core sources.



**FIGURE 3** | Country collaboration map.

The Lancet was the journal with the highest CiteScore 2022 and the highest impact (72.7 citations per paper) with only 7 publications. This journal has already reported in previous years leading the global scientific production in the topic of infectious diseases [13] as well as periodically reporting the impact of pandemics on global public health as was COVID-19 in previous years [14], which would explain its higher impact in the topic of MPXV and HIV. The article with the highest citation (359) in this journal was that of Tarin-Vicente et al. [15], which was a prospective multicenter cohort in Spain that sought to describe the clinical and virological characteristics of 181 patients diagnosed with MPXV, finding that 40% were co-infected with HIV.

The Assistance publique—Hôpitaux de Paris was the institute with the highest reported impact with 128.5 publications per paper. This is in line with the world literature where this institution is identified as the largest university hospital in Europe and one of the major references of French research since it encompasses about 40% of French biomedical research, especially during the last COVID-19 pandemic [16]. Among its most cited publications is Mitjà et al. [10] which was a case series describing 382 cases from 19 countries with a diagnosis of MPXV of which 91% had HIV comorbidity.

Eighty-seven percent of the authors wrote only one paper and similarly as the number of papers written per author increases,

the proportion of authors decreases. This reflects a typical picture of academic productivity, with most authors publishing only one paper. It has been reported that during the surge of publications on MPXV during its pandemic, the majority (5800 authors) published only one paper and this picture was quite like that of the previous COVID-19 pandemic [17]. Despite this, international collaboration in publications on MPXV and HIV was reported, which is in keeping with the increase in cases and the global emergency that both viruses are causing worldwide.

The higher concentration of both publications and collaborative networks in European countries responds to the very extension of MPXV in the world. The recent outbreak of MPXV in several countries and in nonendemic countries was found to have a higher prevalence of HIV coinfection (42.05% and 42.60%, respectively) [11] and up to a 100-fold difference in cases compared with HIV prevalence in the global population [12]. This could be explained by the fact that nonendemic European and American countries have a higher proportion of the population of MSM, bisexuals and homosexuals [18], which are HIV risk groups.

These results highlight the importance of constant vigilance in immunosuppressed patients such as HIV-positive patients by prioritizing vaccination against MPVX in this population and, similarly, HIV screening in patients diagnosed with MPVX [5]. It is also hoped that our results will lay the groundwork for future research and improved public policy on health care, emphasizing appropriate clinical guidance for MPVX.

This study has several limitations. First, the search was limited to the Scopus database only, which may have excluded relevant articles from other databases. Second, the classification of the publications (article, review, letter, etc.) may not fully reflect the content of the articles. Third, the study was limited to articles published between 2017 and 2024, which excluded case reports and research before the MPVX pandemic. However, this study also has some strengths. First, a systematic analysis of the Scopus database was performed, which covers many journals and publications that have undergone a strict review process to ensure high quality and relevance to the global literature compared with other databases [19]. Second, the classification of various types of publications (articles, reviews, letters, book chapters, etc.) allows a more complete and diverse view of the typical study. Finally, considering studies published in the last few years allows us to address a current picture of the reality on the conflation of MPVX and HIV.

## 5 | Conclusions

The bibliometric study of global academic output on Monkeypox and HIV during 2018–2023 revealed significant growth in research, with 366 papers published in 183 different sources. International collaboration was notable, with 19.4% international co-authorship. Papers were distributed in a variety of types, including articles, book chapters, and reviews. Publications are led by the *Journal of Medical Virology* and *The Lancet Infectious Diseases*. Academic productivity was led by the Institut national de la santé et de la recherche médicale in France

and the Centro de Investigación Biomédica en Red in Spain. Most authors published few papers, reflecting the typical distribution of academic productivity. Collaborations between countries are global, highlighting the connections and collaborations between these countries.

## Author Contributions

**Frank Mayta-Tovalino:** conceptualization, investigation, writing – review and editing, software, data curation, supervision. **Carlos Quispe-Vicuña:** investigation, conceptualization, writing – original draft. **Cesar Mauricio-Vilchez:** conceptualization, methodology, investigation, writing – original draft. **Diego Galarza-Valencia:** conceptualization, investigation, methodology, writing – original draft. **Fran Espinoza-Carhuancha:** investigation, writing – original draft, conceptualization, methodology.

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## Conflicts of Interest

The authors declare no conflicts of interest.

## Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Transparency Statement

The lead author Frank Mayta-Tovalino affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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## BASIC RESEARCH:

### Scientometric Analysis of Activated Carbon or Probiotics in Mouthwashes or Toothpastes: Dynamicity, Spatiotemporal Evolution and Trends

Análisis cientométrico del carbón activado o los probióticos en enjuagues bucales o dentífricos:  
dinamicidad, evolución espaciotemporal y tendencias

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**ABSTRACT:** The use of activated charcoal and probiotics is a controversial topic nowadays due to their potential oral health benefits. Thus, the aim of this research was to perform a scientometric analysis of activated charcoal or probiotics in mouthwashes or dentifrices by means of dynamicity, spatiotemporal evolution, and trends. A study was carried out to look back at scientific publications between 2005 and 2022 using the Web of Science. To analyze the data, various bibliometric indicators were used. The process of retrieving information was completed on July 28, 2023. It was found that only 1 article was published in 1990. Furthermore, the highest co-citation occurred in cluster 9 (Dentistry, Dermatology, Surgery), indicating a higher relevance and frequency with cluster 8 (Molecular Biology, Genetics). In the cluster view, 15 large clusters were identified, with cluster 0 (Activated Carbon) being the largest and occupying the greatest centrality. On the other hand, the cross-country collaboration map showed active collaborations between Australia and New Zealand, Brazil, and Canada. We found a significant growth of scientific publications on probiotics and activated charcoal in the field of dentistry and related disciplines between 1990 and 2023.



**KEYWORDS:** Activated carbon; Probiotics; Scientometrics; Web of science.

**RESUMEN:** El uso de carbón activado y probióticos es un tema controvertido en la actualidad debido a sus potenciales beneficios para la salud bucodental. Por ello, el objetivo de esta investigación fue realizar un análisis cientométrico del carbón activado o los probióticos en colutorios o dentífricos mediante su dinamicidad, evolución espaciotemporal y tendencias. Se realizó un estudio retrospectivo de las publicaciones científicas entre 2005 y 2022 utilizando la base de datos Web of Science. Los patrones de visualización, las relaciones temporales y las tendencias se evaluaron mediante mapas superpuestos, visualización de zonas horarias y tres parcelas de campo. El proceso de recuperación de información finalizó el 28 de julio de 2023. Se encontró que sólo 1 artículo fue publicado en 1990. Además, la mayor co-citación se produjo en el clúster 9 (Odontología, Dermatología, Cirugía), indicando una mayor relevancia y frecuencia con el clúster 8 (Biología Molecular, Genética). En la vista de clústeres, se identificaron 15 grandes clústeres, siendo el clúster 0 (Carbón Activado) el más grande y el que ocupa la mayor centralidad. Por otro lado, el mapa de colaboración entre países mostró colaboraciones activas entre Australia y Nueva Zelanda, Brasil y Canadá. Encontramos un crecimiento significativo de las publicaciones científicas sobre probióticos y carbón activado en el campo de la odontología y disciplinas relacionadas entre 1990 y 2023.

**PALABRAS CLAVE:** Carbón activado; Bibliometrix; Probióticos; Estudio cientométrico; Web of science.

## INTRODUCTION

In the field of dentistry, antiseptic mouth rinses have become a common and effective practice to reduce the population of microorganisms in the oral cavity (1). These rinses are especially recommended before undergoing any dental procedure, as they ensure a cleaner and pathogen-free mouth (1). Although there has been a growing interest in the use of these rinses as a preventive measure, it is important to mention that there is currently no concrete evidence to fully support their safety (2). Therefore, it is essential to carefully analyze both their advantages and disadvantages, considering the individual needs and characteristics of each patient and dental procedure. The discussion of mouth rinses and conventional antiseptics used in dentistry is crucial to evaluate their potential role as an adjunct in reducing the microbial load in the mouth during dental treatments (3). By thoroughly understanding the benefits and limitations of these options, dental professionals will be able to make infor-

med decisions and tailor their use appropriately to optimize outcomes.

Dentistry has constantly evolved and has achieved a lower prevalence of edentulism, this is due to a greater awareness of patients. This has increased the expectations regarding dental treatments. It is important to maintain and prevent the soft and hard tissues of the oral cavity in good condition (4, 5). Non-invasive methods are preferred in the prevention of certain pathologies to improve dental practice. This includes the indication of the use of toothbrushes, mouthwashes, and toothpastes to maintain oral health (6, 7).

Nowadays, dental esthetics has become increasingly important due to increased awareness of perfectionism and self-care, and tooth color has become a key aspect for the general public (8, 9). In this context, tooth whitening has been highlighted as a popular procedure, and it is important to note that it does not affect the hard tissues of the tooth, as the activated charcoal used in this process

offers numerous benefits. Currently, many people opt for at-home whitening techniques due to their effective results (10). Among the available options, activated charcoal-based toothpastes have gained popularity, thanks to their promise of fast results. These products contain whitening and abrasive agents that effectively remove extrinsic stains from teeth, providing a convenient and economical solution to improve their appearance (11, 12).

Activated charcoal has generated interest in esthetic dentistry because of its ability to adsorb pigments and stains on the tooth surface. While numerous tooth-whitening products have begun to include activated charcoal in their recipes, the efficacy of this ingredient has yet to be scientifically confirmed (13). The use of high-concentration peroxides for tooth whitening has yielded unmatched outcomes, but it has also resulted in stricter regulations. Whitening toothpastes that contain oxidants or enzymes can chemically alter the pigments on the teeth, while those that contain optical modifiers, such as blue covarine, can alter the perceived tooth color. Activated charcoal has recently gained attention for its potential to absorb surface stains and pigments on teeth (14).

Evidence has shown that probiotics are microorganisms with a beneficial effect on health. In addition, they can improve oral health by maintaining a symbiosis in the bacterial flora (15). They can also potentially reduce the risk of periodontitis, dental caries, halitosis, and other disorders. In addition, their localized activity can have effects throughout the body, reducing the consequences of systemic inflammation (16).

Finally, it is important to mention that the use of activated charcoal or probiotics in toothpastes or mouthwashes is still a controversial issue. Although some companies claim that these products may have certain benefits in dentistry. Therefore, the objective of this research was to perform a scientometric analysis of activated charcoal or probio-

tics in mouthwashes or toothpastes by means of dynamicity, spatiotemporal evolution, and trends.

## MATERIALS AND METHODS

### STUDY DESIGN

An observational, descriptive, and cross-sectional study with a scientometric approach was carried out using the Web of Science (Core Collection) to analyze publications on the topic. The research focused on the period between 1990 and 2023.

### SEARCH STRATEGY

On July 28, 2023, data were extracted from a total of 248 manuscripts using the Web of Science (WOS) database, which is a widely recognized database in the field of health. In addition, it was selected for its prestige and multidimensionality, which guarantees the quality of its contents and allows advanced analysis of metrics and advanced data search. To carry out the research, the thesauri available in the Mesh terms and the Emtree terms of Embase were used and a search strategy was defined using the logical operators "AND" and "OR". The details of the selected search strategy are presented in the following sections. TS=(“Mouth Rinse” OR “Mouth Rinses” OR “Rinse Mouth” OR “Rinses Mouth” OR “Mouth Bath” OR “Bath Mouth” OR “Baths Mouth” OR “Mouth Baths” OR “Mouth Wash” OR “Wash Mouth” OR “Toothpaste” OR “silicic acid-based toothpaste” OR “silica gel-based toothpaste” OR “Colgate Total Fresh Stripe Toothpaste” OR “Colgate Sparkling White with Tartar Control Toothpaste” OR “Colgate Tartar Control Plus Whitening Fluoride dentifrice” OR “CTPW toothpaste” OR “Colgate TCPWFT” OR “Colgate Total” OR “Colgate Total Plus Whitening Toothpaste” OR “Colgate Total toothpaste” OR “Colgate Simply White toothpaste” OR “Colgate Tartar Control Plus Whitening Fluoride Toothpaste” OR “RetarDENT toothpaste” OR “RetarDENT” OR

“Crest Intelliclean liquid toothpaste” OR “Crest Regular Dentifrice” OR “Crest Regular” OR “Crest regular cavity protection” OR “Colgate regular dentifrice” OR “Aquafresh Whitening Toothpaste” OR “Aquafresh Whitening dentifrice” OR “Crest Cavity Fighting Toothpaste with Fluoristat”)AND TS=(“Liqui-Char” OR “Actidose” OR “Actidose-Aqua” OR “Activated Charcoal” OR “Charcoal Activated” OR “Adsorba” OR “Carbomix” OR “Charbon” OR “CharcoAid” OR “CharcoCaps” OR “Charcodote” OR “Formocarbine” OR “Insta-Char” OR “Kohle-Compretten” OR “Kohle-Hevert” OR “Kohle-Pulvis” OR “Kohle-Tabletten Boxo-Pharm” OR “Ultracarbon” OR “Norit” OR “activated charcoal - colloidal silver - dimethicone - liquorice - silicone dioxide” OR “adsorgan” OR “Probiotic” OR “Beneficial microorganisms” OR “Friendly bacteria” OR “Gut flora” OR “Microbiota” OR “Live cultures” OR “Lactobacilli” OR “Bifidobacteria” OR “Lactic ferments” OR “Probiotic supplements” OR “Probiotic foods” OR “Bacteria cultures” OR “Beneficial bacteria” OR “Good bacteria” OR “Microbial supplements” OR “Live microorganisms” OR “Gut-friendly bacteria” OR “Intestinal flora” OR “Friendly flora” OR “Microbiotic agents” OR “Probiotic strains” OR “Digestive health supplements” OR “Beneficial microorganisms” OR “Microbiome boosters” OR “Probiotic microorganisms” OR “Probiotic bacteria” OR “Synbiotics (combination of prebiotics and probiotics)” OR “Biotics” OR “Bifidobacteria” OR “Lactobacillus” OR “Fermented foods”).

#### BIBLIOMETRIC INDICATORS

The study used various indicators of production, collaboration, and impact, as well as document contents, Authors collaboration, document types, annual growth, Lotka's law, Bradford's law and

the annual scientific & train Topic, Overlay map, Timezone visualization, Clustering view, and Timeline view cluster graphs. In addition, thematic maps were used to visualize the relationships and collaborations between authors and countries.

#### DATA ANALYSIS

After the metadata was retrieved, it underwent analysis, which included elements such as the author's name, the number of citations, the journal, and the country. The analyzed data was then exported to CiteSpace 6.2 R2 [2003-2023 Chaomei Chen] and R Studio software, specifically Bibliometrix 3.0.

#### RESULTS

The results of the bibliometric analysis revealed that the data cover a period from 1990 to 2023 and include 150 sources, such as journals and books. A total of 248 documents were analyzed, with an annual growth rate of 9.97% and an average age of 7.49 years. The average number of citations per document was 18.55, with a total of 8206 references. As for the content of the documents, 755 Plus Keywords and 664 Author Keywords were identified. A total of 1176 authors contributed to the papers, and only 5 authors produced single-authored papers. In terms of inter-author collaboration, there were only 5 single-author papers, with an average of 5.36 co-authors per paper. International collaborations accounted for 25% of the total. Regarding document type, most were articles (214), with some classified as article; data paper (1), article; early access (6), article; proceedings paper (2), correction (1), and editorial material (2) (Table 1).

It was found that, in 1990, only 1 article was published, while in 1991, 3 were published. In addition, it could be seen that between 1992 and 2010 there was a sustained growth of less than 10 articles. However, it could be visualized that from the year 2016 onwards there was the greatest increase exceeding 20 manuscripts published over time (Figure 1.A). The analysis evidenced that the most frequent terms in the analyzed papers include "*mutans streptococci*" (7 times), "plaque" (5 times), "lactobacilli" (8 times), among others. In addition, a detailed representation of the most representative terms was found in relation to the distribution (Figure 1.B).

The Dual Map Overlay plot allowed comparison and analysis of the relationship between two data sets. It was observed that the highest co-citation occurred in cluster 9 (Dentistry, Dermatology, Surgery), indicating a higher relevance and frequency with cluster 8 (Molecular Biology, Genetics). This can be seen through the larger nodes and links that are formed in this field of knowledge (Figure 2).

Figure 3.A, which corresponds to the Time Zone Visualization, shows temporal patterns and trends. In particular, the largest nodes correspond to authors Brooks JK (2017), Vaz VTP (2019), and Franco MC (2020), who had high linking activity among the citations of the other nodes. Larger nodes indicated higher relevance, while thicker links indicated a higher amount of inter-document citations. Figure 3.B shows how citation patterns among scientific journals have evolved over the years evaluated. It was identified that in 2013 there was the highest number of nodes, represented by journals such as Plos One, J Dent Res and Oral Health Prev Dent, among others. However, a lower citation frequency was observed between the years 2021 and 2022.

In the cluster view, 15 large clusters were identified, of which cluster 0 (Activated carbon) had the largest size and a central position. This was followed by cluster 1 (Subgingival plaque) in which a great deal of research activity on these topics was evident. Finally, there were 13 other clusters of lesser relevance (Figure 4).

According to Bradford's Law, it was found that the most representative journals were "Caries Reserach" (12 articles), "BMC Oral Health" (8 articles), and the "International Journal of Dental Hygiene" (7 articles), finding that these journals corresponded mainly to zone 1, while in zone 2 the "Journal of Dental Reserach" (3 articles), and "Scientific Reports" (3 articles) were found, which shows an unequal distribution in the concentration of journals (Figure 5.A). According to Lotka's law, it was found that the majority of authors (1074 or 91.3% of the total) wrote only 1 scientific article. While 5.4% wrote only 2 papers. This indicates that the authors generally had only 1 paper written (Figure 5.B).

The cluster timeline view revealed 10 major clusters, with cluster 0 (Dental enamel) being the most prominent because it presented an increase in the number of horizontally arranged nodes over time. In particular, during 2020, high citation activity was observed with authors Vaz VTP (2019) and Greenwall LH (2019) (Figure 6).

The map of collaboration between countries evidenced that collaborations were observed between Australia and New Zealand, Brazil and Canada, Brazil and France, Brazil and Germany, Brazil and Italy, and Brazil and Spain, each with 1 article. Brazil also collaborated with Switzerland on 2 articles. Other collaborations included China and Australia, China and Germany, China and Malaysia, China and New Zealand, and China

and Singapore, each with 1 article. Collaborations were also noted between Denmark and Greece, Finland and Kuwait, and France and Portugal, each

with 1 article. In summary, our analysis shows a wide range of international collaborations in the production of scientific articles (Figure 7).

**Table 1.** Scholarly Output.

Description	Results
<b>Main information about data</b>	
Timespan	1990:2023
Sources (Journals, Books, etc)	150
Documents	248
Annual Growth Rate %	9.97
Document Average Age	7.49
Average citations per doc	18.55
References	8206
<b>Document contents</b>	
Keywords Plus (ID)	755
Author's Keywords (DE)	664
<b>Authors</b>	
Authors	1176
Authors of single-authored docs	5
<b>Authors collaboration</b>	
Single-authored docs	5
Co-Authors per Doc	5.36
International co-authorships %	25
<b>Document types</b>	
article	214
article; data paper	1
article; early access	6
article; proceedings paper	2
correction	1
editorial material	2



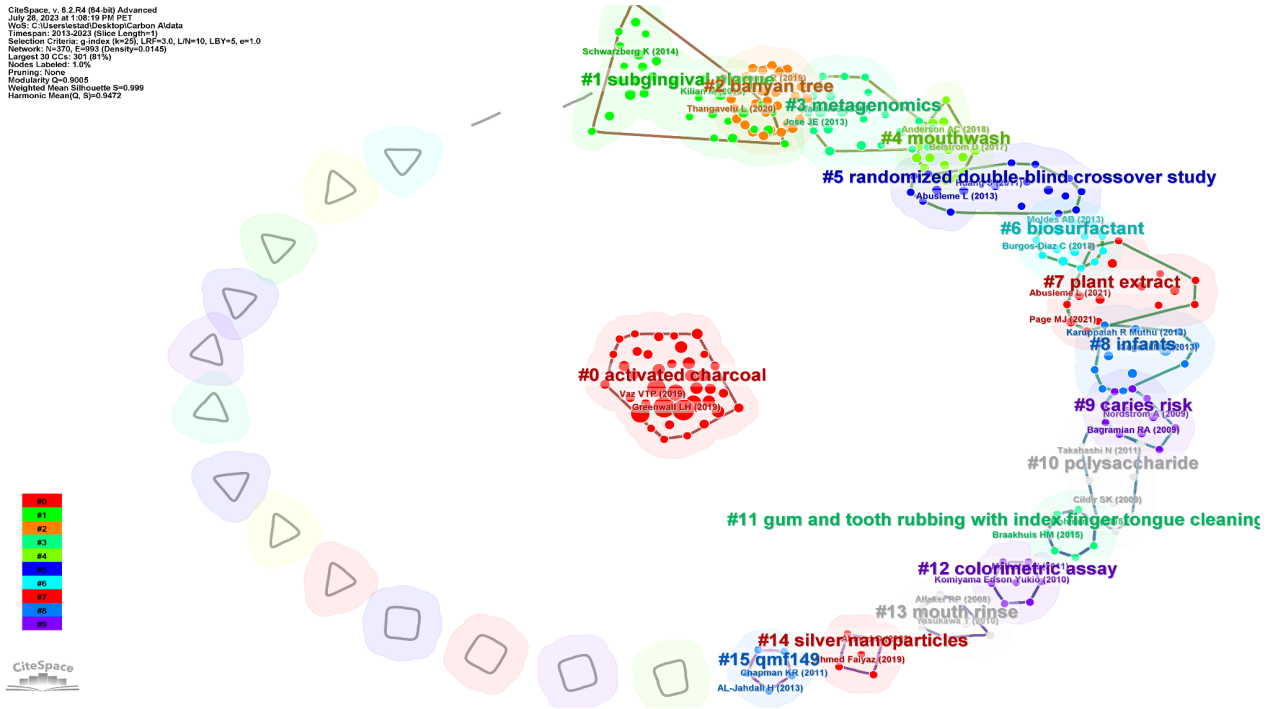


Figure 4. Clustering view.

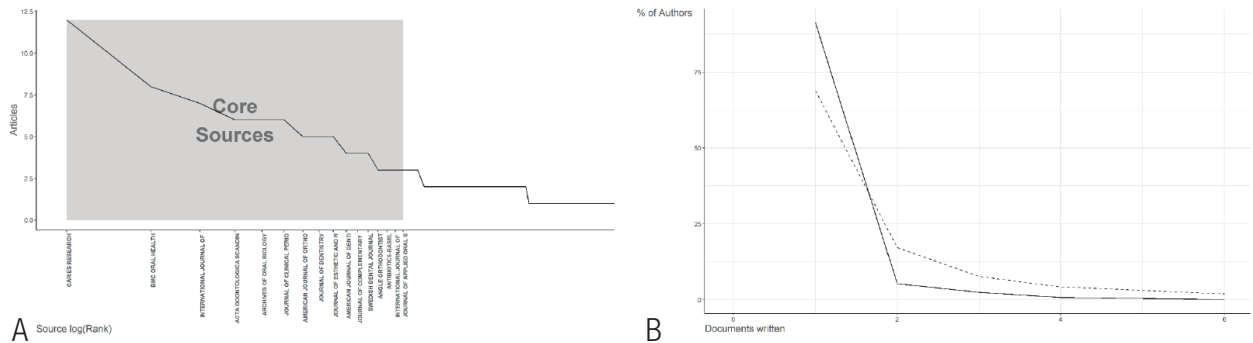


Figure 5. Bradford & Lotka's Law.

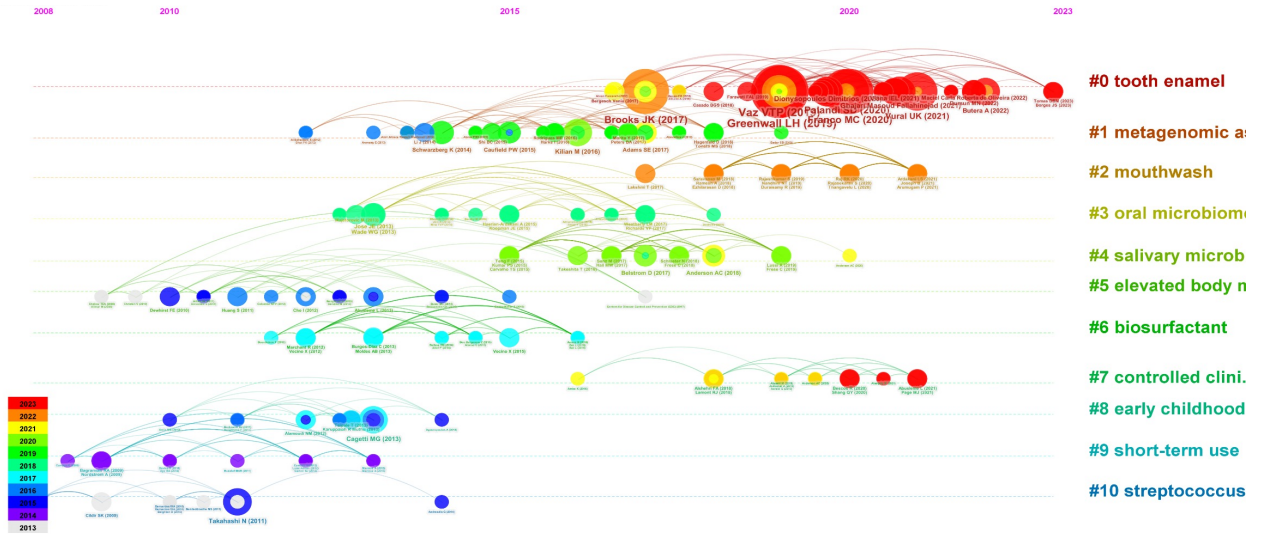


Figure 6. The timeline view clusters.

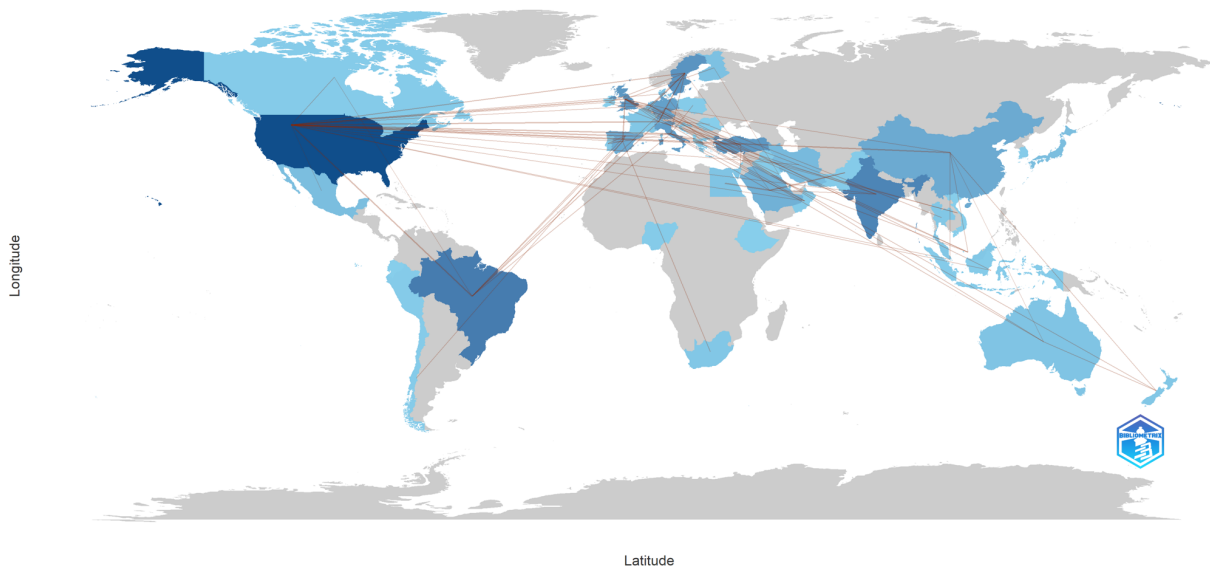


Figure 7. Country collaboration map.

## DISCUSSION

Activated charcoal is a fine black powder obtained by superheating charcoal and other natural products, resulting in a very porous substance. It has long been used in emergency departments for the treatment of drug overdoses (17-19). In dentistry, activated charcoal is used in products such as toothpaste. Although it may sound strange, manufacturers claim that it can be very beneficial for oral health. The alleged benefits of charcoal-based dental antimicrobial and antifungal. However, researchers have found that there is insufficient clinical evidence to support these claims (20).

Although there is little research evaluating the clinical efficacy of organic dentifrices, there appears to be a growing trend in their use. It is important to obtain scientific evidence on their ability to remove external discoloration, their abrasive action, and their possible effects on enamel (21). Given this, questions arise about the remineralizing effects of organic toothpastes. It is essential to answer these questions to promote their use and provide evidence-based clinical recommendations to both practitioners and patients. None of the studied formulations included ozonated olive oil. The additional database can be accessed from the corresponding author upon a reasonable request, and it's possible to search all the individual ingredients listed (22).

Regular use of fluoride toothpastes is an important measure to prevent caries or other dental diseases. However, toothpastes with high concentrations can cause alterations in developing teeth (23). Activated charcoal is a popular component in dental products, such as toothpastes and mouthwashes, due to its adsorption and impurity removal properties. Although further research is needed to confirm its efficiency in these types of products, it should be noted that not all dental products with activated charcoal contain fluoride,

an essential component for combating dental caries. Therefore, it is advised to opt for products with activated charcoal that also contain fluoride for better oral outcomes (24).

The bibliometric analysis of activated charcoal and probiotics provides a detailed overview of research and development in the field of dental products containing these ingredients. This analysis allows researchers and practitioners to better understand current and future trends in the use of activated charcoal and probiotics in dental products, as well as their efficacy and safety. By examining the dynamicity, spatio-temporal evolution and trends in this field, promising areas of research can be identified, and more effective products can be developed to improve oral health. In our research, we conducted a comprehensive bibliometric analysis of activated charcoal applications in dentistry, identifying trends and topics explored and evaluating available research. This analysis allows us to integrate entire fields of research or specific areas of scientific application to gain a more complete understanding of the potential of activated charcoal in improving oral health.

Potential limitations could include the need to look at data from other databases besides Scopus, such as Embase and PubMed. This could provide a broader and more in-depth view of scientific papers related to the topic. Although Scopus is among the largest databases for dental-related content, it's important to carefully consider the findings from it, as they might not encompass the entirety of worldwide research.

## CONCLUSIONS

In conclusion, the scientometric analysis revealed that the data covers a period from 1990 to 2023 and includes 150 sources such as journals and books. A total of 248 documents were analyzed, with an annual growth rate of 9.97% and an

average age of 7.49 years. The average number of citations per document was 18.55, with a total of 8206 references. The most frequent terms in the analyzed papers included "mutans streptococci" (7 times), "plaque" (5 times) and "lactobacilli" (8 times). The highest co-citation occurred in cluster 9 (Dentistry, Dermatology, Surgery), indicating a higher relevance and frequency with cluster 8 (Molecular Biology, Genetics). The most representative journals were "Caries Research" (12 articles), "BMC Oral Health" (8 articles) and "International Journal of Dental Hygiene" (7 articles).

#### CONFLICT OF INTEREST

No conflict of interest.

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This research did not receive grants.

#### AUTHOR CONTRIBUTION STATEMENT

Conceptualization and design: F.M., C.M.V., F.E.C., and F.M.T.

Literature review: L.V., D.G.V and D.A.T.

Methodology and validation: F.M.T. and F.E.C.

Formal analysis: F.M., F.M.T., and C.M.V

Investigation and data collection: F.E.C. and D.G.V.

Resources: F.E.C. and L.V.

Data analysis and interpretation: F.M.T., F.E.C., D.G.V., F.M.

Writing-review and editing: L.V. C.M.V., and F.M.

Supervision: F.M.T.

Project administration: F.M. F.E.C. and L.V.

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## Research Article

# Web of Science-Based Scientometric Assessment of the Importance of Filtered Water in Dentistry: Spatiotemporal Dynamics, Emerging Patterns, and Collaboration

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**Objective.** The aim of this study was to examine the characteristics of scientific production related to the use of filtered water in the field of dentistry. **Material and Methods.** A quantitative and descriptive observational study was carried out with a scientometric approach. Data were collected from the Web of Science (WOS) database during the period January 1991 to December 2023. A search strategy incorporating a combination of MeSH terms, including terms and thesauri related to “filtered water” and “dentistry”, was used. R Studio version 4.3.2 and CiteSpace 6.2.R7 were used for data analysis. **Results.** Over the 32-year study period, 227 scholarly papers from 134 different sources were reviewed. The literature in this field has shown an annual growth rate of 10.44%. During the year 2010, a steady movement in the number of publications and authors was observed, with considerable collaborative interaction. In the year 2020, a large interaction between publications and their citations was found. The “Citation Burst” graph identified three references that have experienced the largest “burst” of citations in an evaluated period. Lotka’s law described the productivity of authors, finding that most authors have published only one paper, while a smaller number of authors have published two papers. Most authors contributed a small number of articles, while a few authors contributed a large amount of the existing literature. **Conclusion.** A comprehensive overview of the scientific production related to the use of filtered water in dentistry over a span of 32 years is provided. The results highlight the growing interdisciplinarity and international collaboration in this field. Finally, the importance of filtered water in dentistry and its growing relevance in the scientific literature are emphasized.

## 1. Introduction

In dental practices, the use of purified water is crucial for ensuring cleanliness and safety during treatments. Ultrafiltration membranes have emerged as an effective alternative to traditional water purification methods due to their ability to filter out particles and microorganisms [1]. Water, being an essential resource in dentistry, is utilized in a myriad of procedures and equipment for purposes such as cooling and sterilization. However, the potential presence of impuri-

ties or contaminants in public water supplies could lead to postprocedural infections. As such, it is imperative that the water employed in dental clinics is of the highest quality [2].

Following dental extraction or any oral surgical procedure, cavities may collect food particles and other debris, potentially disrupting the healing process [3]. Factors such as smoking, inadequate oral hygiene, surgical trauma, and extraction of teeth with preexisting infections or diseases can impact this process. Meanwhile, the quality of tap water available to consumers is determined not only by the

treatment it undergoes but also by its journey through the water distribution system [4]. The development of biofilms on pipe walls or on particulate deposits, and their subsequent detachment, can contribute to the degradation of water quality [5, 6].

The occurrence of certain processes is influenced by various factors, including the presence of bacteria, organic matter and nutrients, and residual disinfectants. As such, it is vital to maintain rigorous control over these elements to guarantee water quality [7]. The goal of water filtration in dentistry extends beyond merely eliminating visible impurities; it also aims to remove pathogenic microorganisms that could be harmful to health. This proactive approach to managing the water used in dental practices aids in reducing the presence of bacteria, viruses, and other infectious agents, thereby minimizing the risk of hospital-acquired infections [8].

In the current context, the adoption of suitable filtration systems has become a standard practice in modern dental offices and clinics. These systems not only adhere to regulations but also offer an efficient and trustworthy solution for ensuring the purity of the water utilized in dental procedures [9, 10]. There has been an increased awareness about the significance of water quality in dentistry, leading to the widespread implementation of practices that enhance safety and health in the dental setting [11, 12]. Many dental clinics have instituted a water treatment cycle to guarantee water decontamination.

Scientific production based on the use of filtered water in dentistry is an area of growing interest due to its direct impact on the quality of patient care and safety in dental practices. The choice to investigate this topic is based on the need to better understand current trends, emerging practices, and collaboration patterns in this field. This scientometric study on filtered water in dentistry has significant clinical relevance. By identifying emerging trends and patterns, it can help dental professionals better understand the importance of filtered water in their practices. In addition, it can guide future research and policy in this field to improve patient care [1–9].

Thus, the aim of this study was to examine the characteristics of scientific production related to the use of filtered water in the field of dentistry.

## 2. Materials and Methods

**2.1. Study Design.** A descriptive study with a scientometric approach was carried out to evaluate the characteristics of the scientific production of filtered water in dentistry.

**2.2. Data Collection.** Data were extracted from the Web of Science (WOS) database for the period January 1991 to December 2023. The search strategy was performed on January 15, 2024, and 227 studies potentially related to the topic were found; this strategy included a combination of various MeSH terms, including terms and thesauri related to “filtered water” and “dentistry”. The strategy that was developed was as follows: TS = (“Filtered Water” OR “Purified Water” OR “Clean Water” OR “Purified Drinking Water”

OR “Distilled Water” OR “Treated Water” OR “Clarified Water” OR “Processed Water” OR “Refined Water” OR “Crystal-Clear Water” OR “Decontaminated Water” OR “Purged Water” OR “Microfiltered Water” OR “Ultrafiltered Water” OR “Reverse Osmosis Water” OR “Spring Water” OR “Pristine Water” OR “Untainted Water” OR “Safe Drinking Water” OR “Potable Water” OR “Crisp Water”) AND TS = (“Dentistry” OR “Oral and Maxillofacial Surgery” OR “Oral Surgery Procedures” OR “Dental Surgery” OR “Maxillofacial Surgery” OR “Oral Surgical Procedures” OR “Oral and Dental Surgery” OR “Dental Oral Surgery” OR “Oral Surgical Interventions” OR “Oral Surgery Treatments” OR “Dental Maxillofacial Surgery” OR “Maxillofacial Oral Surgery” OR “Dental Surgical Procedures” OR “Oral and Facial Surgery” OR “Oral and Dental Surgical Interventions” OR “Oral and Maxillofacial Surgical Techniques” OR “Dental Surgical Treatments” OR “Surgical Procedures in Oral Medicine” OR “Dental and Maxillofacial Surgery” OR “Oral and Facial Surgical Procedures” OR “Surgical Interventions in Oral Care” OR “Postoperative Socket Irrigation” OR “Post-Surgery Socket Rinse” OR “Post-Surgical Socket Cleaning” OR “After Surgery Socket Irrigation” OR “Reduces Risk” OR “Decreases Risk” OR “Lowers Risk” OR “Minimizes Risk” OR “Inflammatory Complications” OR “Inflammation-Related Complications” OR “Complications due to Inflammation” OR “Inflammatory Issues” OR “Surgical Removal of Third Molars” OR “Third Molar Extraction” OR “Wisdom Teeth Removal” OR “Third Molar Surgery”).

**2.3. Analysis Software.** The R Studio software version 4.3.2 (2023-10-31 ucrt) was utilized for this study, given its capabilities as a programming language for statistical analysis and scientometric graphics. Additionally, CiteSpace 6.2.R7 was employed for its ability to visualize and analyze trends and patterns in scientific literature.

**2.4. Data Analysis.** Data from the 227 studies were scrutinized to assess scientific output in this domain, identify literature patterns and trends, and evaluate collaborations among authors, institutions, and countries. The study also examined spatiotemporal dynamics, which involved tracking changes in scientific production in this field over time and across different locations.

## 3. Results

This study was conducted over a 32-year period, from 1991 to 2023. During this time, 227 academic papers from 134 different sources, including both journals and books, were reviewed. The literature in this field has experienced an annual growth rate of 10.44%. The papers have an average age of 9.3 years and have received an average of 15.5 citations each. In total, these documents refer to 7227 different papers. Regarding the content of the papers, 773 additional keywords and 649 keywords provided by the authors were identified. A total of 975 different authors contributed to these papers, with 6 of them writing single-authored papers. On average, each paper was co-authored by 4.57 people, and 20.7% of the papers had international collaboration.

Regarding the typology of the papers, the majority were articles (216), followed by early access articles (2), conference proceedings articles (3), editorial material (1), and reviews (5) (Table 1).

The “Timeline Visualization” facilitated the identification of trends and patterns in the data. This analysis revealed four distinct clusters over time, suggesting the emergence of four main themes. Notably, the visualization highlighted a consistent increase in the number of publications and authors in 2010, accompanied by substantial collaborative activity. Key contributors during this period included De Moor (2010) and Balvedi (2010) (Figure 1). Furthermore, a renewed surge in interaction between publications and their citations was observed from 2020 onwards. Backes (2020) and Liz (2020) were among the most prominent authors in this later period (Figure 1).

The “Dual Map Overlay” graph allowed for visualizing and analyzing the trends and patterns of scientific publications in this field. This graph showed two maps: one representing the disciplines of origin of the citations and the other the disciplines of destination. In this way, it can be observed how an origin influences the destination. The maps revealed a strong influence of the source disciplines (cluster 9 “Dentistry, Dermatology, Surgery”) on the target disciplines (clusters 5 “Health Nursing, Medicine” and 14 “Dentistry, Dermatology, Surgery”), indicating a significant flow of knowledge between these fields. In addition, a large, increasing trend in interdisciplinarity was observed, with an increasing number of citations with other clusters such as 2, 3, 10, and 11. This pattern suggests that the field of study is evolving towards an increasingly interdisciplinary nature (Figure 2).

The Sankey plot allowed us to analyze the relationship between three fields (country, author, and journal). This was useful to visualize the flow of information or the relationship between the different fields. Thus, a significant interaction was observed between the USA, Singapore, and India as the 3 most productive countries and the authors Yap, Aslandi, and Matinlinna. These findings provide a better understanding of the structure and evolution of this field (Figure 3).

The Citation Burst graph identified three references that have experienced the largest “burst” of citations in an evaluated time period. This evidenced a sudden and significant increase in the number of times these papers were cited. These studies correspond to Barutcigil (2012), Scribante (2019), and Acar (2016) (Figure 4).

Lotka’s law described the productivity of authors. It was found that most authors (922) have published a single paper, whereas a smaller number of authors (49) have published two papers, and only a few authors have published more than two papers. These findings suggest that, in this field of study, most authors contribute a small number of papers, while a small number of prolific authors contribute a large amount of the existing literature (Figure 5).

Bradford’s law showed that Zone 1 includes the most productive journals, and it was found that 13 journals have published a total of 73 articles. Zone 2, on the other hand, included 37 journals that have published a total of 70 arti-

TABLE 1: Main data information.

Description	Results
Main information about the data	
Timespan	1991–2023
Sources (journals, books, etc.)	134
Documents	227
Annual growth rate (%)	10.44
Document average age	9.3
Average citations per document	15.5
References	7227
Document contents	
Keywords plus (ID)	773
Author’s keywords (DE)	649
Authors	
Authors	975
Authors of single-authored docs	6
Authors collaboration	
Co-authors per doc	4.57
International co-authorships (%)	20.7
Document types	
Article	216
Article: early access	2
Article: proceedings paper	3
Editorial material	1
Review	5

cles. These findings suggest that a small number of journals contribute a large proportion of the literature in our field of study (Figure 6).

#### 4. Discussion

In a dental office, tap water undergoes multiple treatment steps before use. Initially, it is filtered and stored in a reservoir, then decalcified using a high-performance resin [13]. The dental unit is a system that distributes water to various locations through a hydraulic system: patient cups, bottled water reservoirs, ultrasonic scalers, handpieces for high-speed drills, and air and water syringes [14]. All this is done to prevent infection and contamination. Water systems in residential and older buildings may be contaminated with *Legionella*, posing a potential risk to patients [15].

In addition, water is also important for overall oral health. Drinking sufficient water daily helps to maintain good oral health by preventing several oral conditions [16, 17]. Drinking water, which is a combination of desalinated water and groundwater, is provided at a reduced cost to most households [18]. Community water fluoridation has been recognized for its substantial contribution to enhancing dental health by reducing the prevalence of caries [19]. This approach is not only safe but also economically efficient in mitigating caries across large populations. However, water can serve as a carrier for bacteria, and an elevated



References	Year	Strength	Begin	End	2014 – 2024
Barutcigil C, 2012, J DENT, V40, PE57, DOI 10.1016/j.jdent.2011.12.017, DOI	2012	1.09	2015	2016	
Scribante A, 2019, INT J MOL SCI, V20, P0, DOI 10.3390/ijms20236043, DOI	2019	1.91	2020	2021	
Acar O, 2016, J PROSTHET DENT, V115, P71, DOI 10.1016/j.prosdent.2015.06.014, DOI	2016	0.95	2020	2021	

FIGURE 4: Top 3 references with the strongest citation burst.

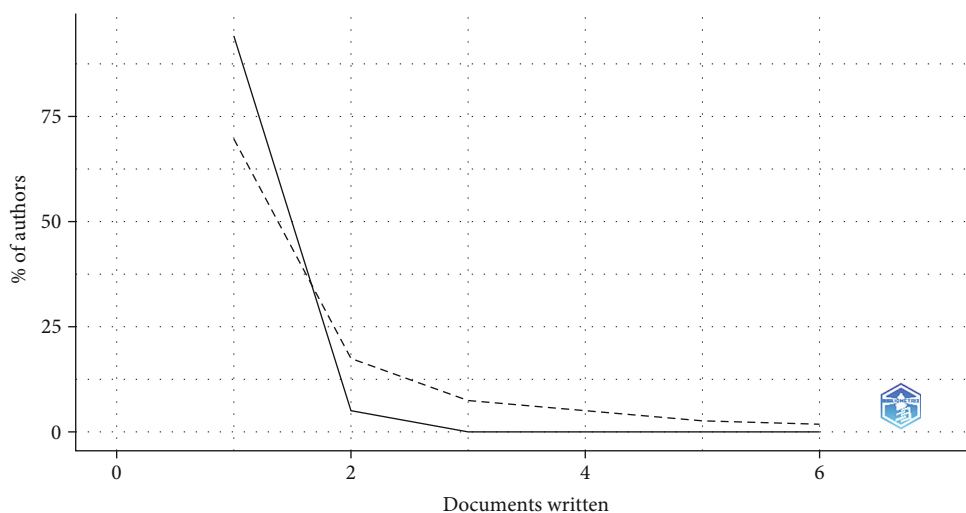


FIGURE 5: Author productivity (Lotka's law).

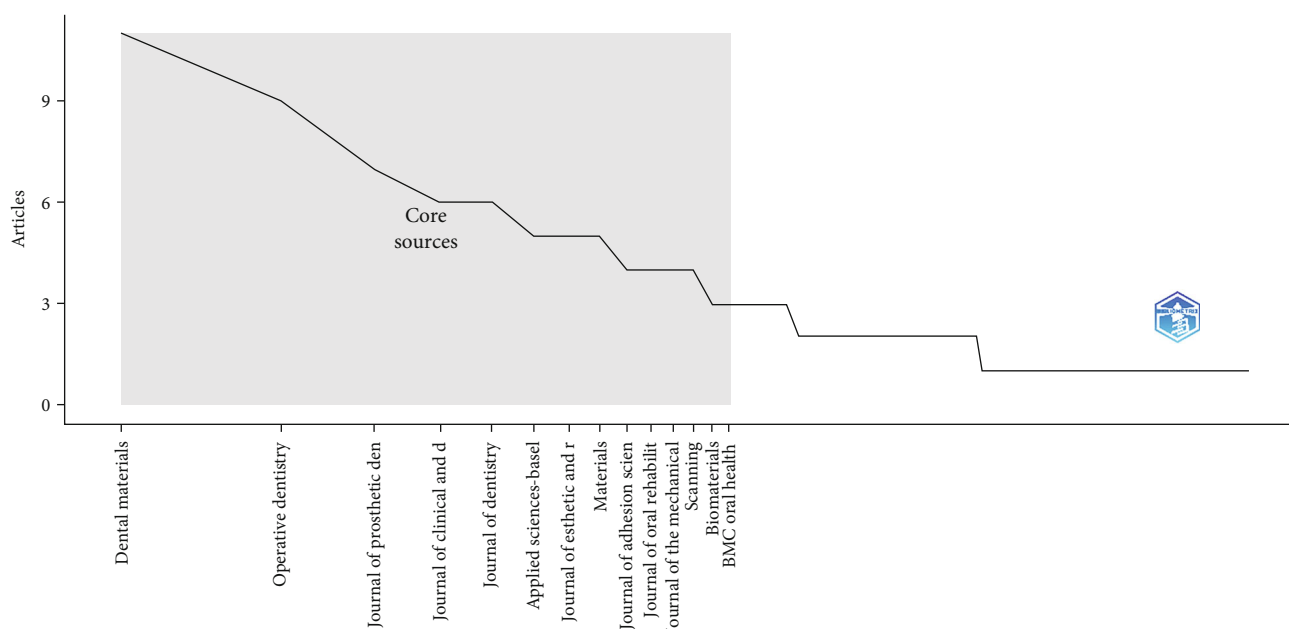


FIGURE 6: Core sources (Bradford's law).

concentration of fluoride in drinking water could result in dental fluorosis [20].

Despite progress in delivering safe drinking water, billions of people worldwide still lack access to this vital resource. The implications of this deficiency are alarming, as they correlate directly with preventable diseases and fatalities [21]. In this context, securing access to safe and sustain-

able drinking water has become a critical objective and an urgent challenge for global public health. Tackling this issue will not only enhance individual health and well-being but is also a fundamental requirement for human survival and prosperity. The provision of safe drinking water has surfaced as one of the most pressing public health challenges of our time [22, 23].

In recent years, technology has broadened its global influence. Reverse osmosis, a process that filters water through a dense membrane to segregate contaminants, removes all suspended particles, including organic residues, colloids, bacterial and viral contaminants, and ionic salts [24]. Consequently, reverse osmosis systems have been widely employed to enhance drinking water quality and ensure water supply, even in emergencies. In dentistry, the use of filtered water is paramount. It not only guarantees the safety and effectiveness of dental procedures but also aids in preventing oral and systemic diseases. As research and technology progress, it is crucial to continue exploring and optimizing water filtration methods to further enhance the quality of dental care [25].

Unlike our study, the bibliometric study on advanced oxidation processes (AOPs) by Macías-Quiroga et al. revealed research trends worldwide and in Ibero-America in the field of wastewater treatment. The 18,751 records were retrieved from Scopus and Web of Science. The information was meticulously sorted and sifted through, pinpointing authors and corresponding institutions. The study provided a visual representation of research trends, encompassing aspects such as the triennial publication count, country-wise publication distribution, continental participation, leading journals and authors, and the most cited institutions. It also offered a global co-author network and a visualization of the keyword network, underscoring the significant contribution of Ibero-America to worldwide research [26].

In contrast, a bibliometric study conducted by Ballesteros et al. on the topic of water disinfection using solar energy unveiled that innovative and sustainable alternatives such as solar water disinfection (SODIS) and solar photocatalysis are being employed. The USA, Spain, and China are leading in terms of publication output in this burgeoning field, while the most acclaimed research groups are based in Europe. The majority of the publications are centered around SODIS and photocatalytic nanomaterials. However, a smaller portion is dedicated to ensuring sufficient levels of water disinfection, testing regulated microbial indicators and emerging pathogens, and applying these methods in real-world scenarios [27].

Lastly, paralleling our study, a bibliometric analysis conducted by Chen et al. offered an extensive overview of research on wastewater treatment and emerging pollutants spanning from 1998 to 2021. The study amassed a total of 10,605 publications, with China leading in terms of publication count and exhibiting the closest collaboration with the United States. The most frequently cited papers underscored that purification or elimination techniques like ozonation or membrane filtration are effective in removing pharmaceutical compounds from water bodies [28].

Some potential limitations were presented in the present study. First, the findings are based only on the existing literature in WOS and, therefore, may be subject to potential selection bias. Second, international collaboration was measured only in terms of co-authorship, which may not necessarily fully reflect the nature and extent of collaboration at the global level. Third, although emerging trends and patterns were identified, these should be interpreted with cau-

tion, as the field of study is constantly evolving and trends may change over time. However, the present study had some strengths; for example, it provides a comprehensive overview of the evolution of scientific production in the use of filtered water in dentistry, covering a broad period of time. A detailed analysis of publications was performed, including collaboration between authors and countries, and emerging trends and patterns were identified, despite the constant evolution of the field. The use of advanced scientometric tools to analyze the data increases the accuracy and validity of the results. In addition, the study highlights the importance of international collaboration in this field, despite limitations in its measurement, which may foster future collaborations and advances in research.

The choice to extract data only from the Web of Science for this study is based on several reasons. Firstly, the Web of Science is one of the most comprehensive and reliable databases for scientific literature, spanning various disciplines and providing detailed citation information, which is crucial for a scientometric study. Secondly, it has a friendly user interface and offers advanced tools for data analysis, making it easy to extract and analyze data. However, we recognize that the exclusive use of the Web of Science may limit the coverage of the study, and we suggest that future research could consider the inclusion of other databases to obtain a more complete view.

## 5. Conclusion

Within the limitations of this study, it is concluded, first, that a detailed vision of the scientific production in the field of water filtration in dentistry is provided over a period of 32 years, which allows us to understand how this has evolved in the field over time. Second, by identifying emerging trends and patterns in the literature, this study can help researchers identify areas of interest and opportunities for future research. Furthermore, by highlighting international collaboration and knowledge sharing between different disciplines, this study underlines the increasingly interdisciplinary nature of this field. Lastly, by emphasizing the importance of water filtration in dentistry, this study may contribute to increasing awareness of the need to ensure the quality of water used in dental practices, which may have direct implications for patient safety and the effectiveness of the treatment. In summary, this review has the potential to inform and guide both clinical practice and future research in the field of dentistry. In addition, the study underscores the critical role of water filtration in patient safety and treatment efficacy, emphasizing the need for stringent quality control measures in dental practices. In essence, this review serves as a roadmap for advancing water filtration practices in dentistry, ensuring optimal patient care and treatment outcomes.

## Data Availability

The data are available upon request to the corresponding author.

## Conflicts of Interest

The authors declare that there are no conflicts of interest.

## Acknowledgments

The authors declare that the entire study was carried out with their own resources.

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# Shear strength of metal brackets using LED lamps with different wavelengths: An *in vitro* comparative study

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## Abstract

**AIM:** To evaluate the shear strength of Orthocem and BracePaste polymerizable cement light-cured with light-emitting diode (LED) units with different wavelengths (Bluephase N) with their high power, low power, and soft start programs in the bonding of metal brackets.

**MATERIALS AND METHODS:** *In vitro* experimental research was performed. Mini Roth 0.022 metal brackets (Roth Orthometric brackets) were used. The adhesives were placed on the metal brackets with Orthocem and BracePaste resin cement. To compare the average strengths, the analysis of variance (ANOVA) test was used ( $P < 0.05$ ).

**RESULTS:** The average shear strength was better with Bracepaste polymerizable cement compared to Orthocem cement in all its high power, low power, and soft star programs; the highest was Bracepaste with soft start of 26.52 MPa, and the lowest was Orthocem with soft start of 13.92 MPa. When evaluating the differences, it was found that these were statistically significant in all groups ( $P < 0.05$ ).

**CONCLUSIONS:** Differences were found in the shear strength of light-curing Orthocem and Bracepaste light-curing cement cured with LED units with different wavelengths in bonding metal brackets to the tooth *in vitro*.

## Keywords:

Bracket, shear bond, strength

## Introduction

Orthodontic treatments are presenting a great technological advance, especially since adhesion was discovered with the use of resins. Previously, brackets were soldered to metal bands, which were cemented on all teeth, which was unfavorable for patients and orthodontists in terms of dental esthetics and clinical consultation time. Over the years, biomaterials in orthodontics have been evolving to present better properties and reduce clinical times, for example, adhesion systems have changed from a first to a seventh generation, and the mesh of the bracket bases

present a series of physical and chemical modifications to obtain better retention and guarantee the results of the treatments.<sup>[1-8]</sup>

Recently, some high-power (light-emitting diode [LED] polymerization sources can emit intense light radiation of 1600–2000 YmW/cm<sup>2</sup>. This allows shorter exposure times, reportedly up to an average of 6 s to bond metal brackets to the enamel surface.<sup>[3]</sup>

Several generations of high-intensity LED units<sup>[2,8]</sup> that have larger emitting areas have been introduced to decrease the time required to bond orthodontic attachments and optimize the bonding procedure.<sup>[5-7]</sup> In addition, it has been suggested that free

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radicals occur when light and diffusion of free radicals take time to polymerize the composite at the base of the bracket. Because the polymerization light cannot pass through the metal alloy, the number of free radicals produced and the degree of conversion appear to be lower when bonded to the metal surface than to the enamel surface.<sup>[8,9]</sup>

Polymerization is initiated using visible light in the blue range of the electromagnetic spectrum to excite the outermost layer of camphorquinone, which has an absorption spectrum of 400 and 500 nm. For this reason, many light-curing options exist such as halogen, laser, and LED units. However, there are only two light sources, halogen and LED. Newer models of dental lamps have various settings that use the yellow spectrum instead of the blue during polymerization. This is a critical factor to avoid premature light curing of the composite.<sup>[10-13]</sup>

Therefore, the aim of this study was to evaluate *in vitro* the shear strength of Orthocem and BracePaste polymerizable cement light-cured with LED units with different wavelengths (Polywave Bluephase N) with their high power, low power, soft start programs in the bonding of metal brackets to the tooth.

## Materials and Methods

### Study design

The study was an *in vitro* experimental design. It was carried out at the High Technology Laboratory Certificate Laboratory, Lima-Peru. The Checklist for Reporting *In-vitro* Studies (CRIS) guidelines were used for the preparation of this manuscript. The unit of analysis consisted of each bovine mandibular incisor tooth. The sample size was calculated with the mean comparison formula and the Stata 17 software. Determining a sample of 90 specimens, 15 teeth per group were divided into the following groups:

With high intensity (high power) and its power of 1200 mW/cm<sup>2</sup>

Group 1: Orthocem resin (high power).

Group 2: BracePaste resin (high power) with intermediate intensity (soft star) and its power of 650 to 1200 mW/cm<sup>2</sup>.

Group 3: Orthocem resin (soft star).

Group 4: BracePaste resin (soft star)

with reduced intensity (low power) and its power of 650 mW/cm<sup>2</sup>.

Group 5: Orthocem resin (low power).

Group 6: BracePaste resin (low power).

### Storage and preparation of the teeth

Immediately after exodontia, the teeth were washed with distilled water, and blood and soft tissue debris were removed. They were then stored in physiological saline and stored in a refrigerator at 4°C. The surface was prepared with abrasive discs and distilled water; finally, it was verified that all surfaces of the teeth had been prepared to a similar depth and that they had a uniform surface.

### Application of Orthocem and BracePaste adhesives

The adhesive material was applied with a thin film on the surface of the bovine tooth for 10 s of polymerization, and then mini Roth 0.022 metal brackets (Roth Orthometric brackets) were used. Resin adhesives were placed over the metal brackets with Orthocem and BracePaste resins. The light-curing time was 20 s in different directions.

After removing the excess resin, as the case may be, the tip of the LED Polywave N lamp, with its different programs of high power, low power, and a soft start, was placed on the bonding resin on the bovine parts.

### Shear strength

The test specimens were carefully stored in simple distilled water at 37°C for 48 h until the appropriate time to perform the shear strength test bonded with Orthocem and BracePaste cement. Shear strength tests were performed on all bovine incisor teeth. During the tensile test, the tensile force was applied at 90 degrees to the surface plane of the substrate. A digital universal testing machine, LG model CMT-5L, was used following the standardized norms, the measurement was supervised by an engineering expert in the use of the machine, and a load force of 0/500 N with an accuracy of  $\pm 0.001$  N was used. Finally, the bond strength value is in MPa (Megapascals).

### Statistical analysis

Summary measures (mean and standard deviation) were determined for each group. To compare tensile strength, the analysis of variance (ANOVA) test was used with a significance level of  $P < 0.05$ . Normal distribution was evaluated with the Shapiro-Wilk test for all groups. The analysis was performed with the Stata 17 program.

## Results

The mean tensile strength was highest with Orthocem polymerizable cement with low power at  $18.80 \pm 2.30$  Mpa, followed by high power at  $17.39 \pm 1.93$  Mpa, and lastly soft start at  $13.92 \pm 1.63$  Mpa. When the differences were evaluated, they were found to be significant ( $P < 0.001$ ) [Table 1].

**Table 1: In vitro comparison of shear strength of light-curing cement cured with different wavelength LED units**

	High power		Soft start		Low power		P*	P**
	Mean	SD	Mean	SD	Mean	SD		
Orthocem	17.39	1.93	13.92	1.63	18.80	2.30	0.05	0.001
BracePaste®	19.58	3.34	26.52	3.54	21.18	2.92	0.05	0.001
P**	0.001		0.001		0.001			

\*Shapiro–Wilk's normality test. \*\*ANOVA statistical test. All values were expressed in Mpa

The mean tensile strength was highest with the BracePaste polymerizable cement with a soft start at  $26.52 \pm 3.54$  Mpa, followed by the low power at  $21.18 \pm 2.92$  Mpa, and lastly the high power at  $19.58 \pm 3.34$  Mpa. When the differences were evaluated, they were found to be significant ( $P < 0.001$ ) [Table 1].

The mean tensile strength was better with BracePaste polymerizable cement compared to Orthocem™ cement in all groups (high, soft, and low powers). The differences were found to be statistically significant ( $P < 0.001$ ) [Table 1].

## Discussion

It is known that light sources for light curing have evolved from halogen light to LED lamps at different wavelengths. To optimize the time required for light curing, it should be kept in mind that the bonding strength achieved between the bracket and the tooth should be sufficient so that the detachment rate is as low as possible to avoid the patient returning frequently to the office for re-attachment of the brackets. There is a wide variety of LED lamps of different intensities, origins, and prices. These can be presented as a single lamp (monowave) or with different intensities or wavelengths (polywave) in the same model, depending on the manufacturers. They can require from 40 to only 3 s to achieve polymerization.<sup>[14-19]</sup> For this reason, the results obtained in the present study make it possible to identify the shear strength of Orthocem polymerizable cement and BracePaste light cured with LED units with different wavelengths (Bluephase N) with their high power, low power, and soft star programs in the bonding of metal brackets.

For example, according to the study by Swanson *et al.*,<sup>[14]</sup> which evaluated the association between the shear strength of metal brackets bonded to enamel under LED light vs. other curing devices with quartz, tungsten, and halogen light, the mean shear strength resistance in all test groups was higher than 8 MPa even at 10 s of light curing. Similarly, Almeida *et al.*<sup>[15]</sup> evaluated the effect of shortening the curing time of a high-power LED device (Valley, Ultradent; South Jordan, UT, USA) on the shear strength of metal brackets. They found that time

and composition significantly affected bracket adhesion. In addition, they mentioned that decreasing the exposure time from 6 to 3 s significantly reduced the average shear strength values even when using a high-power LED unit.

However, De Abreu *et al.*<sup>[16]</sup> also evaluated the effect of different light sources, thermal cycling, and silane application on the bond strength of metal and ceramic brackets. They found that the bond strength of light sources with and without thermal cycling increased the bonding in silane groups. In summary, it can be stated that silane significantly improved the performance of ceramic brackets. Although Rachala *et al.*<sup>[17]</sup> mentioned that diode-curing units have recently been used to light-cure orthodontic brackets; however, they showed that the comparisons had no significant difference in shear strength scores among the groups evaluated.

Amer and Rayyan<sup>[18]</sup> evaluated the effect of many bonding techniques on the shear strength between brackets and other biomaterials. They concluded that the shear strength between zirconia crowns and metal brackets was highly dependent on the surface treatment used. Therefore, sandblasting increased the shear strength.

All this is very important during orthodontic treatment because bracket misalignments will directly impact the success of orthodontic treatment.<sup>[19]</sup> In our research work, it was found that the mean shear strength was highest with BracePaste soft star polymerizable cement with 26.52 MPa and a standard deviation of 3.54, followed by low power with 21.18 MPa and a standard deviation of 2.92, and finally high power with 19.58 MPa and a standard deviation of 3.34. When evaluating the differences, it was found that these were significant ( $P < 0.05$ ); thus, our findings are like those of some studies described in the literature.

Studies are limited on the shear force generated in the bonding of brackets with polymerizable cement using an LED with different wavelengths (Polywave N) with its programs (high power, low power, and soft start) that probably use less time polymerizing than conventional LED lamps, which could optimize the clinical procedure significantly, reducing labor time and providing greater comfort for the patient, and operator. Finally, an adequate adhesion of the brackets to the tooth will be achieved using polymerizable cement.

It is recommended to conduct future research to study the polymerization shrinkage of light-curing cementitious resins with stimuli such as light, heat, ultraviolet, and pressure to determine if these improve or worsen the properties of the resins. The success of clinical treatments involves other aspects besides strength such as proper

planning and correct handling of the material according to the manufacturer's instructions.

## Conclusions

Among the results of this *in vitro* study, significant differences were found in the tensile strength of Orthocem photopolymerizable cement and BracePaste cement light-cured with LED units of different wavelengths (Polywave Bluphase N) with their high power, low power, and soft star programs; therefore, it is important to consider these findings as parameters to be considered during the choice of biomaterials for bracket cementation.

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## Author contributions

FM, JM, CMV, LV, RM, and FMT conceived the ideas. FM, JM, CMV, LV, RM, and FMT contributed to data collection. FM, JM, CMV, LV, RM, and FMT analyzed the data. FMT led the writing. FM, JM, CMV, LV, RM, and FMT critically revised the manuscript and gave final approval.

## Ethical policy and institutional review board statement

Not applicable as this was a narrative review.

## Patient declaration of consent

Not applicable.

## Data availability statement

Data is available on appropriate request to the corresponding author.

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## Conflicts of interest

There are no conflicts of interest.

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