






A bibliometric analysis of the top 100 most-cited articles concerning the use of propolis in dentistry

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Aim: The objective of this bibliometric analysis was to identify and analyze the key characteristics of the 100 most-cited articles related to the use of propolis in dentistry. **Methods:** The search was conducted in the Web of Science Core Collection, and two independent reviewers selected the articles, excluding meeting articles. The number of citations for each article was compared across the Scopus and Google Scholar databases. The extracted data included the number and density of citations, year of publication, journal and impact factor, study design and theme, country and continent, institution, keywords, and authors. VOSviewer software was employed to generate collaborative network maps. Spearman correlation and Poisson regression analyses were performed on the data. **Results:** The number of citations ranged from 26 to 247, with a citation density varying between 1.08 and 20.00. Articles were published between 1991 and 2021, with laboratory studies (70%) and antimicrobial activity (39%) being the most prevalent study design and theme, respectively. The most discussed dental specialty was microbiology (49%). Rosalen PL (27%) emerged as the author with the highest number of articles, and the University of Campinas (Brazil) was the most prolific institution. Poisson regression indicated a declining trend in citations over the years, though literature reviews exhibited higher citation performance. Brazil contributed the highest percentage of articles (41%). **Conclusion:** In conclusion, the 100 most-cited articles predominantly comprised laboratory studies investigating the antimicrobial activity of propolis, primarily originating from Brazil, with notable emphasis on the University of Campinas.

Keywords: Propolis. Biological products. Dentistry. Oral health. Bibliometrics.



Introduction

Natural origin products are extensively studied due to their therapeutic potential for various diseases, with a lower risk of adverse effects¹. Currently, 80% of the world's population uses natural products or phytotherapeutics². Thus, there has been an exponential increase in the evaluation and utilization of bee products such as propolis in various healthcare areas due to the efficacy of its pharmacological properties³.

Propolis is a mixture of resin collected by bees, dependent on the availability of regional plants, geographical conditions, local climate, and the age of the bees⁴. It has a diverse composition of resins, sap flowers, wax, trees, pollen, aromatic oils, and essential oils⁵. Bees use it to seal spaces, increase hive temperature, and protect against the entry of microorganisms⁶. Chemically, its composition presents an immense diversity of molecular compounds such as vitamins, amino acids, minerals, polyphenols, flavonoids, terpenoids, and phenolic acids, consequently exhibiting broad biological activity⁷.

Among the main biological properties of propolis described in the literature, notable actions include antibacterial, anti-acne, hepatoprotective, anticancer, anti-inflammatory, anti-SARS-CoV-2, antifungal, antioxidant, and neuroprotective effects^{8,9}. Its use in dentistry has shown promising results, especially for the control of periodontal diseases such as periodontitis and gingivitis, storage and transportation of avulsed teeth, dentin hypersensitivity, oral mucositis, prosthetic stomatitis, endodontic irrigant, cold sores, and aphthous ulcers^{3,10}.

Bibliometric analysis employs quantitative tools based on data extracted from published studies to reveal scientific trends in a specific clinical field. In broad areas with a high number of publications, it is suggested to analyze the most relevant articles in terms of citation count¹¹. Therefore, by analyzing the citations of an article, it quantitatively demonstrates the importance of that area, providing insights into future perspectives on a specific topic based on classical articles, as well as recognizing institutions, authors, countries, and journals¹².

In this context, some previous studies conducted bibliometric analyses on relevant dental topics to determine the scientific status of a particular subject^{11,13}. However, to our knowledge, no bibliometric review has been conducted on the use of propolis in dentistry, making this the first. Therefore, this study aims to analyze the key characteristics of the 100 most-cited articles related to the use of propolis in dentistry, identifying authors, journals, countries, institutions, study designs, and prominent themes.

Methodology

Information Sources and Search Strategy

On June 8, 2023, an electronic search was conducted in the Web of Science Core Collection (WoS-CC) database. The following search strategy was employed for study selection: TS = ("Propolis" OR "Green Propolis" OR "Red Propolis" OR "Honeybee" OR

"Polish Propolis") AND (Dentistry OR "Diagnosis, Oral" OR "Oral Diagnosis" OR "Oral Medicine" OR "Dental Science" OR "Oral Research" OR "Oral Health").

Eligibility Criteria

Studies included in this bibliometric analysis investigated, described, or mentioned the properties of propolis in dental applications. There were no restrictions on the year of publication or language. Excluded publications were those where propolis was not used for dental purposes, as well as conference articles, editorials, and meeting abstracts.

Selection Process

Identified articles were arranged in descending order based on the absolute number of citations. Three independent reviewers (JAOT, AOR, and LMA) selected articles after reviewing the title, abstract, and full text when necessary. Discrepancies were resolved through consensus with a fourth reviewer (FAS). In case of a tie in the number of citations, the article's position on the list was based on the higher density (number of citations per year) from WoS-CC.

Data Extraction

Bibliometric data were extracted for each article, including the number of citations, publication year, journal, impact factor (IF) (Journal Citation Reports from Clarivate Analytics, 2021), study design, theme, country and continent, institution (based on the corresponding author's affiliation), keywords, and authors. Study designs were classified as systematic reviews, literature reviews, laboratory studies, and intervention studies. Two researchers (AOR and LMA) extracted the data. Subsequently, the number of citations for each selected article was cross-referenced with Scopus and Google Scholar.

Articles were grouped into two themes. The first theme addressed the primary objectives related to the use of propolis in the study, categorized into: anti-inflammatory, antimicrobial activity, anti-plaque, aphthous ulcers, chronic periodontitis, dental caries, oral cancer, pulp protection, and re-implanted teeth. The second theme grouped studies based on the associated dental specialty: endodontics, microbiology, periodontics, oral pathology, and traumatology. Studies appearing only once and not fitting into the mentioned themes were classified as "others." Extracted data were transferred to Microsoft Excel® 2010 for categorization.

Statistical Analysis

The Visualization of Similarities Viewer (VOSviewer, Leiden University, Netherlands) software was used to generate a graphical representation of bibliometric networks, illustrating the connections between authors and keywords. Circle size is proportional to the data strength in the network. Items represented by similar colors and interconnected in the same cluster demonstrate correlation between the data. The Kolmogorov-Smirnov test assessed data distribution normality. Spearman's correlation coefficient test, due to non-normal distribution, was used for statistical analysis. Poisson regression analysis determined associations between the number of cita-

tions (WoS-CC) and the journal's impact factor, study design, continent, and year of publication. These analyses were conducted using IBM SPSS Statistics for Windows version 24.0 (IBM Corp.) with a significance level of 5% ($p = 0.05$).

Results

Search Results

The primary search yielded 698 articles, which were organized in descending order based on the number of citations. To identify the top 100 most-cited articles related to the use of propolis in dentistry, the first 160 documents were analyzed, of which 60 were excluded for not addressing the proposed theme. After the selection process, the top 100 most-cited articles related to the use of propolis in dentistry were identified (Supplementary Table 1).

Citation Analysis

The top 100 articles received a total of 6,553 citations in WoS-CC. The number of citations ranged from 26 to 247. Self-citations accounted for 6.7% ($n=436$) of WoS-CC citations. Fifteen articles were cited more than 100 times. In the other two databases, a higher number of citations was observed, with 7,767 (ranging from 28 to 293) in Scopus and 15,205 (ranging from 22 to 556) in Google Scholar. There was a strong positive correlation between the number of citations in WoS-CC and Google Scholar ($\rho = 0.820$; $p < 0.001$) and a very strong positive correlation between WoS-CC and Scopus ($\rho = 0.953$; $p < 0.001$). The findings reveal a consistent trend in the number of citations across databases, particularly between WoS-CC and Scopus.

The most-cited article in WoS-CC¹⁴, accumulating an average of 15.44 citations per year, was also the most-cited in Google Scholar (556 citations). However, another study performed better in Scopus¹⁵. The second most-cited article in WoS-CC¹⁶, accumulating an average of 11.62 citations per year, was also the second most-cited in Scopus (288 citations). However, the second most-cited in Google Scholar (554 citations) was the first most-cited in Scopus¹⁵.

The article with the highest citation density in WoS-CC (20.00)¹⁷ was a literature review published in the journal *Foods*. The second article with the highest citation density in WoS-CC (17.17)¹⁸ was a literature review published in the *Archives of Oral Biology*.

Year of Publication

The oldest article was published in 1991¹⁹, and the most recent articles were published in 2021^{17,20}. The majority of articles among the top 100 cited ($n=58$) were published in the decade between 2007 and 2016. A description of the number of publications each year can be seen in Supplementary Figure 1. The Poisson regression analysis indicated a correlation between the number of citations in WoS-CC and the publication year of the studies. Specifically, the number of WoS-CC citations exhibited a decrease of 4.5% per year (RR: 0.955; 95% CI: 0.951-0.959; $p < 0.001$) (Table 1). This outcome suggests that, on average, older articles tended to accumulate a higher number of citations.

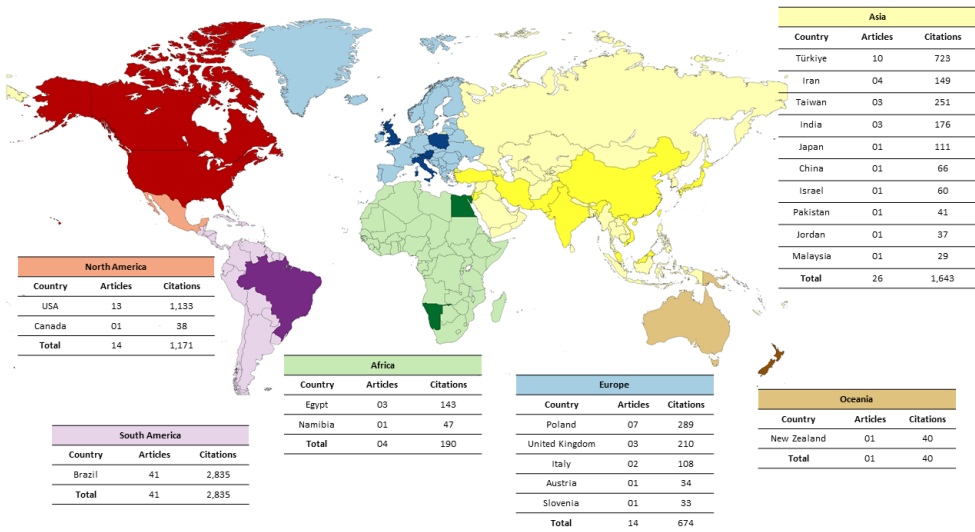


Fig 1. Worldwide distribution of the origin of publications on propolis and dentistry. The continents then delimited in lighter tones and the countries associated with the articles are identified with darker tones referring to their continent. Brazil and South America stand out with the highest number of publications.

Table 1. Poisson regression between the total number of WOS-CC citations and independent variables

Independent variables	WOS-CC number of citations	
	RR (95% CI)	p
Study design		
Laboratorial	1	
Literature review	1.453 (1.349 – 1.566)	<0.001
Interventional	0.796 (0.733 – 0.865)	<0.001
Systematic review	1.044 (0.763 – 1.429)	0.786
Continent		
South America	1	
North America	1.040 (0.970 – 1.115)	0.269
Asia	0.893 (0.840 – 0.950)	<0.001
Europe	0.692 (0.632 – 0.757)	<.001
Africa	0.942 (0.808 – 1.099)	0.447
Oceania	0.685 (0.497 – 0.944)	0.012
Year of publication	0.955 (0.951 – 0.959)	<0.001
Journals' impact factor	1.021 (1.015 – 1.028)	<0.001

Legend: (CI) confidence interval, (RR) rate ratio, (WOS-CC) Web of Science Core Collection

Contributing Journals and Impact Factor

The journals in which the top 100 articles were published are presented in Supplementary Table 2. Evidence-Based Complementary and Alternative Medicine was the

top journal, with eight articles (285 citations), followed by Archives of Oral Biology (494 citations), Caries Research (468 citations), and Journal of Endodontics, each with five articles. According to journal citation reports, the journals with the highest impact factors (IF) in 2021 related to propolis use in dentistry were: International Journal of Oral Science with two articles (IF 24.897; 84 citations), Journal of Advanced Research with one article (IF 12.822; 48 citations), and Current Opinion in Biotechnology with one article (IF 10.279; 45 citations). The Poisson regression analysis revealed that for a unit increase in impact factor, the number of WoS-CC citations tended to increase by 2.1% (RR: 1.021; 95% CI: 1.015-1.028; $p < 0.001$) (Table 1). This finding suggests that, on the whole, articles published in journals with higher impact factors exhibited a greater likelihood of garnering a higher number of citations.

Table 2. Top 10 institutions with the highest number of articles among the 100 most-cited.

Institution	Country	Number of articles	Number of citations
University of Campinas	Brazil	17	1,398
University of Sao Paulo	Brazil	7	695
Medical University of Silesia	Poland	6	254
University of Rochester	USA	5	672
Federal University of Minas Gerais	Brazil	5	238
Shahid Beheshti University of Medical Science	Iran	3	88
Ege University	Turkiye	2	289
Cumhuriyet University	Turkiye	2	121
University of Florida	USA	2	99
University of Pittsburgh	USA	2	89

Study Design and Themes

The majority of studies were laboratory-based ($n=70$; 4,721 citations), followed by literature reviews ($n=15$; 1,071 citations), intervention studies ($n=14$; 720 citations), and one systematic review ($n=1$; 41 citations). The Poisson regression analysis indicated that the number of citations was influenced by the study design ($p < 0.001$), as shown in Table 1. In general, literature reviews exhibited superior citation performance compared to laboratory studies. This finding suggests that despite a smaller number of publications, literature reviews had a higher likelihood of being cited compared to other study designs.

Concerning the primary theme, the following distribution was observed: antimicrobial activity ($n=39$; 2,933 citations), dental caries ($n=22$; 1,686 citations), others ($n=9$; 352 citations), replanted teeth ($n=7$; 312 citations), antiplaque ($n=6$; 362 citations), oral cancer ($n=5$; 369 citations), pulp protection ($n=4$; 175 citations), anti-inflammatory ($n=4$; 154 citations), chronic periodontitis ($n=2$; 107 citations), and aphthous ulcer ($n=2$; 103 citations). For the secondary theme, the following distribution was

observed: microbiology (n=49; 4,013 citations), oral pathology (n=21; 1,163 citations), periodontics (n=11; 540 citations), endodontics (n=11; 499 citations), traumatology (n=7; 312 citations), and others (n=1; 26 citations).

Countries and Continents

A total of 21 countries contributed to the top 100 most-cited articles. Considering the number of publications per country, the top three were Brazil (n=41; 2,835 citations), the United States of America (n=13; 1,133 citations), and Turkey (n=10; 723 citations). Among continents with more articles in the top 100 (Figure 1), South America (n=41; 2,835 citations) and Asia (n=26; 1,643 citations) stood out. The Poisson regression analysis revealed an association between the continents of Europe ($p < 0.001$), Asia ($p < 0.001$), and Oceania ($p = 0.012$) with the number of WoS-CC citations, as shown in Table 1. However, these continents demonstrated lower citation trends compared to South America. This outcome suggests that, irrespective of the number of publications, articles originating from South America have a greater tendency to be cited.

Institutions

A total of 55 institutions contributed to the top 100 most-cited articles. Table 2 presents the top 10 institutions with the highest number of publications. Ties were resolved considering the highest number of citations. The top three positions belonged to the University of Campinas (Brazil) with 17 articles and 1,398 citations, the University of São Paulo (Brazil) with 7 articles and 695 citations, and the Medical University of Silesia (Poland) with 6 articles and 254 citations.

Keywords

A total of 563 keywords were identified in the top 100 most-cited articles. The most prevalent term was propolis (n=56), followed by antibacterial activity (n=26), chemical composition (n=24), antimicrobial activity (n=24), and Brazilian propolis (n=22). Figure 2 displays the most prevalent keywords (5 or more occurrences) and their relationships. Keywords that correspond to larger foci and appear in bold are the terms that had higher occurrences. On the other hand, keywords appearing in smaller foci had lower occurrences. Keywords connected in bibliometric networks are terms that showed a relationship between studies.

Continuation					
Alencar SM	16	1,209	207	5,759	42
Cury JA	13	1,584	391	8,020	49
Park YK	9	1,103	21	2,122	15
Bowen WH	6	662	418	8,691	48
Bueno-Silva B	5	364	44	1,235	20
Dziedzic A	5	225	61	1,138	19
Duarte S	4	307	54	1,461	20

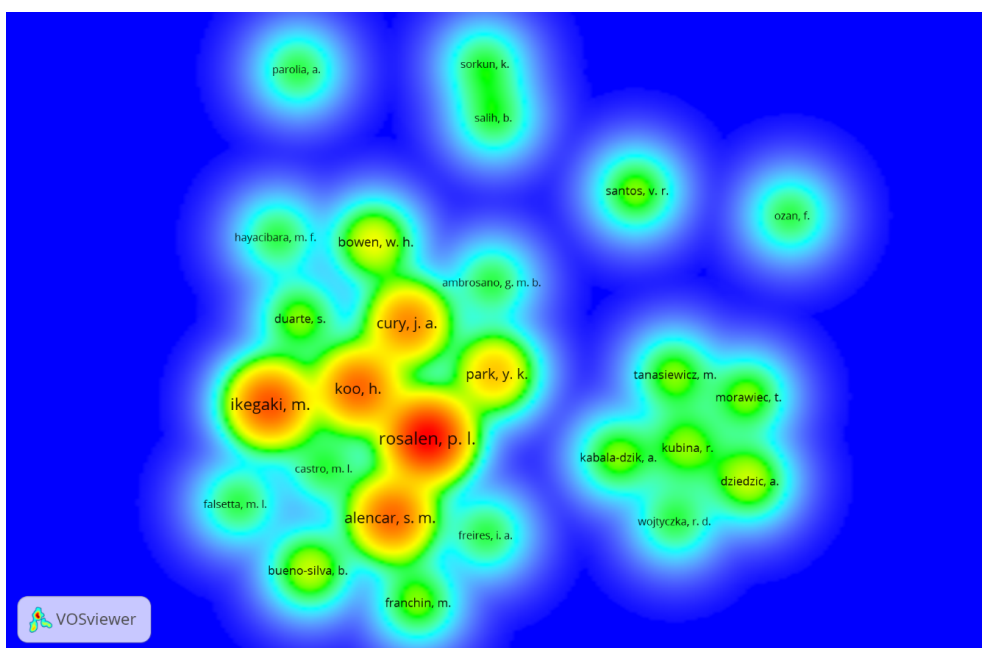


Fig 3. Main groups/authors who conducted researched on propolis and dentistry. The authors present in the same cluster indicate groups and collaboration between authors. The names associated with red-colored foci indicate greater contributions from the authors.

Discussion

The apicultural products are widely used in traditional and alternative dentistry due to their effective results against inflammatory and infectious processes, thus characterizing a promising area. Consequently, numerous studies have been conducted evaluating and investigating the properties of propolis in dentistry²¹. In this perspective, the present study analyzed the main characteristics of the 100 most-cited articles on the use of propolis in dentistry in the WoS-CC database. There was a greater tendency in laboratory research investigating the use of propolis for antimicrobial purposes, mainly originating from Brazil.

The utilization of citation indicators serves as a tool for evaluating the scientific performance of research groups, topics, and institutions²². Consequently, the current study reveals a substantial number of citations among the 100 most-cited articles on the use of propolis in dentistry, in comparison to other bibliometric studies^{12,23}. In a specific study area, a classic article is typically anticipated to accumulate at least 100 citations²⁴. It is worth noting that 15% of the articles analyzed in WoS-CC in this review exceeded this metric. Self-citations were incorporated into the overall count of the most-cited articles. Analyzing self-citations, a considerable number was observed. Although self-citation is not viewed positively, it may occur because authors belonging to the same research group conduct various experiments on a specific topic²⁵. In these instances, self-citations are not viewed as a negative practice; instead, they are recognized as a result of authors making substantial contributions to a specific area of knowledge. Moreover, in previous studies, it has been observed that self-citations did not significantly impact the ranking order of a most-cited list^{12,13}.

The most-cited article in WoS-CC aimed to evaluate the antimicrobial, antioxidant, and cytotoxic activity and analyze the chemical composition of red propolis, presenting promising results and new biologically active compounds. This may have encouraged further studies based on laboratory results. It is noteworthy that red propolis has gained increasing relevance in the international market, originating from tropical countries, with flavonoids as its main compounds¹⁴. Google Scholar encompasses a larger number of indexed journals and incorporates citations from books and thesis documents, leading to a notable disparity in the count of citations when compared to WoS-CC¹². Nevertheless, Spearman's correlation analysis demonstrated a robust correlation between the number of citations in these databases, aligning with findings in other bibliometric reviews^{11,13}.

A crucial point during citation analysis is that the absolute number of citations may differ from its density, as older articles generally have a higher probability of being cited more times in absolute terms²⁶. In this study, it is evident that the most-cited article in absolute numbers does not have the highest number of citations per year, as another article led the citation density in WoS-CC¹⁷. This can be explained because narrative reviews cover a broader range of topics compared to laboratory studies²⁷. Nonetheless, the Poisson regression analysis indicated that older articles exhibited a significant tendency to accumulate higher citation counts.

Although the first article on the topic was published in 1991, the highest concentration of publications among the top 100 most-cited works occurred between 2007 and 2016, indicating that it is a current and relevant topic with the development of many studies yielding promising results. Despite the abundance of studies on propolis, there are still many gaps in the literature regarding biological activities such as antimicrobial, antifungal, and antiviral effects, as well as synergies with other products due to the various types produced in apiculture centers such as New Zealand, Brazil, and Australia²⁸. Thus, propolis-based products have been developed by dental industries, supported by laboratory and clinical studies for various pathologies, including gingivitis, aphthous ulcers, oral candidiasis, and herpes, among others²⁹.

One of the most relevant actions of propolis is its broad antimicrobial capacity, attributed to the presence of flavonoids and phenolic compounds, which may be linked to a direct action on microorganisms or the activation of the immune system. This mechanism interferes with the rupture of the cell membrane, membrane permeability, and adenosine triphosphate production³⁰. Considering the effect of this substance on the cellular organism, it is crucial to conduct multiple laboratory studies to confirm its safety for use in humans. This fact justifies the emphasis on laboratory studies as the most frequent study design in the top 100. Supporting the antimicrobial activity of propolis, this theme gained prominence among studies primarily related to microbiology. However, the Poisson regression analysis result indicated that literature reviews demonstrated superior performance in terms of the number of citations. This could be attributed to the emphasis on citations even with a smaller number of literature review articles.

There was a considerably low number of intervention articles and systematic reviews. Therefore, the present analysis highlights the need to increase the number of randomized clinical trials and consequently systematic reviews to enhance the level of scientific evidence on the efficacy of propolis in dental pathologies. It is known that randomized clinical trials are considered the “gold standard” to serve as a reference for clinical decision-making in each therapy³¹. However, their execution requires establishing several factors that depend on the availability of patients, materials, and specific pathologies³². This fact may explain the low number of articles with such a study design.

Considering the scientific journals in which the most-cited articles were published, most had a broad scope, possibly reflecting the use of propolis in various health areas⁴. Among the top 10 journals, only three were exclusively related to dentistry. Regarding the impact factor, it is noteworthy that the Journal Citation Reports considers only journals indexed in WoS-CC²⁵. The Poisson regression analysis indicated a subtle trend of publications towards higher journal impact factors.

In terms of contributing countries, Brazil had the highest number of publications in the current top 100. The United States of America ranked second, as shown in a previous bibliometric review on apitherapy in complementary medicine³³. An association can be made because Brazil is one of the world’s largest propolis producers, thus leading research in this field. Another important factor is the significant variation in the types of propolis produced in Brazil³⁴. Additionally, South America stood out as the continent with the highest number of publications, with Brazil being the only South American country that produced studies on this theme. According to the Poisson regression analysis, this continent exhibited higher citation trends compared to others, potentially associated with the large number of documents originating from this continent. Asia ranked second, despite being separate from the second most prominent country. The combination of other Asian countries provided visibility to the Asian continent. Brazil’s prominence as the most frequent country reflected in the most prolific institutions, where the top two were Brazilian institutions: the University of Campinas ranked first, and the University of São Paulo ranked second.

The authors who stood out in the most-cited articles were Rosalen PL, Ikegaki, Koo H, Alencar SM, and Cury JA. The collaboration network performed in Vosviewer demonstrated that these authors belonged to the same cluster, indicating their participation in a common research group, all affiliated with Brazilian institutions. Additionally, it was observed that this group primarily focused on conducting laboratory studies analyzing the antimicrobial activity of propolis in dentistry, with applications mainly in microbiology.

A strength observed in this study is the absence of filters limiting the year of publication, citations, or language, allowing for a comprehensive and complete analysis of all documents published on the topic up to the search date. However, the broad time window may compromise the assessment of authors who are no longer actively engaged in research, yet it ensures a fair retrieval of the most-cited articles without excluding older and relevant contributions on the topic. The inclusion of authors irrespective of their position in the article may introduce bias to this review. Nevertheless, focusing solely on first-position authors could potentially exclude important researchers who contributed significantly to the development of this topic. Another limitation of this study is the reliance solely on the WoS-CC database, without considering other available bibliometric databases such as Scopus, Medline, and Google Scholar. The decision to use only WoS-CC was based on its prominence in significant bibliometric analyses in dentistry, being considered the most prestigious database for such analyses and providing a suitable interface for document selection and export in various formats¹¹⁻¹³.

This bibliometric analysis covers the 100 most-cited articles related to the use of propolis in dentistry. The majority of these articles were published in Brazil, the USA, and Turkey, with a notable emphasis on laboratory studies, particularly addressing the topic of antimicrobial activity. The findings highlight a need to elevate the level of scientific evidence by promoting well-designed randomized clinical trials, subsequently enabling the conduct of systematic reviews with meta-analysis.

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Conflicts of interest

None.

Data Availability

Datasets related to this article will be available upon request from the corresponding author.

Author Contribution

Johnny Alexandre Oliveira Tavares: Conceptualization, Methodology, Writing - Original Draft. **Aurélio de Oliveira Rocha:** Conceptualization, Methodology, Writing -

Original Draft, Software. **Lucas Menezes dos Anjos**: Conceptualization, Methodology, Writing - Original Draft. **Mariane Cardoso**: Conceptualization, Writing - Review & Editing. **Francilene Amaral da Silva**: Conceptualization, Writing - Review & Editing, Supervision.

All authors actively participated in the manuscript's findings, revised and approved the final version of the manuscript.

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