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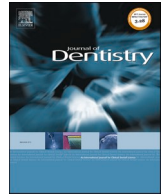
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Review article

The use of quantitative light-induced fluorescence in carious lesions research: A bibliometric review

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ABSTRACT

Objective: This bibliometric analysis evaluated the top 100 most-cited articles on the application of quantitative light-induced fluorescence (QLF) technology in caries research.

Data: The following data were collected: title, authors, country, institution, citations count, title and year of article, study design, topic and keywords. Networks among authors and keywords were constructed by VOSviewer software.

Sources: Scopus database on April 25, 2024.

Study selection: A global citation score of 4633 (average 46.33 citations) was calculated with publication years ranged from 1999 to 2020. *Caries Research* emerged as the top contributing journal. Pretty IA was the most prolific author (18 %). United Kingdom had the highest number of most-cited papers (32 %), followed by Netherlands and USA (20 % each). Laboratory studies constituted the predominant study design (45 %), followed by randomized clinical trials (20 %) and non-systematic reviews (11 %). The keywords “dental caries” and “fluorescence” had 81 and 79 occurrences, respectively. The main topic was QLF use for caries detection (45 %).

Conclusions: This paper provides an update summary of the scientific impact of QLF technology application in caries research. QLF has gained increasing attention worldwide, accompanied by a consistent rise in scientific investigations exploring its application in caries research.

Clinical significance: The findings offer valuable insights into the most influential articles in QLF technology for caries assessment, serving as a critical resource for researchers, clinicians, and students. Understanding the trends in this field can aid in informed decision-making and the advancement of evidence-based practices in caries management and prevention.

1. Introduction

Dental caries and periodontal disease have long been recognized as significant oral health challenges globally, with carious lesions posing a considerable burden on individuals and healthcare systems. Early detection of caries lesions, particularly white spot lesions (WSLs), is crucial for timely intervention and preventive measures to arrest or reverse the progression of decay [1–3]. WSLs, also known as early caries lesions (ECLs), represent the earliest evidence of enamel

demineralization and are typically categorized within the international caries detection and assessment system (ICDAS) II 1–2 range [4,5]. Detecting WSLs is essential as they indicate an imbalance between demineralization and remineralization at the enamel surface, often resulting from altered pH levels [6].

Traditional methods of caries detection, such as visual inspection, while effective, have limitations in detecting very early defects, especially in proximal areas or smooth surfaces near the gingiva. Moreover, assessing caries progression or regression solely through visual

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inspection can be challenging under everyday clinical conditions [7,8]. Failure to detect lesions in the early stages may hinder the implementation of effective caries preventive measures [9,10].

In recent years, advancements in non-invasive light-based methods have revolutionized the field of caries detection and assessment. One such technology gaining prominence is quantitative light-induced fluorescence (QLF), which exploits the auto-fluorescence of teeth to detect demineralization [11–13]. QLF offers the advantage of providing quantitative measurements for the disparity in fluorescence radiance between healthy tooth structures and those affected by caries, enabling the detection of lesions as shallow as 500 micrometers in depth [14]. Moreover, QLF has demonstrated high sensitivity and reproducibility in detecting early caries lesions, as well as monitoring their progression or regression over time [15,16].

As the use of QLF technology for caries detection continues to evolve, it becomes imperative to conduct a comprehensive analysis of the existing literature to assess its impact and explore emerging trends. In this context, bibliometric analysis offers a valuable approach to systematically evaluate the quantity, quality, and impact of research output in a specific field [17]. By examining publication patterns, citation networks, and collaboration trends, bibliometric analysis provides insights into the growth and development of research, guiding future directions and informing evidence-based practice. Although the number of citations does not necessarily reflect the quality of an article or the prominence of its authors, highly cited articles can influence clinical practice, generate discussions, and stimulate further research in a specific field [18]. Currently, no bibliometric analyses have been conducted on QLF use in caries research.

Therefore, this study aims to provide a comprehensive bibliometric analysis of the top 100 most cited articles on QLF technology in carious lesions research. By identifying and reviewing these highly cited articles, we aim to:

- Provide an updated overview of the key aspects such as journals, authors, countries, study designs and keywords related to the top 100 most cited articles.
- Identify current research trends and emerging topics.
- Explore research gaps and stimulate new collaborative networks between researchers and institutions.
- Evaluate the impact and influence of these articles in the field of caries research, highlighting the practical and clinical implications of QLF applications.

2. Materials and methods

This bibliometric analysis was designed in accordance with the most recent methodological guidelines for this study design [19].

2.1. Bibliometric search strategy

A comprehensive search on the Scopus database was conducted on April 25, 2024 to identify all available articles applying the QLF technology in carious lesions research.

The following keywords were used: “Quantitative light-induced fluorescence”, “Quantitative light-induced fluorescence-digital” and “cari*”, “demineraliz*”, “decay”, “white spot”. The arrangement of papers followed a descending order according to their citation counts. Two review authors independently examined the titles, abstracts to determine the 100 most-cited papers. To ensure the articles remain pertinent and focused on the QLF application in caries evaluation, only articles addressing this application were included, while articles on other topics, such as dental aesthetics, were excluded. Under the designation of “caries”, all lesions from demineralization to advanced caries were included to provide a complete overview of current QLF uses. In cases where articles had an identical total number of citations, those with the highest citation density (i.e., total number of citations divided by the

number of years) were prioritized and placed higher in the list. When the abstract lacked essential information, full texts were analyzed.

No restrictions were imposed regarding year, language, or publication status. Exclusions comprised studies not used QLF technology for caries detection or progression. Any disagreement regarding the studies were resolved through consensus after consulting a third reviewer.

2.2. Data extraction

Two reviewers independently assessed the articles and extracted the following data: citation details (journal, authorship, publication year, number of citations, citation density, document H-index with and without self-citations), institution, country and continent and study characteristics (title, study design and addressed topic). The mean age of publications was calculated as the average of the number of years since each paper was published up to the current year. Data were double-checked to avoid any errors. The study designs were classified adapting the Cochrane Collaboration Glossary as laboratory-based studies (*in vitro*, *in vivo*, *ex vivo*), randomized clinical trial (RCT), non-randomized clinical trial, case report/case series, observational studies (cross-sectional, prospective, retrospective), reviews, and systematic reviews (SR)/meta-analysis(MA) [20]. All articles were grouped according to the most general topics in: caries detection (refers to the initial diagnosis and identification of carious lesions); caries monitoring (involves tracking the progression of carious lesions over time); caries management (refers to the strategies and interventions used to treat and manage carious lesions). Topics that appeared only once and could not be included in the previous categories were indicated as “other.”

2.3. VOSviewer networks

Networks maps between authors and between keywords were created using VOSviewer software (version 1.6.20; Leiden University Center for Science and Technology Studies, Netherlands). A collaboration network was developed for the authors who contributed to 3 or more articles of the 100 highly cited article list. The node size represents the number of publications by each author, while the strength of a link indicates the number of publications two researchers have co-authored.

A keyword network map was created to report the most frequent keywords throughout the decades (including only keywords with at least three occurrences using the “All Keywords” option) [21]. The minimum cluster size was set at three, that is the items below the minimum cluster size were included to the bigger cluster. The dimensions of the nodes correspond to the frequency of a keyword’s occurrence across the studies, while the connection between two nodes illustrates the simultaneous appearance of both keywords. The width of each connection reflects the strength of the relationship between the keywords.

2.4. Statistical analysis

Descriptive analysis was performed using STATA/BE v.17 statistical package (StataCorp LT, College Station, TX, USA). Kolmogorov-Smirnov test was used to verify the normality of data distribution. Spearman’s rank correlation coefficient test was used to verify the relationship between publication duration and the number of citations, as the data were not normally distributed.

3. Results

3.1. Overview

Initially, the search strategy identified 263 records on Scopus. After applying the specified filters and criteria, the top 100 most-cited papers focusing on QLF application in caries research were selected for inclusion in this study (Table S1 in Suppl. Mat.). These studies involved 160 authors from 29 different countries and were published across 45

journals. The publication period ranges from 1999 to 2020. The chronological trend of publication is shown in Fig. 1. All selected papers were published in the English language. The document H-index and the H-index after excluding self-citations were 40 and 38, respectively.

3.2. Citations count and year of publication

The global citation score was 4633 (with an average of 46.33 ± 33.72 citations per paper), ranging from 17 to 202. The top five articles have received more than 100 citations each. The paper with the highest number of citations was the prospective observational study "Caries prevalence measured with QLF after treatment with fixed orthodontic appliances: Influencing factors" authored by Boersma et al. (2005), published in the *Caries Research*, which gained 202 citations [22]. van der Veen et al.'s review in *Monographs in Oral Science* has received 163 citations [23]. This was followed by Gomez's which was cited 159 times [24]. The least number of citations ($n = 17$) was received by the laboratory study of Jablonski-Momeni [25]. The article with the highest citation density (i.e., 20.77) was that of Boersma et al. [22] whilst the lowest (i.e., 1.77) was received by Pretty et al. and Kühnisch et al. studies [26,27]. The top 10 most-cited papers, including their concluding remarks, are listed in the Table 1 [22–24,28–34].

The mean age of publications was 14.17 ± 5.85 years. The year with the highest publication count was 2003 ($n = 10$), followed by 2013 and 2015 ($n = 9$, each). Analysis using the Kolmogorov–Smirnov test indicated a non-normal distribution of the duration of publication and the number of citations data (p -value < 0.001). While a positive correlation was observed between these two parameters, it was assessed as weak ($R = 0.3026$; $P = .0022$).

3.3. Journals and impact factor

Table 2 displays the list of the top 10 journals with the highest number of papers in the top 100 most-cited list. The search uncovered articles from 45 journals of which 32 classified in Dentistry, Oral Surgery & Medicine category according to the Journal Citation Reports, 2022 by Clarivate. Among these, 5 were in the first quartile, 9 in the second, 8 in the third and 10 in the fourth. *Caries research* led with the highest number of articles ($n = 10$), followed by *Journal of Dentistry* and *Acta Odontologica Scandinavica* ($n = 8$, each), *American Journal of Orthodontics*

and *Dentofacial Orthopedics and European Journal of Oral Sciences* ($n = 6$, each), *European Journal of Orthodontics* ($n = 5$) and *Photodiagnosis and Photodynamic Therapy* ($n = 4$). Collectively, these journals contributed to 47 % of the top-cited articles in QLF in caries research. Among the 45 journals, twenty-seven (60 %) contributed only one article each to the top 100 list. The top most-cited journals were *Caries research* ($n = 576$), *Journal of Dentistry* ($n = 462$) and *European Journal of Oral Sciences* ($n = 347$). The IF of the journals ranged from 0.818 to 8.4, with a mean of 2.94 ± 1.56 . The Cochrane Database of Systematic Reviews had the highest IF (i.e., 8.4) and contributed one article.

3.4. Authors and collaboration network

A total of 160 authors contributed to the top-cited articles. Pretty IA held the highest number of papers and citations, with 18 papers and 767 citations. Additionally, Higham SM and Tranæus S authored 17 and 11 papers each to the top 100 list, garnering 744 and 551 citations, respectively. The top 10 authors with the highest number of papers in the top 100 most-cited papers are reported in Table S2 in Suppl. Mat.. Furthermore, a collaboration network was constructed for authors who contributed to three or more articles among the highly cited 100 (Fig. 2). Within this network, 32 of the 160 most influential authors were interconnected. Overall, 6 clusters of authors were identified. The largest clusters, led by Tranæus S (red cluster) and by Pretty IA (green cluster), included nine and seven authors, respectively. Moreover, Pretty IA had the highest total link strength (i.e., 41).

3.5. Country region, affiliations and funding

The most 100 influential articles on QLF technology in caries research presented contributions from 24 countries. Europe hosted 94 of the 100 most-cited papers and, thus, had the highest number of citations ($n = 1875$). Asia was the second continent most represented with China ($n = 9$), South Korea ($n = 6$), Japan ($n = 5$) Jordan ($n = 3$), Saudi Arabia ($n = 2$), Thailand ($n = 2$), India, Kuwait, Malaysia, and Pakistan ($n = 1$ each) (31 papers; 1213 citations). The papers from Anglo-Saxon America were from the USA (20 papers; 977 citations) and Canada (2 papers; 70 citations); Brazil (6 papers; 202 citations) and Colombia (2 papers; 155 citations) represented Latin America. Finally, Australia represented Oceania with two papers (141 citations). Africa had no papers in the top

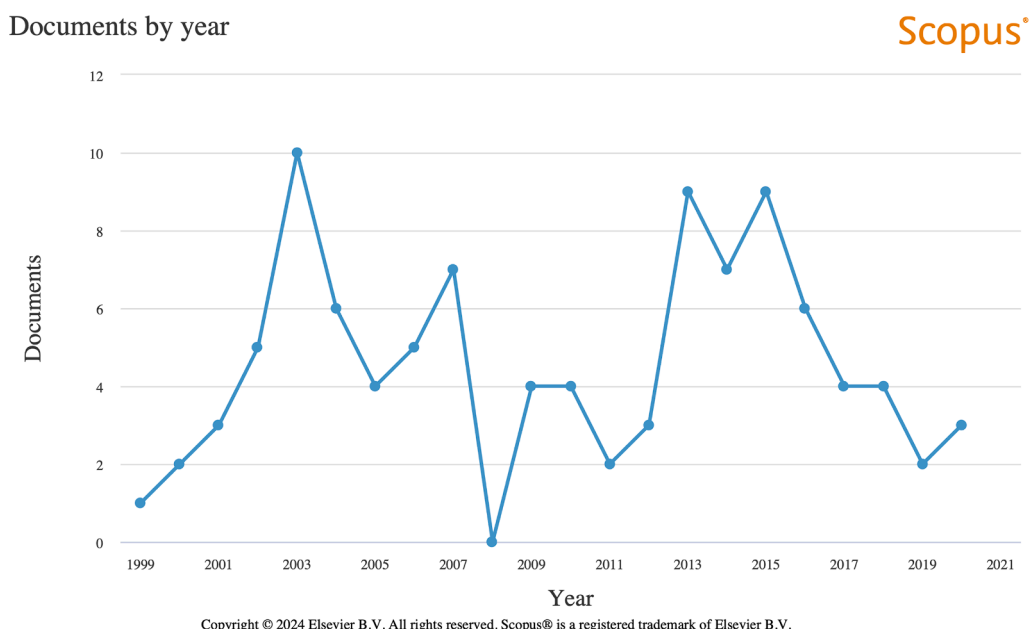


Fig. 1. Publication timeline of the top 100 most-cited articles focused on QLF applications in caries research.

Table 1
Top 10 most-cited papers in QLF for caries research.

Ranking	Authors	Title	Publication year	Journal	Total citation score	Study design	Main findings
1	Boersma J.G., van Der Veen M.H., Lagerweij M.D., Bokhout B., Prahl-Andersen B.	Caries prevalence measured with QLF after treatment with fixed orthodontic appliances: Influencing factors	2005	Caries Research	202	Observational prospective study	The number of lesions detected by QLF greatly exceeded those found through visual examination, although the distribution pattern was similar. Assessing lactobacillus counts, alongside visual inspection and ideally QLF inspection, during orthodontic treatment may help identify individuals at higher risk for developing caries.
2	van der Veen M.H., de Josselin de Jong E.	Application of quantitative light-induced fluorescence for assessing early caries lesions	2000	Monographs in oral science	163	Review	QLF is a suitable tool for monitoring mineral changes in incipient enamel lesions on both permanent and deciduous teeth. It can be used in vitro, in situ, and in vivo. However, QLF for application on approximal surfaces requires further development.
3	Gomez J.	Detection and diagnosis of the early caries lesion	2015	BMC Oral Health	159	Review	Drawing from prior systematic reviews, a more precise diagnosis of NCCLs could potentially be attained by employing a combination of visual examination alongside supplementary techniques like electrical methods and QLF, particularly for ongoing monitoring purposes.
4	Amaechi B.T., Podoleanu A., Higham S.M., Jackson D.A.	Correlation of quantitative light-induced fluorescence and optical coherence tomography applied for detection and quantification of early dental caries	2003	Journal of Biomedical Optics	127	Laboratory (in vitro)	The findings indicate that as demineralization time increases, there is a decrease in both enamel fluorescence radiance and reflectivity. Furthermore, a direct linear relationship was noted between the percentage of fluorescence loss detected via QLF and the percentage of reflectivity loss detected via OCT.
5	Bröchner A., Christensen C., Kristensen B., Tranæus S., Karlsson L., Sonnesen L., Twetman S.	Treatment of post-orthodontic white spot lesions with casein phosphopeptide-stabilised amorphous calcium phosphate	2011	Clinical Oral Investigations	116	Randomized clinical trial	Application of a CP-SACP agent for topical treatment of white spot lesions post-orthodontic appliance removal led to notable reductions in fluorescence and lesion area, as evaluated by QLF after 4 weeks. However, this improvement did not surpass the natural regression observed with daily use of fluoride toothpaste. Clinical scores closely mirrored the QLF findings.
6	Sudjalim T.R., Woods M.G., Manton D.J., Reynolds E.C.	Prevention of demineralization around orthodontic brackets in vitro	2007	American Journal of Orthodontics and Dentofacial Orthopedics	114	Laboratory (in vitro)	Following the assessment of fluorescence difference through QLF, the application of both agents (ie, sodium fluoride and 10 % casein phosphopeptide-amorphous calcium phosphate) is advisable for orthodontic patients deemed at risk. This recommendation aims to encourage preventive measures and potentially facilitate the remineralization of early-stage (subclinical) enamel demineralization.
7	Angmar-Månsson B., ten Bosch J.J.	Quantitative light-induced fluorescence (QLF): A method for assessment of incipient caries lesions	2001	Dentomaxillofacial Radiology	109	Review	QLF presents a promising avenue for expediting clinical research timelines, potentially minimizing the duration

(continued on next page)

Table 1 (continued)

Ranking	Authors	Title	Publication year	Journal	Total citation score	Study design	Main findings
8	Tranaeus S., Al-Khateeb S., Björkman S., Twetman S., Angmar-Månsson B.	Application of quantitative light-induced fluorescence to monitor incipient lesions in caries-active children. A comparative study of remineralisation by fluoride varnish and professional cleaning	2001	European Journal of Oral Sciences	104	Randomized clinical trial	required. Its inherent objectivity renders it valuable for epidemiological surveys. Furthermore, QLF offers both visual and quantitative feedback to patients. The QLF technique proves to be highly sensitive, making it well-suited for the longitudinal assessment of incipient caries lesions on smooth surfaces. Additionally, it was observed that repeated fluoride applications yielded a beneficial impact on the remineralization of white spot lesions, as evidenced by measurements taken after 6 months.
9	Beerens M.W., van Der Veen M.H., van Beek H., ten Cate J. M.	Effects of casein phosphopeptide amorphous calcium fluoride phosphate paste on white spot lesions and dental plaque after orthodontic treatment: A 3-month follow-up	2010	European Journal of Oral Sciences	102	Randomised clinical trial	A notable reduction in fluorescence loss, as assessed by QLF, was observed in both groups compared to baseline, with no discernible disparity between the groups. There was no apparent clinical advantage noted for the utilization of the CPP-ACFP paste in addition to regular oral hygiene practices over the 12-week period.
10	Mattousch T.J.H., van Der Veen M.H., Zentner A.	Caries lesions after orthodontic treatment followed by quantitative light-induced fluorescence: A 2-year follow-up	2007	European Journal of Orthodontics	93	Observational prospective study	According to QLF assessment, white spots persist even after debonding. Considering the prevalence of these lesions observed during debonding within this study population, it underscores the need for further research to explore strategies aimed at remineralizing such lesions.

Abbreviations. CP-SACP: casein phosphopeptide-stabilised amorphous calcium phosphate; CPP-ACFP: casein phosphopeptide amorphous calcium fluoride phosphate; NCCLs: non-cavity carious lesions; OCT: optical coherence tomography; QLF: quantitative light-induced fluorescence.

Table 2

Top 10 journals with the highest number of articles in the top 100 most-cited

Journal indices (ie, Impact Factor, Quartile and Category) are reported according to the Journal Citation Reports, 2022 by Clarivate.

Rank	Journal	Impact Factor (2022)	Quartile	Category	Articles in the 100 most-cited	Citation count in the 100 most-cited
1	Caries Research	4.2	Q1	Dentistry, Oral Surgery & Medicine	10	576
2	Journal of Dentistry	4.4	Q1	Dentistry, Oral Surgery & Medicine	8	462
3	Acta Odontologica Scandinavica	2.0	Q3	Dentistry, Oral Surgery & Medicine	8	269
4	European Journal of Oral Sciences	1.9	Q4	Dentistry, Oral Surgery & Medicine	6	347
5	American Journal of Orthodontics and Dentofacial Orthopedics	3.0	Q2	Dentistry, Oral Surgery & Medicine	6	295
6	European Journal of Orthodontics	2.6	Q3	Dentistry, Oral Surgery & Medicine	5	252
7	Photodiagnosis and Photodynamic Therapy	3.3	Q3	Oncology	4	96
8	Journal of Biomedical Optics	3.5	Q2	Biochemical Research Methods; Optics; Radiology, Nuclear Medicine & Medical Imaging	3	229
9	Journal of Dental Research	7.6	Q1	Dentistry, Oral Surgery & Medicine	3	172
10	Archives of Oral Biology	3	Q2	Dentistry, Oral Surgery & Medicine	3	102

100 list. At a country level, United Kingdom had the highest number of papers and citations (32 papers and 1477 citations), followed by Netherlands (20 papers; 1265 citations) and USA (20 papers; 977 citations).

A total of 112 institutions participated in the 100 most-cited papers. The affiliation with the highest number of publications was the University of Liverpool (n = 19) and Karolinska Institutet (n = 17) as shown

in Fig. 3.

Colgate-Palmolive Company (n = 4), National Institute of Dental and Craniofacial Research (n = 3), National Natural Science Foundation of China (n = 3), Korea Health Industry Development Institute (n = 2) and Yonsei University College of Dentistry (n = 2) were the top five organizations to fund the research project.

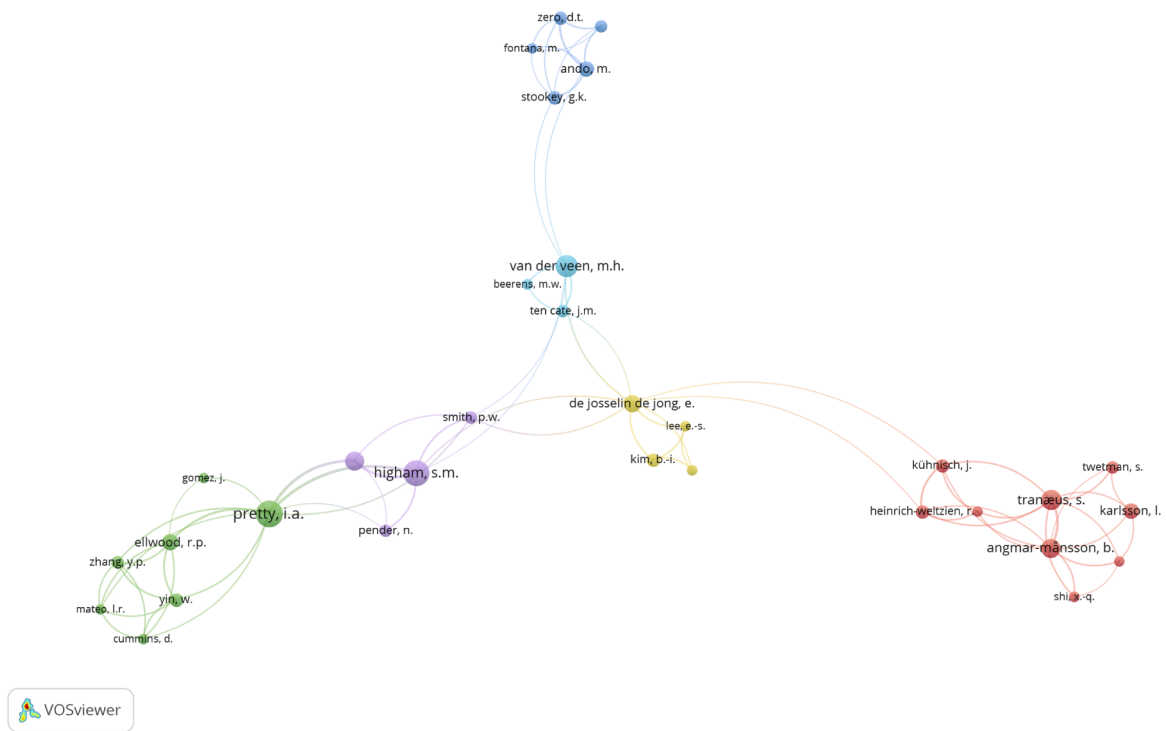
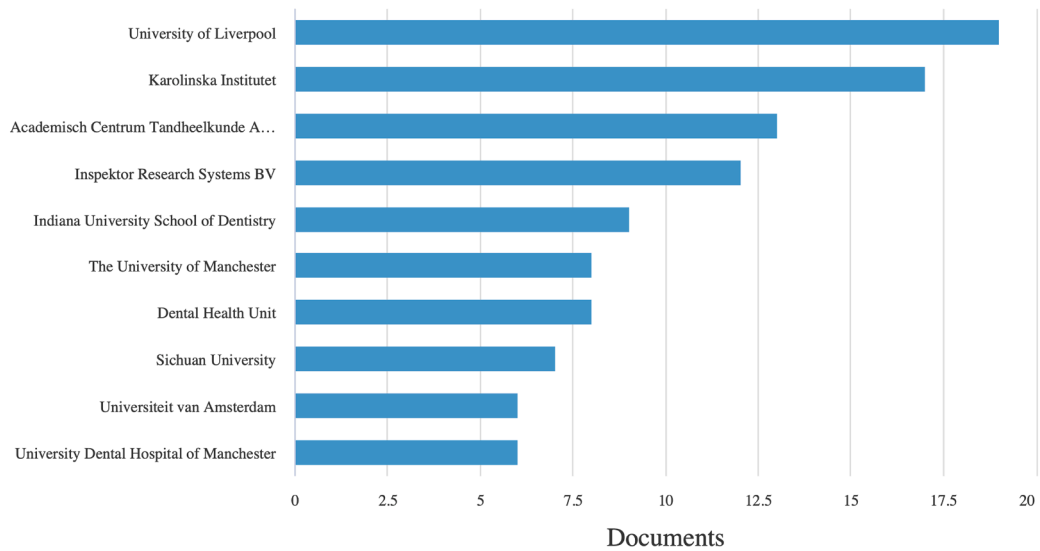


Fig. 2. Network of authors contributed with three or more articles in the top 100 most-cited.

Documents by affiliation

Compare the document counts for up to 15 affiliations.



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Fig. 3. The institutions with the highest number of articles among the top 100 most-cited.

3.6. Study designs

The analysis identified 83 original articles and 17 review papers. The predominant study design was laboratory study (n = 45), followed by randomized clinical trial (n = 20) and non-systematic review (n = 11), collectively representing 76 % of all articles reviewed. Among the studies with the highest level of evidence, 20 were RCTs and 6 SR/MA (Fig. 4).

3.7. Keywords and trending topics

A total of 236 keywords were retrieved from the 100 most-cited papers within 5 clusters: red color (cluster one, 74 items), green color (cluster two, 55 items), blue color (cluster three, 46 items), yellow color (cluster four, 38 items), purple color (cluster five, 23 items) as presented in Figure S1 in Suppl. Mat.. The most frequent keyword was “human” and “humans” with 86 and 83 occurrences, followed by “dental caries”

deemed highly cited [37,38]. Nine out of the top 10 most-cited articles in this analysis have accumulated more than 100 citations, showing the increasing interest and clinical relevance of QLF technology for caries evaluation. The ability to quantify lesion severity by assessing fluorescence loss and lesion area offers significant advantages over the qualitative and subjective data obtained through conventional visual examination [22,23]. Moreover, quantification facilitates the monitoring of lesion progression or regression over time [32].

The 100 most-cited papers span a 25-year period. Specifically, there was a consistent increase in publications from 1999 to 2003, followed by a decline until 2008, and subsequent peaks in 2013 and 2015. Considering the subject matter concerning the application of technologies in caries research, this temporal trend may partly derive from advancements in technology and changes in the most utilized devices, alongside the growing attention and usage of technologies with demonstrated clinical reliability. Additionally, citation analysis is often critiqued due to its susceptibility to the influence of time [39]. Older articles tend to have more time to gain global recognition, thus having a higher likelihood of receiving additional citations regardless of their scientific merit [39,40]. Consequently, recent publications, while highly significant, may not be fully reflected in such analyses. Despite observing a positive correlation between publication duration and citation count in this study, the relationship between them was found to be weak. Moreover, the analysis of citation density serves as a crucial indicator of a paper's relevance. For instance, the first most-cited paper demonstrates alignment between citation count and citation density (202 and 20.77, respectively), whereas the third most-cited paper, published in 2015, exhibits a citation density of 17.66 compared to 12.44 from the second most-cited paper (published in 2000).

Among the top 100 most-cited articles, *Caries Research*, *Journal of Dentistry*, and *Acta Odontologica Scandinavica* emerge as the scientific journals with the highest publication frequency. This observation aligns with a previous bibliometric analysis, which underscored *Caries Research* and *Journal of Dentistry* as prominent sources in caries research [21]. Of note, among the ten journals with the highest number of articles on the topic, two specialized orthodontic journals are included, indicating the significant application of QLF technology in early caries monitoring among orthodontic patients.

The five most influential authors have primarily focused on the application of QLF for the identification and monitoring of carious lesions (both *in vivo* and *in vitro*), as well as the effectiveness of remineralizing agents on early caries assessed through QLF. Particularly, Pretty IA, the foremost prolific and cited author, co-authored the most cited systematic review titled "Non-cavitated carious lesions detection methods: A systematic review," published in 2013 [41]. The review highlighted significant variations in sensitivity and specificity values among detection methods, along with inconsistencies in disease definition and analytical methods. QLF showed promise in early lesion detection, although the authors recommended visual methods as the standard for clinical assessment due to cost and practicality considerations. Higham SM, the second most prolific author, primarily conducted experiments in a laboratory setting. These experiments monitored the development of cavities over time by using QLF technology and also assessed how reliable QLF measurements are. Most of these studies were coauthored by Pretty IA. Tranæus S, the third most prolific and cited author, predominantly co-authored *in vivo* studies assessing the validity and reliability of QLF measurements for caries detection and quantification. Considering the co-authorship network from VOSviewer, Tranæus S and Pretty IA led the two largest clusters of authors, underscoring their significance and influence in the QLF field. This analysis suggests that most authors collaborate frequently with peers affiliated with the same organization or country, emphasizing the potential benefits of enhancing international cooperation, especially for expanding the use of QLF devices in middle and low-income countries, and improving strategies for caries prevention and management. The cumulative impact of an author's scholarly contribution is often

evaluated by the Hirsch's index (H-index) [42]. An H-index of 40 was found for the 100 most-cited articles, indicating that 40 papers, focusing on QLF application for caries evaluation, have gained at least 40 citations. However, it is important to note that the H-index alone does not provide a comprehensive measure of an author's cumulative research contribution [43].

Europe emerges as the continent with the most papers among the 100 most cited, a trend frequently observed in other bibliometric studies. Asia follows as the second continent, with developed nations such as China, South Korea, and Japan leading the contribution. These results likely depend from the quality of European institutions and research centers, associated with the availability of funding for research development [21]. Specifically, the United Kingdom stands out with the highest number of papers and citations, with affiliations following this trend, prominently featuring institutions like the University of Liverpool. However, the absence of papers from African and low-income countries in the top 100 highlights a significant limitation in the field. The cost and learning curve associated with QLF technology often restrict its accessibility, particularly in low-income countries, presenting a complex challenge that requires multifaceted solutions. Addressing this issue involves broad perspectives, including public policies incorporating governmental research funding and incentives. Furthermore, the lack of collaboration among authors from different continents exacerbates this accessibility gap. Establishing academic partnerships between influential research centers and less affluent ones could facilitate the dissemination of resources and knowledge, ultimately enhancing accessibility and fostering the establishment of new academic centers.

In terms of reliability and strength of evidence, systematic reviews and RCTs represent the best form of evidence upon which clinicians and researchers should base future research and clinical decisions [39]. Depending on the nature of the outcome, prospective observational studies can also be considered informative. Among the 100 most cited papers, laboratory (*in vitro*) studies were the most frequent study design, comprising 44 %, confirming a trend observed in other dental research [21]. Additionally, 20 % of the studies were RCTs and 7 % prospective observational studies. Considering that one of the most common applications of QLF technology is monitoring the progression of early caries (white spots), a well-designed observational study can be deemed useful, although the strongest evidence derives from RCTs and systematic reviews.

Careful selection of keywords is necessary to facilitate the identification of the most relevant papers [40]. "Fluorescence" and "caries" are among the most frequent terms, indicating that the primary topic is indicated in most papers. However, the representative term, "quantitative light-induced fluorescence," appears only 22 times in at least three articles. This may be because, over time, articles primarily focus on the application of the technology for other purposes, the main one being the use of QLF for assessing the effectiveness of remineralizing agents on initial carious lesions. This trend is confirmed by the fact that keywords associated with remineralizing agents are more frequent in recent years.

The majority of the studies focused on the application of QLF in caries detection, followed by caries management and caries monitoring. An interesting finding is that among the studies evaluating the efficacy of remineralizing agents for the management of early lesions, especially in orthodontic patients, the majority were RCTs, increasing confidence in the reliability of the results obtained. Furthermore, the fact that most of the reviews address the application of QLF in caries detection confirms the attention given to a technology that could provide undeniable benefits in clinical practice for a more accurate and early assessment of carious lesions.

4.1. Implications and future trends

The application of QLF technology to caries assessment has become a major area of interest in recent research, with a growing trend focusing on its use to evaluate the efficacy of remineralising agents on initial

carious lesions. Recent studies have shown that QLF can effectively measure the efficacy of various remineralising agents [4,25,44]. For example, Al-Batayneh et al (2020) demonstrated that QLF could track changes in enamel lesions treated with fluoride dentifrice and casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) mousse, highlighting the potential of these treatments to enhance remineralization [4]. The use of QLF to monitor early carious lesions associated with orthodontic treatment and the effectiveness of remineralizing agents is of particular interest because carious lesions can occur as a side effect during orthodontic treatment with fixed appliances [25]. QLF can represent a practical and effective method for monitoring the progression of lesions over time [22]. Mineral loss in enamel is estimated by calculating the percentage fluorescence loss between carious enamel and adjacent healthy enamel, expressed as ΔF . This method is considered more specific than other methods, such as laser fluorescence (LF), for detecting early signs of surface caries [45]. Objective quantification is beneficial for research purposes, allowing the evaluation of new remineralising products whose effects may not be clinically quantified. For patients, it may increase the acceptability of home or professional treatments, and for clinicians, it facilitates decisions based on solid, verifiable evidence.

In addition, the establishment of new research networks and collaborations between authors and institutions could significantly improve both the screening and monitoring phases of lesions over time, with notable public health implications. Our results indicate that one of the main challenges is to improve access to these technologies in low and middle income countries, which could be addressed by promoting international research networks based on funded projects.

Furthermore, while our research focused on the use of QLF in carious lesions research, current applications such as plaque assessment and quantification represent additional areas that warrant investigation [46, 47].

Finally, researchers and clinicians should base their research and clinical decisions on reliable, methodologically validated literature. The fact that only six systematic reviews, which represent the highest level of evidence, are among the 100 most cited studies suggests that even highly cited research should always be critically appraised to account for potential methodological bias.

4.2. Limitations

Some limitations need to be acknowledged. In this study, citation analysis information was retrieved from the Scopus database [39]. Scopus is known to offer approximately 20 % more coverage than Web of Science, while findings from Google Scholar are often inconsistent [48]. Despite being considered the most authentic and comprehensive database, Scopus may not fully represent all peer-reviewed publications. Therefore, there is a possibility of excluding influential articles from other databases such as Web of Science, PubMed, and Google Scholar. Additionally, although citation rates are formally acknowledged as indicators of scientific paper relevance and merit, concerns about their validity arise due to instances of self-citation [49]. Despite observed misconduct, self-citation rates in dental journals listed in the Journal Citation Reports did not correlate with journal impact factors [50]. Furthermore, authors who consistently study specific topics are expected to cite their own papers [35,51]. This bias was unlikely in our analysis, as there was minimal difference between the document H-index and H-index after excluding self-citations. Another limitation is our focus solely on the top 100 most-cited papers. A bibliometric study encompassing all published QLF papers on caries research may provide more general information for readers.

5. Conclusions

This article represents the first bibliometric analysis in evidence-based dentistry focusing on the application of QLF technology in

carious lesions research, providing an update view of the most impactful QLF research in the caries' field. The list of the top 100 most-cited articles will serve as a valuable resource for researchers, clinicians, and students, enabling them to assess the current impact of QLF application on caries. The majority of studies conducted were in Europe, primarily laboratory-based, evaluating QLF application in caries lesion detection. Among studies assessing the effectiveness of remineralizing agents on initial caries, RCT design was the most prevalent. However, there remains a notable gap in top cited studies with higher levels of evidence, such as systematic reviews and RCTs. Therefore, researchers should prioritize randomized clinical trials and systematic reviews as the preferred evidence models to offer more robust support for their experiments. Moreover, improving connectivity among researchers could enhance global accessibility to technologies with the potential to enhance oral health quality for patients. Research findings can provide valuable insights for the development of public prevention and monitoring interventions for caries, which remains one of the most prevalent dental infectious diseases worldwide.

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CRediT authorship contribution statement

Giusy Rita Maria La Rosa: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Conceptualization. **Eugenio Pedullà:** Writing – review & editing, Visualization, Validation, Investigation. **Iain Chapple:** Writing – review & editing, Visualization, Validation, Formal analysis. **Sebastiano Antonio Pacino:** Writing – review & editing, Validation, Investigation. **Riccardo Polosa:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

Giusy Rita Maria La Rosa, Eugenio Pedullà and Sebastiano Antonio Pacino have nothing to disclose.

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Riccardo Polosa is full tenured professor of Internal Medicine at the University of Catania (Italy) and Medical Director of the Institute for Internal Medicine and Clinical Immunology at the same University. He has received grants from U-BIOPRED and AIR-PROM, Integral Rheumatology & Immunology Specialists Network (IRIS), Foundation for a Smoke Free World, Pfizer, GlaxoSmithKline, CV Therapeutics, NeuroSearch A/S, Sandoz, Merk Sharp & Dohme, Boehringer Ingelheim, Novartis, Arbi Group Srl., Duska Therapeutics, Forest Laboratories, Ministero dell'Università e della Ricerca (MUR) Bando PNRR 3277/2021 (CUP E63C22000900006) and 341/2022 (CUP E63C22002080006), funded by NextGenerationEU of the European Union (EU), and the ministerial grant PON REACT-EU 2021 GREEN-Bando 3411/2021 by Ministero dell'Università e (MUR) – PNRR EU Community. He is founder of the Center for Tobacco Prevention and Treatment (CPCT) at the University of Catania and of the Center of Excellence for the Acceleration of Harm Reduction at the same university. He receives consultancy fees from Pfizer, Boehringer Ingelheim, Duska Therapeutics, Forest Laboratories, CV Therapeutics, Sermo Inc., GRG Health, Clarivate Analytics, Guidepoint Expert Network, and GLG Group. He receives textbooks royalties from Elsevier. He is also involved in a patent application for ECLAT Srl. He is a pro bono scientific advisor for Lega Italiana Anti Fumo (LIAF) and the International Network of Nicotine Consumers Organizations (INNCO); and he is Chair of the

European Technical Committee for Standardization on “Requirements and test methods for emissions of electronic cigarettes” (CEN/TC 437; WG

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jdent.2024.105220](https://doi.org/10.1016/j.jdent.2024.105220).

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