SCIENCE MAPPING OF RESEARCH CLUSTERS AND CORE RESEARCH AREAS IN REMOVABLE PARTIAL DENTURES

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Abstract
Science mapping helps provide a comprehensive review of a topic of interest based on the enormous scientific output in the academic literature. The study aims to identify research clusters, core research areas, and the highest impact terms based on the co-occurrence of keywords in removable partial dentures (RPDs) research for the past ten years, from 2012–2022. The search was done using the truncated search term "removable partial denture*" OR "removable prostho*" based on the papers extracted from the Scopus database, and a bibliometric analysis tool was employed to automate keyword mapping. Data analysis and visualisation were done using Biblioshiny software (RStudio Desktop) and VOSviewer (Version 1.6.18). The search yielded 1043 articles following the refinement criteria. Data was cleaned to remove duplication and exclude irrelevant topics, leaving 888 documents from 114 journals to be analysed. From the 679 keywords extracted, six clusters were identified, enabling researchers to find research clusters: cluster 1 (predominantly complete dentures and shortened dental arches), cluster 2 (clasp in relation to materials), cluster 3 (latest technologies in RPDs fabrication), cluster 4 (implant-related), cluster 5 (quality-of-life (QoL)) and cluster 6 (abutment teeth). For the year 2012-2022, further analysis reveals that “polyetheretherketone (PEEK)”, “3D-printing”, and “systematic review” were identified as the top three high-impact terms based on the annual citation and annual normalised citation scores. Research on "implant’ and "oral health QoL" has been identified as primary core research areas in RPDs-related research from 2012-2017, while “CAD-CAM”, “3D-printing”, “clasp" and “PEEK” emerged as new areas of interest among researchers in 2018-2022. PEEK has been identified as the highest impact term for the past ten years, highlighting the possible future research interest in RPDs-related research. Incorporating digital technologies in RPDs fabrication using high-performance polymers as materials is expected to increase in the future.

Keywords: Bibliometric Analysis, High-Impact Terms, Removable Partial Denture, Prosthodontics, Science Mapping

Introduction

A bibliometric study helps provide a comprehensive review of a topic of interest based on the enormous amounts of scientific output in the academic literature (1, 2). Science mapping is a visual representation of bibliometric data that allows researchers to explore the structure and dynamics of scientific knowledge and gain a comprehensive understanding of the emerging research patterns in a specific field (2-4). It reveals relationships, patterns, clusters, and trends in scientific literature by employing techniques such as co-occurrence word analysis, co-citation analysis, and network visualisation (1, 5).

In recent years, the field of science mapping has gained significant attention due to the increasing need for systematic and objective analysis of scientific research domains. Several tools have been developed to facilitate the analysis of complex landscapes of scientific research domains, such as

VOSviewer (6), R Studio Biblioshiny (7), CiteSpace (8) and the Sci2 tool (9). These tools have different characteristics and functionalities that make them suitable for various aspects of scientific mapping analysis (4, 10). VOSviewer, a freely available tool created by van Eck and Waltman in 2010, is a frequently used software tool for science mapping (6). It is popular due to its specific focus on constructing and visualising the bibliometric map, with particular attention given to the graphical representation of these maps. Additionally, RStudio Biblioshiny is a web-based bibliometric analysis tool built on the R and Shiny app, offering researchers a user-friendly interface and allows for customisable and comprehensive analyses, with interactive visualisations (7).

Identification of the most frequently studied topics and themes can be made by analysing author keywords or terms extracted from terms' co-occurrence title, abstract or document's body (4). Using co-word analysis, researchers can map the conceptual structure of a research field, identify and illustrate major research themes, and explore future research opportunities in the field (2, 4, 11). Besides, keyword analysis in bibliometric studies enhances the efficiency of literature reviews by refining search queries and capturing relevant articles in relation to the study field.

When hard and soft tissue replacement is necessary for aesthetic purposes or for restoring long-span edentulous areas, removable partial dentures (RPDs) are one of the best treatment options for restoring the missing teeth (12, 13). While there has been significant advancement in RPDs research, there appears to be a lack of in-depth thematic analyses in the literature. To the best of the authors' knowledge, no study has been conducted to explore thematic topics within the research field related to RPDs research using co-occurrence word analysis. Thus, the purpose of this study is to identify and embark on a detailed investigation into the research landscape of RPDs, utilising co-occurrence word analysis to delineate research clusters, highlight core research areas, and unveil high-impact terms from the period spanning 2012 to 2022. Identifying future research topics and the current focal points of RPDs research will benefit clinicians, researchers, and industry stakeholders by providing guidance for future research, enabling them to stay at the forefront of developments in removable partial denture (RPD), advance scientific knowledge, and drive innovation in the field.

Materials and Methods

Bibliometric search

A search was conducted on July 7, 2023, using the truncated search term "removable partial denture*" OR "removable prostho* from the Elsevier Scopus database (http://www.scopus.com) within the topic field (title, keywords, and abstract). A predefined search filter was limited from 1 January 2012 until 31 December 2022 to only articles and review articles in English, both in press and at the final publication stage, and in the dental field only. The initial search yielded a total of 1,043 documents. Following data cleaning, 155 documents were excluded due to duplication and irrelevant topics. The excluded articles were those focused solely on fixed dental prostheses, dental implants, restoration of endodontically treated teeth, post and core, or removable complete dentures, without any mention or comparison involving RPD. This meticulous selection ensures that the articles included in the study maintain accuracy and relevance, leaving a total of 888 documents for analysis.

Data analysis

Data analysis and visualisation of large networks were performed using statistical analysis software, Biblioshiny (RStudio Desktop, Boston, Massachusetts) and VOSviewer (Version 1.6.18). For the core research area, data analysis was conducted for each 5- and 10-year period to signify the "hot" or "cold" research topic. It utilises the keyword co-occurrence network, where the colour spectrum shifts between red and blue to signify variations in density. The density of these nodes correlates with their importance within the network; hence, 'hot' (red) nodes signify popular and significant research topics, while 'cold' (blue) nodes denote less influential or less prevalent topics. Data preprocessing was conducted to improve the quality of the units of analysis and obtain better results in the science mapping analysis (4). Word derivatives were merged from thesaurus files during citation analysis with the software VOSviewer. For example, "removable partial dentures", "partial denture*", and "rpd" were merged as "removable partial denture".

Results

Descriptive analysis

The annual publication growth of RPD research has decreased by 1.34% over the course of ten years. A total of 2,773 authors contributed to the included articles, including 40 authors of single-authored documents. The main information from RPDs-related research for the past ten years (2012-2022) is summarised in Figure 1.

Figure 1: The main information of RPDs-related research from 2012-2022

Co-occurrences of keywords

For visual content analysis of the relationship between the most frequently used keywords, VOSviewer software (version 1.6.18) was used. Figure 2 depicts the number of occurrences of the author's keywords between 2012 and 2022. “Removable partial dentures” show the highest frequency with 298 times, followed by "implant” (62 times), “CAD-CAM” (51 times), and “quality of life” (QoL) (41 times)," among the highest frequencies manifested by the growing circles.

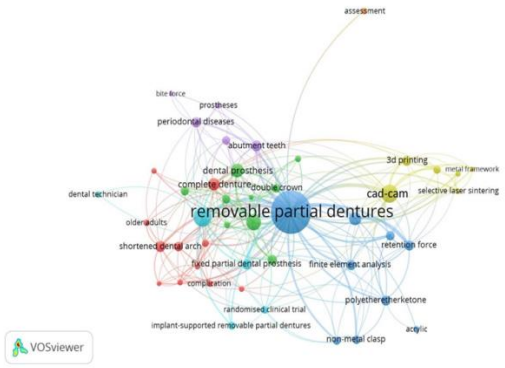

Figure 2: Co-occurrence of keywords in RPDs research from 679 keywords with minimum five keywords. The size of the label and the circle of the item is determined by its weight, the higher the weight of the keyword, the larger the label and the circle. The distance between two keywords indicates the relatedness of the keywords in terms of co-citation links. The closer two keywords are to each other, the stronger their relatedness.

Research clusters

From the 679 keywords extracted, six clusters were identified, enabling researchers to find research clusters. From the mapping, 41 keywords were divided into six major clusters, as shown in Figure 3, where different colours indicated the different clusters. Cluster 1, marked in red, consists of 13 items (predominantly complete dentures and shortened dental arches). Cluster 2, marked in blue, consists mainly of 8 items associated with clasps in relation to material. Cluster 3 (6 items), which is marked in olive green, centres on the latest technologies in RPD fabrication, while Cluster 4 (5 items) is marked in light blue and focuses on implant-related research. Cluster 5 has five items (marked in green) centred on QoL, and Cluster 6 has four items marked in purple centred on abutment teeth.

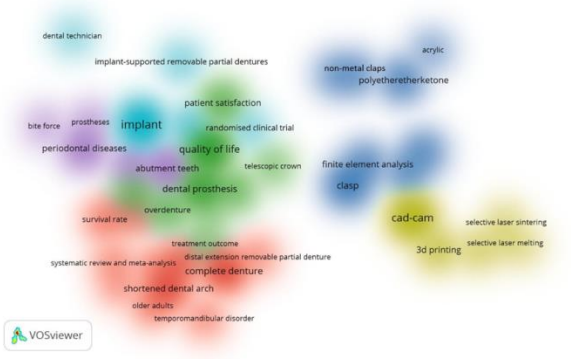

Figure 3: Cluster density visualisation reveals six major research clusters in the RPDs in 2012-2022

High-frequency keywords for 2012-2022

The emerging, high-frequency keywords attracting growing attention in recent years are enumerated. A high-frequency keyword refers to a term that is commonly used and referenced in journal articles, making it a prominent and influential topic in a particular field. It can be assessed by annual citations (AC) or average normalised citations (ANC). AC refers to a specific keyword or term that frequently appears in academic papers and research articles and has received a high number of citations annually. ANC is the average citation count for papers published in a specific year and normalises the citation count of a particular paper accordingly (6).

Further analysis reveals that the following keywords represent "hot" topics that have attracted the growing attention of the RPDs research in the past ten years, as shown in Table 1. “polyetheretherketone” (PEEK), "3D printing," and "systematic review" were identified as the top three high-impact terms based on the annual citation (AC) and annual normalised citation scores (ANC). Identifying high-frequency keywords based on annual citations can help researchers and academics understand the most impactful and trending subjects in their respective domains. These keywords often represent areas of active research and can indicate the direction in which a particular field is progressing.

Table 1: Average citation (AC) and average normalised citation (ANC) scores of high-impact keywords from 2012 to 2022.

Keywords	Average citations	Average normalised citations	Average publication year
polyetherethe rketone	34.7	3.0708	2020
3D printing	26.4	2.3515	2019
systematic review	20.5	1.7695	2016
implant-supported FPDs	19.6	1.4788	2017
clinical trial	19.6	1.6477	2016
implant	19.0	1.6342	2016
selective laser sintering	18.8	2.3461	2019
non-metal clasp	17.5	1.7409	2017
cad-cam	16.6	1.8467	2019
thermoplastic resin	15.9	1.5433	2017

Core research areas: Analysis of the trend of keywords over 5-year intervals

The keyword co-occurrence analysis was based on author keyword analysis, which reflects how "hot" or "cold" a research topic was divided in a 5-year interval (2012-2017 and 2018-2018), as shown in Figures 4 and 5. The shifting colours between red and blue reflect these changes in the density map of a keyword co-occurrence network, where a red colour node (hot) indicates a high-density keyword while a blue colour node (cold) indicates a low-density keyword. The greater the density, the higher the importance of the nodes, i.e., the "hotter (red node)" or more popular a specific research topic is, the more changes in the density distribution of these topics are examined over time (4). Research on "implant’ and "oral health QoL" has been identified as primary core research areas in RPD-related research from 2012-2017, while "CAD-CAM", "3D-printing", "clasp" and "PEEK" emerged as new areas of interest among researchers in 2018-2022.

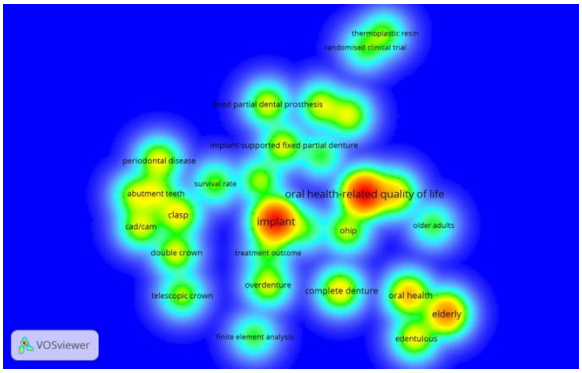

Figure 4: For years 2012–2017, research core areas (marked in red) are identified as "implant" and "oral-health-quality of life”

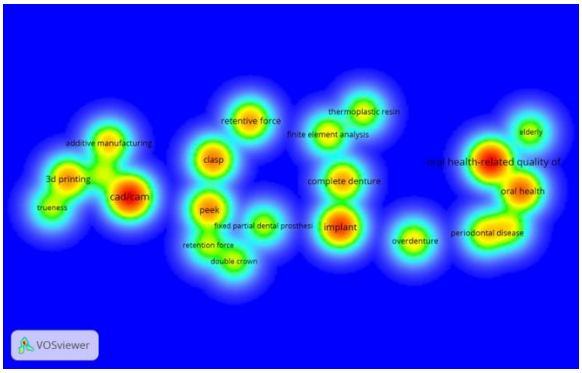

Figure 5: Apart from “implant” and “quality of life, emerging research in RPDs for the year 2018-2022 includes recent technologies in RPD fabrication, research on clasps and/or retentive forces using new materials.

Discussion

The identification of research clusters offers insights into the connection of different topics based on co-occurrence keyword analysis, while the investigation of core research areas highlights the focal points of RPDs research (2). VOSviewer functionality enables the construction and visualisation of co-occurrence networks based on important terms extracted from scientific literature (6, 14). It allows for the graphical

representation of bibliometric maps, which is crucial for understanding the relationships and patterns within the scientific domains. Moreover, VOSviewer implements the similarities mapping method to create a distance-based network, where the distance between two keywords represents their relatedness (6).

Apart from being able to identify trend development among keywords, it is also able to cluster the keywords into various themes, which might help identify future research topics in the research field, which can be significant to clinicians and researchers (11). Our study found six major clusters, with complete dentures and shortened dental arches being the biggest clusters. This follows Cluster 2, which centres on clasp, non-metal clasp, and polyetheretherketone (PEEK). Based on AC and ANC, PEEK received the highest score among other keywords, indicating the high-impact terms used in RPD's research. As PEEK exhibits desirable properties such as biocompatibility, high strength, and wear resistance, several studies are investigating the feasibility and clinical outcomes of PEEK-based RPDs, exploring their potential to overcome limitations associated with traditional materials (15-18).

Another notable trend in RPDs research is "3D printing," which falls under Cluster 3, is centred on the latest technologies in RPDs fabrication, and is among the emerging clusters based on the AC and ANC. This implies a significant shift in the way RPDs are being manufactured, where the advancement of digital technologies such as subtractive manufacturing (such as computer-aided design-computer aided manufacturing (CAD/CAM)) or additive manufacturing (such as 3-dimensional printing or laser sintering) not only enhances the precision and customisation of these dental prostheses but also opens up opportunities for faster and more cost-effective production methods (19-21).

One systematic review that evaluated the accuracy of CAD/CAM systems for RPD frameworks concluded that digital techniques for RPD frameworks are within clinically acceptable gaps (21). This study was in line with a recent study that stated that, although both direct and indirect CAD/CAM techniques are within the clinically acceptable fit, the direct technique revealed better overall trueness values compared with the indirect technique (22). Another study evaluated whether direct CAD/CAM showed a significantly better fit than additive manufacturing, which exhibited the highest discrepancies among all groups (23).

Additionally, cluster 4 focuses on implant-related research in comparison to the RPDs. Implant-supported RPDs are among the innovative approaches that combine the stability of dental implants with the convenience of RPDs. Compared to conventional RPDs, integrating implants into the RPD design can significantly enhance stability, retention, and overall functionality. Lemos et al. (24) highlighted in a recent systematic review and meta-analysis that implant-supported RPDs demonstrated acceptable levels of bone loss associated with high implant survival rates.

In addition, it also indicated an improvement in patients' quality of life and satisfaction compared to conventional RPDs (24). Concurrently, studies on RPDs that explore their impact on patients' QoL (Cluster 5) remain significant, as the effectiveness of treatments like RPDs is not solely measured by technical success but also by their influence on enhancing patients' satisfaction. Another study by Bandiaky et al. also highlighted that implant-supported RPDs showed promising enhancements in patients' QoL and satisfaction compared to conventional RPDs while suggesting longitudinal prospective clinical studies to validate the initial finding (25).

The core research areas in RPD fabrication have experienced a significant transformation, shifting from a focus on implants and QoL in 2012–2017 to embracing digital technologies and exploring novel materials in 2018–2022. The noticeable shift has occurred in the last five years, with one key area that has gained traction being the integration of digital technologies in RPD fabrication. In response to the advancement of technology, most of RPD's research currently focuses on subtractive and/or additive manufacturing compared to traditional lost wax techniques in assessing the accuracy of the different types of framework material (22, 23, 26). High-performance polymers such as PEEK are continually being explored as potential substitutes for the prosthodontic framework (15, 18). Understanding these evolving core research areas will provide valuable insights to guide researchers, clinicians, and industry stakeholders into the future of RPDs research.

This bibliometric study has some limitations. First, data extraction was from one database only (Elsevier Scopus); thus, the results of this study could have been different if another database had been used. Secondly, because bibliometric analysis is quantitative in nature, researchers should employ extra caution when making qualitative statements regarding bibliometric observations, as the relationship between quantitative and qualitative results is often unclear, and it is best to support them with content analysis (2). Additionally, researchers should refrain from making overly optimistic claims about the research area and its long-term influence, as bibliometric studies can only provide a short-term projection of the research field (27).

Conclusion

This paper summarises major research clusters, core research areas, and high-impact terms based on co-occurrences of keywords in RPDs research using a visual scientific mapping analysis of the literature for the past ten years, from 2012 to 2022. PEEK and 3D printing have been identified as the highest impact terms for the past ten years, highlighting the possible future interest in RPDs-related research. The incorporation of digital technologies in RPDs fabrication using novel high-performance polymers as materials is anticipated to increase in the future.

Competing interests

The authors declare that they have no competing interests.

Ethical Clearance

Not applicable.

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