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Review Article

Cyclic fatigue in endodontics: A bibliometric analysis

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ABSTRACT

Objectives: The aim of this study is to measure the effects and relationships of cyclical fatigue in scientific studies with bibliometric analysis methods in the field of endodontics, and to identify the main trends supported by visualization.

Materials and Methods: Studies on "cyclic fatigue" in the field of endodontics were searched in Web of Science (WoS) and Scopus academic databases on 30 August 2022, including publications for 2022. The Pandas Library, one of the Python libraries, was used to compile the data obtained from two different data sources, the Biblioshiny program was used in the analysis of the data, and the Tableau program was used to visualize the data.

Results: As a result of the first search on the WoS, 554 articles were reached. If the same search strategy in the PubMed database was searched, 452 articles were reached. By using PubMed ID numbers of the articles in the data set downloaded from the PubMed, 364 more articles were found by searching the WoS again. By combining both data sets, duplicates were extracted and 682 articles were obtained from the WoS database. As a result of the scans, a total of 905 articles were reached, including 682 articles in the WoS and 223 articles in Scopus. Since it is assumed that any article can be indexed in more than one data source, duplicate data control were performed in the combined data set, and it was determined that there were 171 duplicate data points deleted from the data set. As a result, 734 studies were obtained.

Conclusions: It is seen that the effort of endodontists to develop new formations and designs of NiTi rotary files in order to facilitate the cleaning and shaping of root canals during root canal treatment, and the number of articles on this subject continues to increase.

1. Introduction

In engineering, fatigue can be defined as the loss of strength or other mechanical properties as a result of stress over a period of time. It can be divided into various categories, such as cyclic fatigue and static fatigue. If the deformation of a material under cyclic loading is in question, cyclic fatigue can be mentioned. The accumulation of these loading cycles can create ruptures and breaks in this material.[1]

Especially in dentistry, the undesirable breakage of rotary instrument files used in the field of endodontics in the canal is among the factors affecting the success of root canal treatment. The success of the treatment depends on the chemomechanical shaping of the root canals and an effective disinfection protocol. The files used in this shaping process constitute the main element of shaping.[2]

One of the main causes of file damage and fracture during canal instrumentation is cyclic fatigue.[3] In recent years, many developments have occurred in NiTi rotary files.[4] Despite these advances, fractures due to cyclic fatigue in NiTi instruments pose great challenges for clinicians.[5]

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However, these separates and fractures are important in the fields of medicine, dentistry and engineering.

In today's world, where the production of scientific publications has increased considerably, it has become even more important for academicians to track scientific studies in different fields. For this reason, the examination and analysis of published scientific articles and the comparison of document, author, source, country information of these publications, examining the relations between them, and content analysis have increased. Bibliometric analysis methods are used to examine, analyze and visualize scientific publications.[6–9]

There are two main areas of use of bibliometric analysis methods: performance analysis and science mapping. Performance analysis aims to measure the research and publication performance of individuals and institutions. Science mapping, on the other hand, aims to reveal the structure and dynamics of the determined scientific field.[10]

The aim of this study is to measure the effects and relationships of cyclical fatigue in scientific studies with bibliometric analysis methods in the field of endodontics, and to identify the main trends supported by visualization.

2. Materials and Methods

In this study, the field of study consists of academic studies such as research and review articles on "cyclic fatigue" in the field of endodontics. To reach these studies, Web of Science (WoS) and Scopus academic databases were searched on 30 August 2022, including publications in 2022.

2.1. Search strategy

A search was made using the "and" operator to cover the studies in which the terms "cyclic fatigue" and "endodontic" were used together. In academic studies, "Article" and "Review Article" in WoS, and "Article" and "Review" in Scopus were chosen as document types.[11] English was chosen as the document language. As the search field, "Topic" in WoS and "Title, Abstract, Keywords" in Scopus were selected.[12,13]

2.2. Data- collection

The Pandas Library, one of the Python libraries, was used in the process of compiling the data obtained from two different data sources by combining them. The Biblioshiny program was used in the data analysis. Developed by Biblioshiny Massimo Aria.[14] It is a program written in Java with a user interface that uses the R-based bibliometric library.[15] Owing to its user interface, it allows analysis and visualization without the need for coding.[16,17] In addition to the visualization with the Biblioshiny program, the Tableau program was also made in the visualization by using the data obtained as a result of the analysis.[18] The flowchart showing the process from data acquisition to visualization is shown in Figure 1.

2.3. Data analysis

The analyses applied in this study are listed in Table 1.

3. Results

3.1. Main ınformation

As a result of the first search on the WoS, 554 articles were reached. If the same search strategy in the PubMed database was searched, 452 articles were reached. By using the PubMed ID numbers of the articles in the data set downloaded from PubMed, 364 more articles were found by searching WoS again. By combining both data sets, duplicates were extracted, and 682 articles were obtained from the WoS database. As a result of the scans, a total of 905 articles were reached, including 682 articles in WoS and 223 in Scopus. Since it is assumed that any article can be indexed in more than one data source, duplicate data control was performed in the combined data set and it was determined that there were 171 duplicate data points deleted from the data set. As a result, 734 studies were obtained. (Figure 1)

The first article included in the study area was published in 1993. A total of 734 articles were published by 114 sources between 1993 and 2022 (August). Forty-two (42) of these articles are reviews. The number of author keywords is 1059. Out of a total of 1894 authors, only 13 published articles with a single author without collaborating. The coauthor is 5.04 per document. The number of single-author documents is only 14. The number of authors per document is 2.58.

3.2. Annual scientific production and average citations per year

There was no increasing trend in article production between 1993, when the first article was published, and 1999, and there has been an increasing trend since 1999 (Figure 2). It can be said that there was a breakdown, especially in 2008 and 2015. Since 2015, interest in the study area has increased considerably. Most articles were published in 2018 (n=75).

The annual average citation is the value obtained by dividing the total citations received by the articles published in the previous year up to the date of data collection by the elapsed time. When the average citation is examined, it is seen that the average citation of only 2 articles published in 1997 is 12, which is the highest value.

3.3. Three-fields plot

The relationships between the most relevant source (left), the most relevant author (middle), and the most frequently

used author keywords (right) are shown in Figure 3 as three area graphs based on a Sankey diagram. It seems that the most relevant resource in our field of study is overwhelmingly the "Journal of Endodontics". “International Endodontic Journal” comes right after it. The author who published the most articles in the "Journal of Endodontics" is "Kim HC". "Kim HC" published 24 of her 42 studies in the "Journal of Endodontics". Thirteen (13) of the "Gambarini G" (n=74) studies that have the most publications in your field of study were published in the "Journal of Endodontics". The most frequently used keyword of “Gambarini G” is “cyclic fatigue”, with 30 uses. The author frequently used the terms "nickel-titanium" and "endodontics" as keywords together with "cyclic fatigue". The most frequently used author keywords were “cyclic fatigue” (n=174), mostly “Gambarini G” (n=30), “Plotino G” (n=28), “Grande NM” (n=226”) and ”Testarelli L” (n=23).

3.4. Author analysis

3.4.1. Authors’ production over time

Analyses were made and visualized to determine the interest and effects of the authors who produced scientific articles on "cyclic fatigue" in the field of endodontics. These analyses were examined under the titles of Authors’ Production over Time, Author Impact, Authors Collaboration Network and Authors Co-citation Network. The authors’ production over time is shown in (Figure 4A) in the form of heat maps. The numerical values in the figure represent the number of articles produced during the year. The intensity of cell color tones is proportional to the total number of citations per year (TCpY) of the articles published that year. “Gambarini G”, with the most studies (n=59), published its first article in 2001. Between 2008 and 2022, he published an article every year. He published the most articles in 2012 (n=7).

3.4.2. Author ımpact

Author impact analysis was conducted to measure the impact of the authors who published articles in our study area. The impact of an author who has published an article in any discipline can be measured by evaluating the h-index, m-index and g-indexes. The H-index is measured by n citations of n works by the author. The M-index is proposed to facilitate comparison of the author’s careers. It is obtained by dividing the H-index by the time elapsed since the first published article.[16] The G-index was introduced in 2006 to measure the overall citation performance of a series of articles defined by Egghe as an improvement of the h-index.

To calculate the G-index, the cited articles by the author or the source are sorted in descending order of citation numbers, and it is the largest value of the total number of citations of the n most cited articles with a minimum n^2value.[14] The author impact information of the publications of the first 10 authors according to the total number of publications is shown in Table 2.

3.4.3. Authors collaboration network

Collaboration between authors is a network graph showing the work of authors together. Collaboration refers to the state of working together. Each of the nodes in the network represents an author working in the field. The size of the nodes is proportional to the number of broadcasts. The line between each node indicates the collaboration between the authors represented by those nodes, and its thickness is proportional to the number of works done together.[14] The number of nodes was determined as 50 in the analysis parameters. Louvain was chosen as the clustering algorithm. The minimum number of edges, that is, the minimum number of citations together, has been determined as 1. In the inter-author collaboration network, 10 clusters were formed (Figure 4B). The most intense cooperation was in the red colored cluster. In the center of the red cluster, which includes 9 authors, there is an author named "Gambarini G". Collaborated most intensely with "Testarelli I" of "Gambarini G". There is also an intense cooperation between “Grande NM” and “Plotino G”. Only two authors are in cooperation in 2 clusters. Some of the authors in 6 clusters, mostly in the red cluster, are also in cooperation with authors outside their own cluster.

3.4.4. Author co-citation network

Co-citation analysis is one of the ways to measure the influence of authors in any discipline. Citations to the author’s work can be used as a measure of impact.

The author co-citation analysis performed in our field of study is shown in Figure 4C. Each of the nodes in the network represents the cited author. The size of the nodes is proportional to the number of citations. The line between each node indicates the presence of common citations, and its thickness is proportional to the number of common citations received. The number of nodes was determined to be 50 in the analysis parameters. Louvain was chosen as the clustering algorithm. The minimum number of edges, that is, the minimum number of citations together, was determined to be 10. According to the results of the co-citation network analysis, there were two clusters. At the center of the blue cluster is “Gambarini G”. “Sattapan B”, “Peters OA” and “Pruett JP” are the other most commonly cited authors in the blue cluster. In the center of the red cluster is "Plotino G". The most co-cited author after "Plotine G" is "Shen Y".

3.5. Document analysis

3.5.1. Most cited documents

Analyses were made and visualized to measure the effects of the published documents on "cyclic fatigue" in the field of endodontics and to obtain an idea about the frequencies of the author keywords, their development over time and

the themes of the study area. For this purpose, most cited documents, most frequent words, word dynamics, author keyword, co-occurrence network analyses were applied.

The findings of local and global citations to the documents in our study area are shown in Figure 5A, as the top 10 documents according to the number of global citations. Local citation refers to the documents cited by the documents in our dataset, while global citation refers to the citations made by all documents in the database from which we obtained the dataset. The most cited article, both globally and locally, was the article “Cyclic fatigue testing of nickel-titanium endodontic instruments” with the doi number 10.1016/s0099-2399(97)80250-6 published in 1997. The number of global citations of the article in question is 568, and the number of local citations is 302.

3.5.2. Most frequent words

The frequency of use of author keywords in the articles published in our study area, including the frequencies, is shown in Figure 5B with a wordcloud image. The most frequently used keyword is “cyclic fatigue” in proportion to our search term (n=242). The keywords “nickel-titanium” and “endodontics” were used most frequently after the keyword cyclic fatigue. The top 10 most frequently used keyword frequencies are shown in the figure.

3.5.3. Word dynamics

A Word Dynamics chart was used to understand the evolution of author keywords over time (Figure 5C). For this purpose, the top 10 most frequently used author keywords were evaluated cumulatively. The keywords of these two authors "cyclic fatigue" and "nickel-titanium" have been used with an increasing trend since 2005.

3.5.4. Author keywords co-occurrence network

The word co-occurrence network graph of the first 50 most used author keywords used in the articles in the study area is shown in Figure 5D. During the analysis, the minimum number of edges was determined as 2. Louvain algorithm was chosen as the clustering algorithm. It is seen that there are 5 clusters in the co-occurrence network. Nodes in the network represent keywords. The size of the nodes, the number of usage and the lines connecting the two nodes mean that there is a relationship between the two words, that is, they are used together in at least 2 articles. The thickness of the lines is directly proportional to the frequency of use together. There is an intense relationship between the red and blue colored clusters. The word “cyclic fatigue” is in the center of the red colored cluster. The word "cyclic fatigue" is most often associated with the words "endodontics". Nickel-titanium is located in the center of the blue colored cluster. It is also observed that there is an intense relationship between "nickel-titanium" in the center of the blue cluster and "cyclic fatigue" in the center of the red cluster.

3.6. Source analysis

3.6.1. Source dynamics

In this study, the journal that publishes the article is expressed as a source. To see the development of the publications of the sources on "cyclic fatigue" in the field of endodontics over time, resource clustering analyses were conducted through source dynamics analysis and Bradford’s law.

In Figure 6A, there is a source dynamic chart showing the development of resources over time. The annual article production of the sources was calculated cumulatively, and the data of the top 5 sources that produced the most articles were visualized. The journal "Journal of Endodontics", which produces the most articles in its field, has increased in article production since 1998, and it produced articles with a serious increase, especially between 2006 and 2018.

3.6.2. Source clustering through bradford’s law

Cluster analysis was applied according to Bradford’s law to determine the most efficient ones among the resources in the study area. According to Bradford’s law, first defined by Bradford SC in 1934, only a few sources publish a large proportion of the literature in any discipline. The rest are published by many sources, each with only a few studies. Resources in Zone 1 form the core of the literature and can be calculated to identify the most productive series in a particular discipline.

The resource cluster analysis via Bradford’s law is shown in Figure 6 B. According to resource clustering analysis, the journals "Journal of endodontics" and "International Endodontic Journal" were located in Zone 1 and became the core resources in our study area. Eleven (11) sources are in Zone 2, and 128 sources are in Zone 3.

3.7. Countries analysis

3.7.1. Corresponding author’s country

Within the scope of the country analysis, most relevant countries by corresponding author were used to see the cooperation status with the countries that contributed the most according to the responsible authors, and the countries collaboration network analysis was performed to see the cooperation between the countries.

The image created for the analysis of the top 20 countries that contributed the most to the study area according to the responsible authors is shown in Figure 7. Accordingly, the country with the highest number of responsible authors is Italy (n=116). Italy has collaborated 30% of its work with authors from other countries. After Italy, the country with the highest number of responsible authors is Brazil (n=109). Brazil, on the other hand, performed 15% of the studies with authors from other countries.

Table 1: Analyzes applied in the study

Main Information	Author Analysis	Document Analysis	Source Analysis	Country Analysis
Annual Scientific Production and Average Citations per Year	Authors' Production over Time	Most Cited Documents	Source Dinamics	Corresponding Author's Country
Three-Fields Plot	Author Impact	Most Frequent Words	Source Clustering Through Bradford's Law	Countries Collaboration Network
	Authors Collaboration Network	Word Dynamics		
	Authors Co-citation Network	Author's Keywords Co-occurrence Network		

Table 2: Author impact information of the publications of the top 10 authors according to the total number of publications

Authors	h_index	g_index	m_index	Total Citation	Number of Publications	Publications Year Start
Gambarini G	23	45	1,045	2107	53	2001
Plotino G	26	47	1,529	2282	49	2006
Testarelli L	20	38	1,333	1497	45	2008
Grande NM	25	42	1,471	2207	42	2006
Kim HC	15	31	1	986	38	2008
Peters OA	17	28	0,81	919	28	2002
Shen Y	17	27	0,944	1140	27	2005
Pedulla E	13	24	1,083	592	24	2011
Vieira VTL	13	23	1	579	23	2010
HA JH	8	15	0,8	241	21	2013

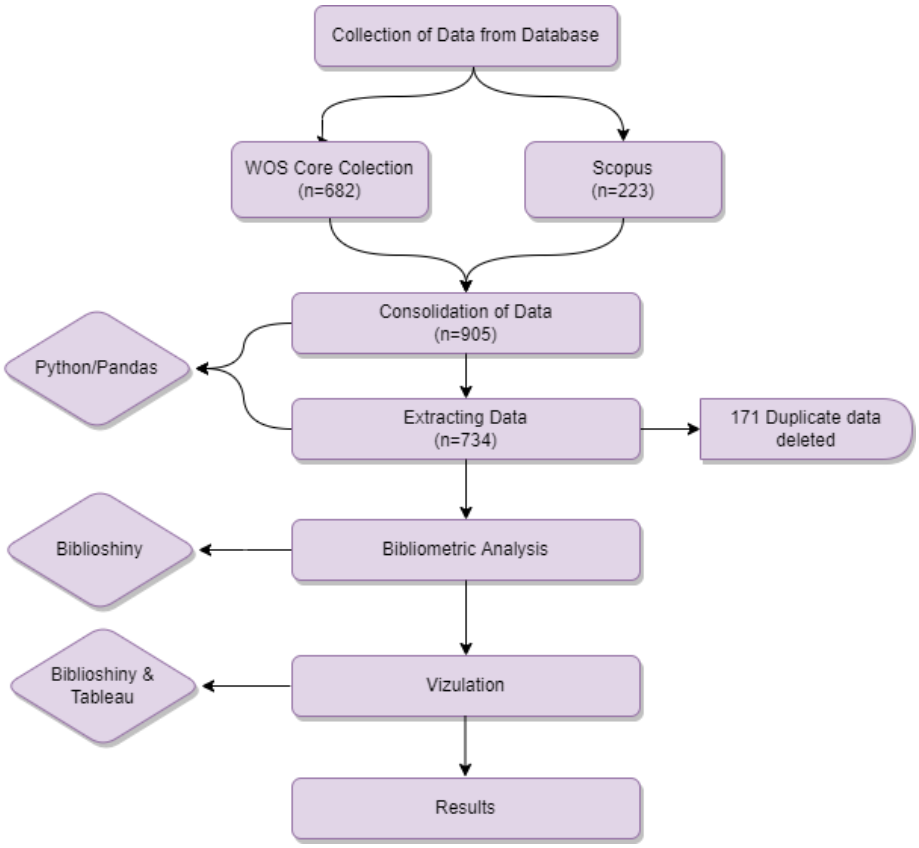

Fig. 1: Flow-chart

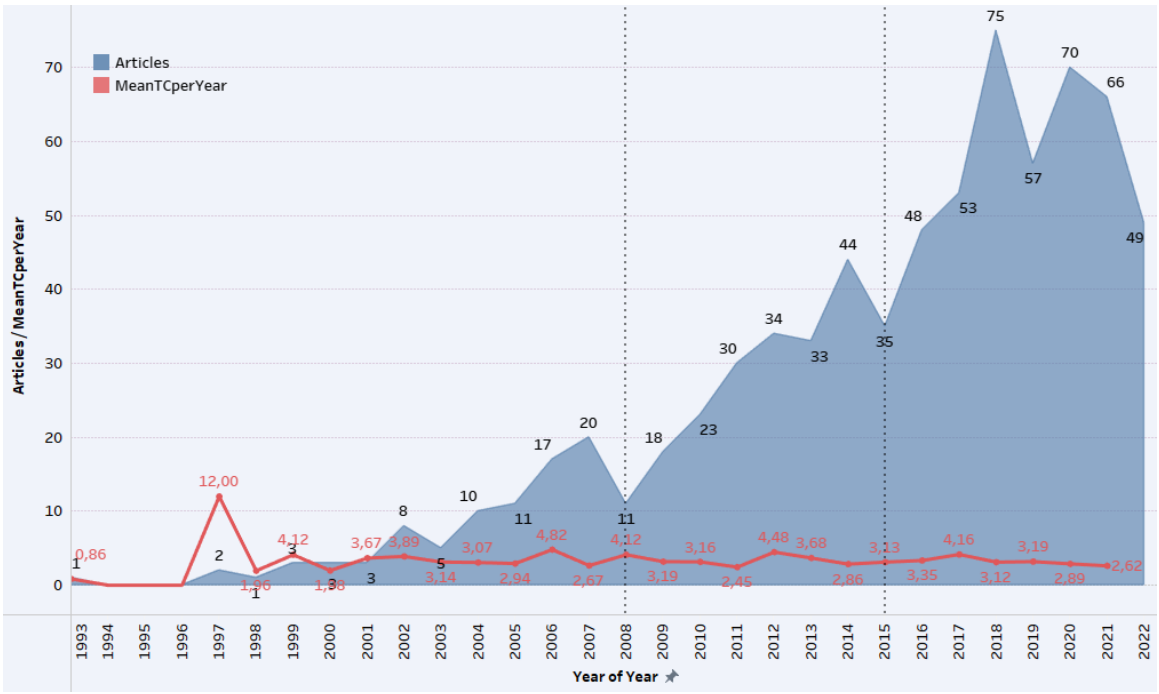

Fig. 2: Annual scientific production and average citations per year

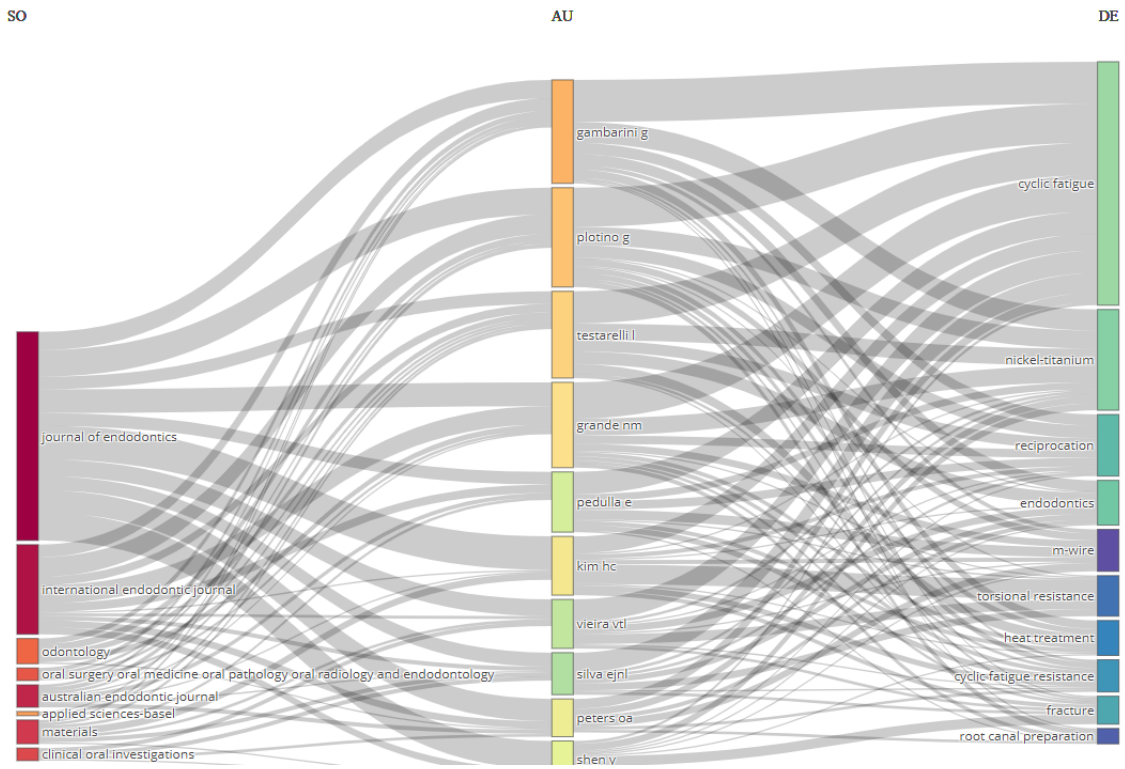

Fig. 3: Source, author and author keyword relationships (Three-Fields Plot)

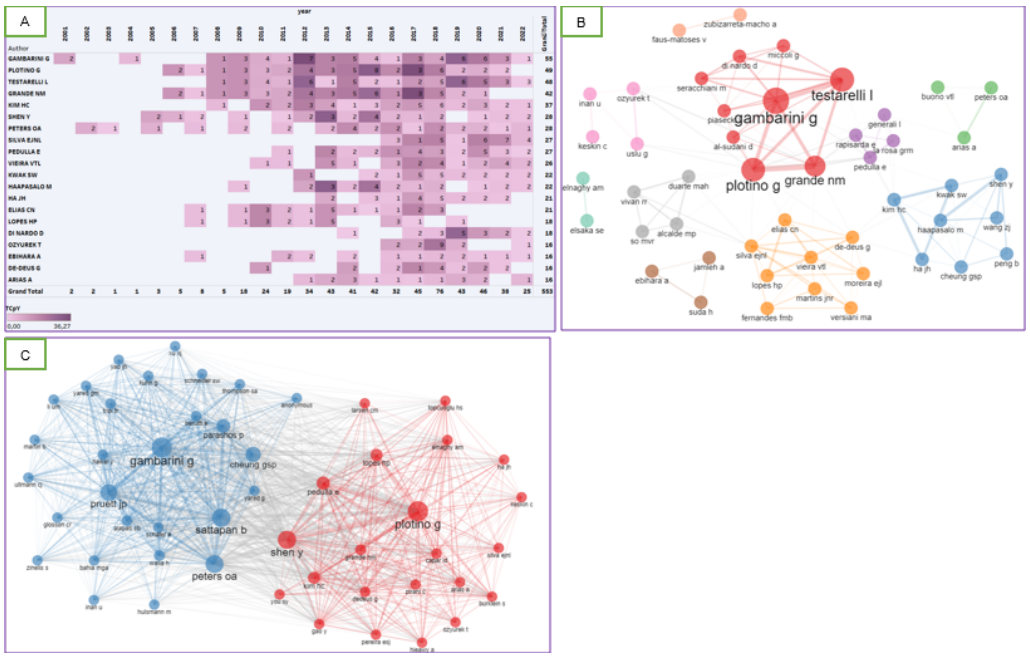

Fig. 4: A: Authors' production over time; **B:** Authors collaboration network; **C:** Author co-citation network

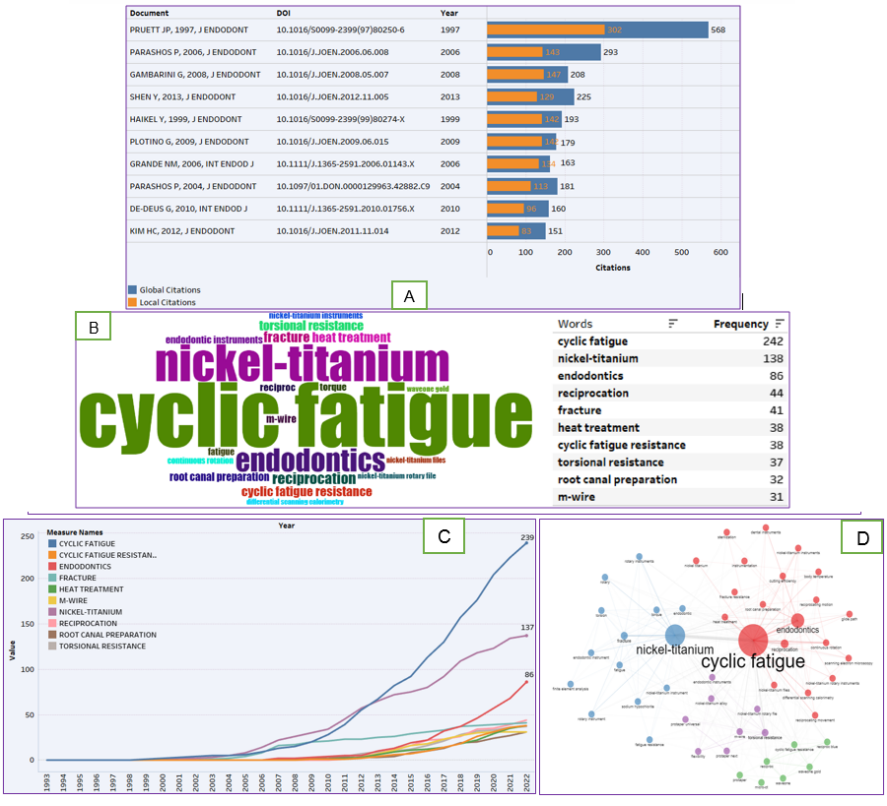

Fig. 5: A: Top10 most cited documents; **B:** Most frequently used author keywords (wordcloud)**; C:** Author's key words word dynamics; **D:** Author's keywords co-occurrence network.

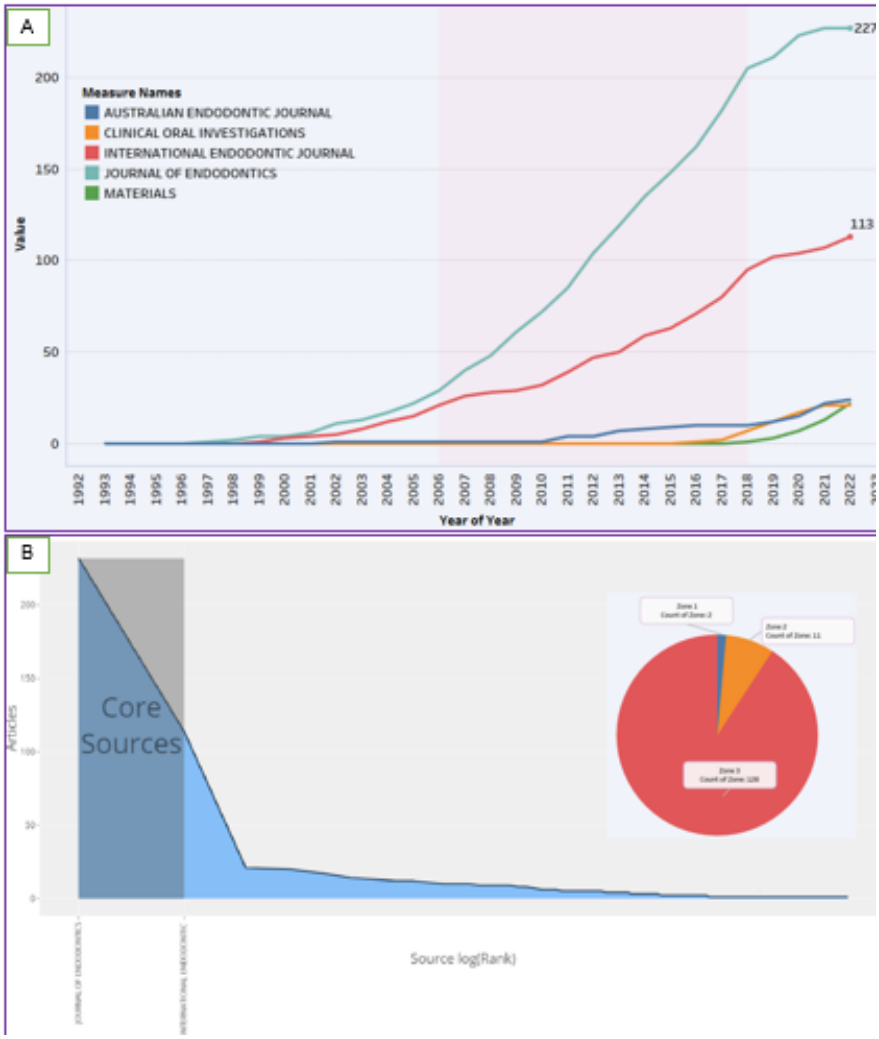

Fig. 6: **A** Source dinamics; **B:** Source clustering through bradford's law

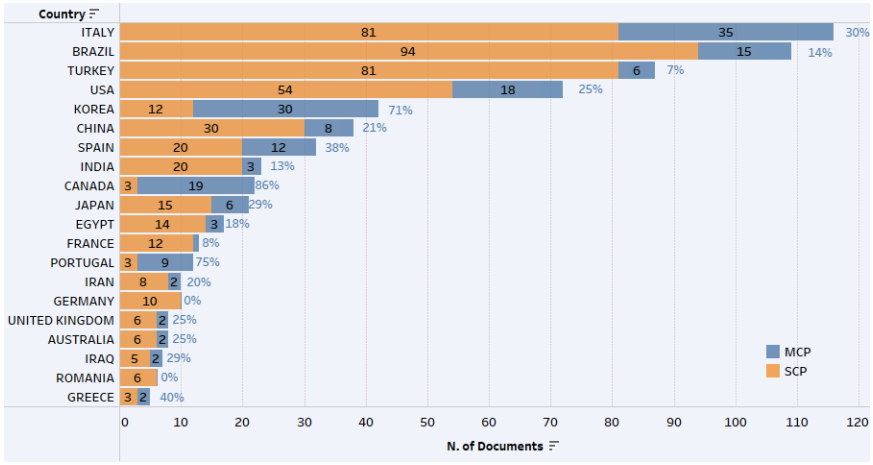

Fig. 7: Most relevant countries by corresponding author.
SCP :Single Country Publications, MCP :Multiple Country Publications
% expressions represent the Multiple Country Publications ratio.

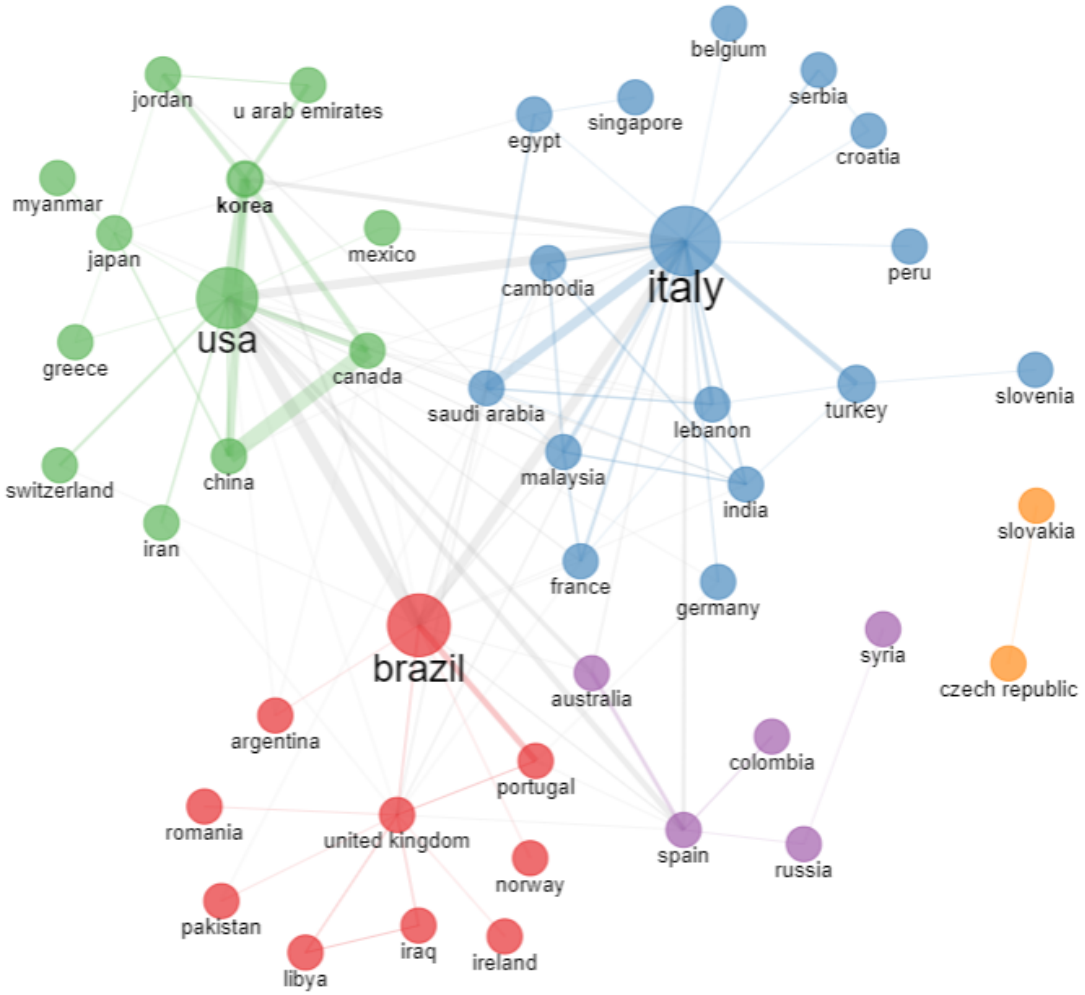

Fig. 8: Countries collaboration network

3.8. Countries collaboration network

The cross-country cooperation analysis image using network analysis metrics to see cooperation between countries is shown in Figure 8. Minimum Number of Edges is set to 1. As a result of the analysis, 5 clusters were formed. Italy is at the center of the blue cluster, which has the most intense relationship and includes 16 countries. The country with which Italy has the most intense cooperation is Saudi Arabia.

4. Discussion

Since citation analysis could not be performed for the articles obtained from PubMed, the data set obtained from the PubMed database was not included in the analysis. However, 622 of the 734 articles in our data set are also indexed in PubMed. The data of 734 academic studies obtained were included in the analysis.

It has been determined that only 13 of 1894 authors have published an article with a single author. Thus, there is intense author collaboration in the studies carried out.

Although most articles were published in 2018, the low number of articles in 2022 is due to the inclusion of only the first 8 months in the study area.

Although there is an increasing trend in the number of articles, there is no increasing trend in average citations. It could be said that the effect of the recently published articles in our study area is insufficient.

The top 5 authors with the most studies were quite productive between 2008 and 2022. “Ozyurek T”, the author who produces the most articles in a year, published 9 articles in 2018.

As seen in Table 2, the author "Plotino G", which is in the second place with 49 studies in the total number of articles, is the most influential author of the study field, both with the total number of citations and by being the first in all indexes. The author made his first publication in 2006. “Gambirini G”, which has the highest number of publications with 53, is also in the second place in terms of impact.

Based on the assumption that authors will cite documents they consider important to their work, it is assumed that because of heavy citations to a work, it means that work is important.[18–20]

Co-citation is defined as the frequency of citing two different studies together. One of the basic assumptions of co-citation analysis is that the more two items are cited together, the more likely their content is to be related.[21,22]

It is seen that 2005 was the breaking point for the keywords "cyclic fatigue" and "nickel-titanium", which are in the first two places according to the frequency of use.

In particular, "cyclic fatigue" tends to increase significantly. The word “fracture” has been used since 2004, and there is no serious upward trend. The term "endodontics" continues to be used with a slight upward trend since 2012.

The "International Endodontic Journal" has not yet published an article in 2022, which is in 2nd place, and continues to produce articles with increasing momentum since 1999. Other journals in the top 5 also showed a slight increase since 2017.

According to resource clustering analysis, the “Journal of Endodontics” and “International Endodontic Journal” confirm that they are the most productive resources in this field.

When evaluated in terms of the studies of the coauthors with the authors of other countries, it is seen that most of the studies collaborated with the authors of their own country. The most cooperating country is Canada with 86%. Canadian coauthors published 19 of the 22 articles in partnership with authors from other countries.

There are 10 countries in the red cluster. Although Brazil is the country that publishes the most articles in the red cluster, the United Kingdom is in the center. In the United Kingdom, it has relations with 7 countries in the cluster. At the center of the green cluster is the USA. The most intense relationship in the green cluster was between Canada and China. Italy, Brazil and the USA, which are at the center of their own clusters, also have an intense relationship among themselves. There are only 2 countries in the yellow cluster and they are not related to any other country other than themselves.

5. Conclusion

This bibliometric study focused on many variables that may possibly affect the fatigue resistance of instruments used in the field of endodontics since 1993. Because most of the studies were carried out in Italy, Brazil, Turkey, USA and Korea, it has been seen that this subject is an indispensable element worldwide. It is seen that the effort of endodontists to develop new formations and designs of NiTi rotary files in order to facilitate the cleaning and shaping of root canals during root canal treatment, and the number of articles on this subject continues to increase. Therefore reflected the fact that it is one of the main themes are open to improvement of the best journals in the field of endodontics.

6. Conflicts of Interests

The author has no financial interests or conflicts of interests.

7. Source of Funding

None.

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