International Journal of Information Science and Management
Vol. 18, No. 2, 2020, 189-201

An Analysis of Laser Researches in Biomedicine Literature with a Scientometric Approach

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∗ Received: 22 October 2019
Accepted: 12 June 2020

Abstract

The co-words analysis, as a scientometric method, helps us to discover the conceptual relationships between scientific texts and application of such relationships as a means to demonstrate important links that may be difficult to discover in other ways. This article is intended to use an analytical approach and identify research areas and to reveal the intellectual structure of knowledge in laser researches in biomedicine literature during 2009-2018. In this descriptive-analytical study with a scientometric approach, the data about laser were retrieved from PubMed in MEDINE format, including 7,682 articles with 18,227 keywords. By using co-word analysis, clustering methods, and strategic diagram; the data were analyzed with the help of SPSS 20, UcInet, and VOSviewer software. This study found that a steady growth could be seen on the laser research and 19.47% of publications are found in 5 journals. The most frequent keywords in the field of laser have been "lasers, solid-state", "laser therapy", "lasers, excimer", etc. The results of cluster analysis shaped the concepts of laser in 7 clusters. The cluster "laser, excimer" was well developed and it plays an effective role. In contrast, "Photo chemotherapy", "skin diseases with Emphasis on Lasers, gas", "Laser Effects", "Laser dentistry "and "Corneal Surgery, Laser" were relatively immature, which necessitates potential research space for future study. This research used co-word networks that indicate the important links between keywords of research areas. Disclosing the thorough context of issues which were encountered at the time of investigating, these networks will be used in locating knowledge gaps. Majority of research approaches include treatments or therapeutic aspects of laser in ophthalmology. The lack of some topics such as cardiology, oncology, optogenetics etc. shows that they have not been considered. Moreover, nevertheless of the practice site, application, or system in use, there is the goal of making and keeping a laser-safe environment for the staff, the user, and patient. These subjects have not been sufficiently considered.

Keywords: Laser, Scientometrics, Co-Word Analysis, Intellectual Structure, Biomedicine Literature.

Introduction

"A **laser** is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term "laser" originated as an acronym for Light Amplification by Stimulated Emission of Radiation" (Gould, 1959). Due to the widespread use of laser, it is essential in everyday life. Among several applications of laser, there is a particular focus on medicine as an attempt to identify appropriate therapies and as a tool for research in biology. (Kalaiselvi & Gopalakrishnan, 2017).

In recent years, lasers have been used in ophthalmology, oncology, cosmetic surgery, and many other fields of medicine and biomedical research. The use of light in the treatment of diseases has been known for thousands of years (Hilgers & Tracey, 2004; Olivi. Genovese & Caprioglio, 2009). "The ancient Greeks and Egyptians used sunlight as a therapy and the two ideas were even tied together in mythology, with the Greek god Apollo taking responsibility for both light and healing. However, it has only been since the invention of the laser 50 years ago that the potential of light in medicine has been revealed. The special properties of lasers make them much better than sunlight or other light sources at targeting medical applications. Each laser operates within a very narrow wavelength range, and the light emitted is coherent. They can also be very powerful. The beams can be focused to a very small point, giving them a high power density. These properties have led to lasers being used in many areas of medical diagnosis and treatment" (Ross, Ross, 2008).

After five decades of intense basic research, it is time to have a global look at the updated and comprehensive picture of laser researches. In other words, the study of scientific productions in the field of laser can be effective in policy making and scientific development in this field. In this paper, it has been attempted to visualize the scientific profiles of laser research. The article also studies the main topics in laser research and reviews thematic relations using co-word analysis method. "The co-words analysis, as a scientometric method, helps us to study and identify conceptual relationships between scientific texts, to use such relationships to make general policies, and to choose research topics. This type of analysis can help us discover concepts which are dominant in the works" (Makkizadeh & Sa'adat, 2017). In co-word analysis, it is assumed that keywords extracted from papers could represent a specific research direction, research topic or subject of a field. If two keywords co-occur within one paper, the two research topics they represent are related. Higher co-word frequency means a stronger correlation in keyword pairs, which can further suggest that two keywords are related to a specific research topic (Cambrosio, Limoges, Courtial, & Laville, 1993).

Many scholars have used the co-word analysis and topic clustering as one of the most important ways to examine the concept of a network in different domains.

Reviewing the texts on co-word analysis and topic clustering shows that numerous researches have examined various fields of science through co-word analysis, including anticancer (Xie, 2015), infertility (Makkizadeh & Sa'adat, 2017), medical big data (Leung, Sun, Bai, 2017), social media (Makhoba & Pouris, 2017), medical big data (Hsu, Li, 2019), Linked Data Field (Kyaw, & Wang, 2018), and andrology (Makkizadeh, & Bigdeloo, 2019).. Although the use of co-word analysis, as one of the bibliometric techniques, has been increasingly accepted by researchers and has been used to study the intellectual structure of knowledge in various fields, such research has not yet been conducted in the field of laser. One should note that reviewing texts on scientometrics studies, particularly dealing with different aspects of

laser research, has been done by many researchers (Jain & Garg, 1992; Garg & Padhi, 1998; Garg, 2002; Garg & Padhi, 2001; Kalaiselvi & Gopalakrishnan, 2017).

Thus, according to the above discussion, this study aims to take an analytic approach to identify laser research areas and to reveal the intellectual structure of knowledge in laser field on PubMed from 2009 to 2018 using co-word analysis, network analysis, and scientific visualization tools. Furthermore, this article will present the annual publication of articles and journals that contributed to producing scientific articles in laser field.

Methods

This research is an applied study with Scientometrics approach that employed co-word analysis. "Co-word analysis has been proved to be a fairly reliable method of data analysis, and it is still being used constantly" (Hsu & Li, 2019). The data were downloaded from PubMed in MEDINE format on January 16th, 2019. PubMed database (http://www.ncbi.nlm.nih.gov/pubmed) was developed by the National Center for Biotechnology Information (NCBI) at the National Library of Medicine (NLM). PubMed was chosen as the source of data because it is the most widely used research index in medicine and biomedical topics (Boudry, Denion, Mortemousque, Mouriaux, 2016). The search terms were: "Laser [MH] AND journal article [PT] AND 2009:2018 [DP]" where MH stands for "Medical Subject Headings," DP "Date of Publication", and PT "Publication Type"."MeSH is the National Library of Medicine's controlled vocabulary thesaurus (http://www.nlm.nih.gov/pubs/factsheets/mesh.html) and consists of sets of terms named "MeSH terms" arranged in a hierarchical structure with more specific terms arranged beneath less specific terms".

The data were collected from PubMed, including18, 227 keywords from 7,682 articles. Using those keywords, this research investigated about 224 high frequency keywords to examine the co-occurrence matrix. Co-word analysis utilizes a co-occurrence matrix for calculating cluster analysis by SPSS software. Cluster analysis finds the entities within a group, which is related to one another, and it is different from unrelated entities in other groups (Kyaw & Wang, 2018). Eventually, network analysis was used on network graphs to illustrate a research field. It was done by using Ucinet6.0 and VOSviewer. Various network characteristics can be used to describe a field of research. The network characteristics in the research are as follows:

"Centrality is used to measure the strength of the interaction of a subject area with other subject areas. Ranking subject areas (clusters) with respect to their centrality shows the extent to which each area is central within a global network. Density is the internal strength of a cluster and provides a good representation of the cluster's capacity to maintain itself and to develop over the course of time in the field under consideration" (Bredillet, 2006).

Utilizing centrality and density, a strategic diagram can be created to better visualize and understand the maturity and cohesion of network clusters (Hu, Hu, Deng, Liu, 2013). A strategic diagram that offers a global representation of the structure of any field or subfield can be created by plotting centrality and density into a two-dimensional diagram. The horizontal axis represents centrality, the vertical axis represents density, and the origin of the graph is at the median of the respective axis values. Different centralities and densities display the different status of research topics in four different quadrants. In quadrant 1, clusters are coherent and the core of the field in general. In quadrant 2, Clusters are linked by numerous keywords (high centrality), while they are very different from each other (low density). Clusters in quadrant 3

are close to each other, but they are specialized on one theme. Finally, the ones in quadrant 4 are central but are undeveloped or immature (figure 1) (ibid). In this research, a strategic diagram is drawn based on centrality and density of each topic cluster in the laser field.

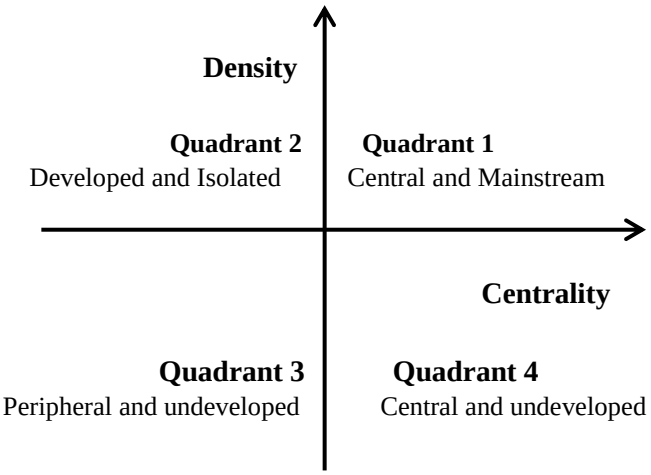

Figure 1. Strategic Diagram (Hu, Hu, Deng, Liu, 2013)

Table 1
Distribution of output in laser research papers in 5 top journals

No.	Journal	Frequency	Percentage
1	LASERS IN MEDICAL SCIENCE	777	6.47
2	JOURNAL OF REFRACTIVE SURGERY	430	3.58
3	JOURNAL OF CATARACT AND REFRACTIVE SURGERY	426	3.55
4	PHOTOMEDICINE AND LASER SURGERY	367	3.06
5	DERMATOLOGIC SURGERY	339	2.82

Results

In total, 7,682 articles were found in the field of laser indexed on PubMed through the period of 2009-2018. In the past 10 years, researchers have been paying increasing attention to laser. As reflected in Figure 1, the annual publication of articles has steadily grown hitting the peak in the year 2015. As many as 1,028 journals have been involved in this field. The top five most productive journals, which are considered as the core journals in this research area, were shown in Table 1. Among the top five journals, the top three journals are Lasers in Medical Science, Journal of Refractive Surgery, and Journal of Cataract and Refractive Surgery. These journals published 19.47% of the articles.

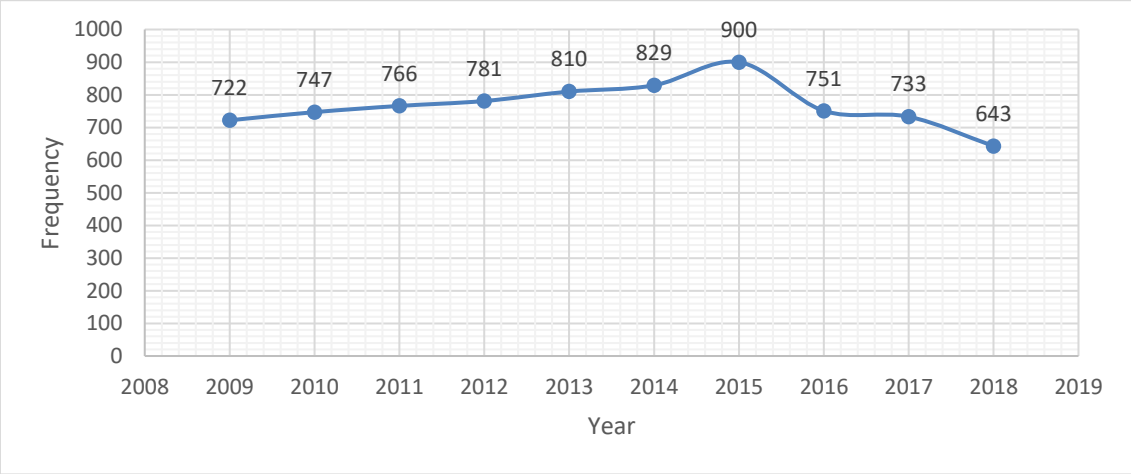

Figure 2. Number of publications on laser from 2019 to 2018

To increase accuracy of the co-word analysis, the keywords were first smoothed with check tags and stop word lists. As a result, out of the 7,682 articles retrieved, a total of 18,227 keywords were extracted with an occurrence greater than or equal to 224 times. In other words, 55 high frequency keywords (more than 224) were selected as the research sample for co-word analysis. These 55 keywords covered almost 30% of the total keyword frequency. The top 20 keywords are shown in Table 2. As shown in the table, high frequency words contain concepts such as “lasers, solid-state”, “laser therapy”, “lasers, excimer”, etc.

Table 2
High frequency keywords used in laser research papers

No.	Keywords	Frequency	No.	Keywords	Frequency
1	Lasers, solid-state	3320	11	Postoperative complications	729
2	Laser therapy	2143	12	Refraction, ocular	694
3	Lasers, excimer	1730	13	Equipment design	548
4	Lasers, gas	1436	14	Combined modality therapy	531
5	Visual acuity	1390	15	Surface properties	521
6	Lasers, semiconductor	1349	16	Cornea	513
7	Low-level light therapy	1124	17	Tomography, optical coherence	489
8	Myopia	931	18	Corneal stroma	485
9	Keratomileusis, laser in situ	924	19	Reproducibility of results	472
10	Time factors	807	20	Microscopy, electron, scanning	448

Analysis of co-word network

To construct and visualize co-occurrence networks of research on laser field, the network-visualization tool VOSviewer was used to analyze each keyword and its co-occurrence connection with other keywords, (i.e. two (or more) words that tend to occur in a related text)

(Figure 3).“Each node in a network represents a keyword while the size of the node indicates how frequently the keyword appears, with a bigger node meaning a higher frequency. The thickness of the lines connecting two nodes represents how frequently the two keywords appear together, with a thicker line indicating a higher frequency” (Boudry, Denion, Mortemousque, Mouriau, 2016). Figure 3 displays co-occurrence of the laser words network. The words ‘laser, solid state’, ‘laser excimer’, ‘visual acuity’, and ‘myopia’ have greater relation to other words. thus, they form the core of research on the laser field.

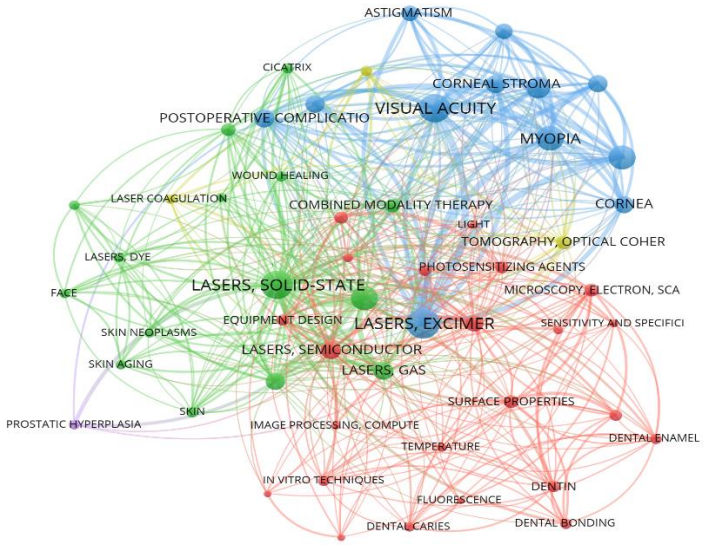

Figure 3. Co-occurrence laser words network over the period 2009-2018

Multivariate statistical analysis

In this study, hierarchical cluster analysis is performed on the co-occurrence matrix, with Ward’s method and Squared Euclidean distance being used as the distance measurement. “Cluster analysis finds the entities within a group that are related to one another and are different from unrelated entities in other groups” (Kyaw, Wang, 2018). As a result, it uses the Ward's method and is shown with a dendogram as in Figure 4.

The dendogram can be divided into three big clusters. In the first cluster, there are two keywords including “Photo chemotherapy” and “Photosensitizing agents”. The second cluster, which forms a group, includes 11 keywords from “Lasers, gas” to “Combined modality therapy”. The third big cluster, which is a large group, describes 21 keywords from “Dental caries” to “Light”. Table 3 shows more details of the clusters, which are based on cluster analysis of the dendogram.

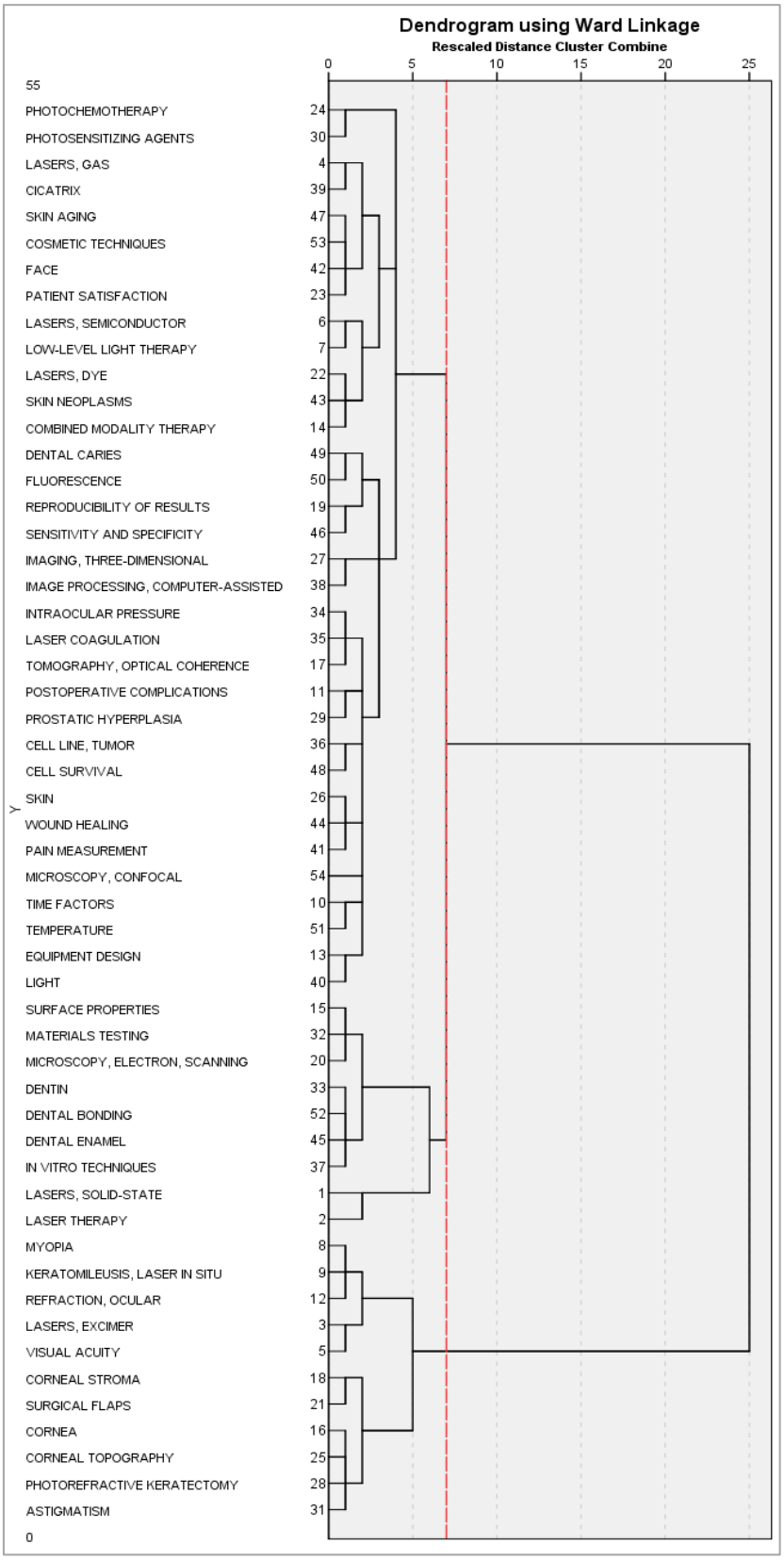

Figure 4.Result of Hierarchical Group Analysis

Table 3
Seven Clusters of laser field

Group	Cluster	Keywords	Cluster name
1st	C1	Photo chemotherapy; Photosensitizing agents	Photo chemotherapy
	C2	Lasers, gas; Cicatrix; Skin aging; Cosmetic techniques; Face; Patient satisfaction; Lasers, semiconductor; Low-level light therapy; Lasers, dye; Skin neoplasms; Combined modality therapy	skin diseases with Emphasis on Lasers, gas
	C3	Dental caries; Fluorescence; Reproducibility of results; Sensitivity and specificity; Imaging, three-dimensional; Image processing, computer-assisted; Skin; Intraocular pressure; Laser coagulation; Tomography, optical coherence; Postoperative complications; Prostatic hyperplasia; Cell line, tumor; Cell survival; Wound healing; Pain measurement; Microscopy, confocal; Time factors; Temperature; Equipment design; Light	laser effects
2nd	C4	Surface properties; Materials testing; Microscopy, electron, scanning;Dentin;Dental bonding;Dental enamel;In vitro techniques;	Laser dentistry
	C5	Lasers, solid-state; Laser therapy;	Lasers, solid-state
3rd	C6	Myopia; Keratomileusis, laser in situ;Refraction, ocular;Lasers, excimer;Visual acuity;	Lasers, excimer
	C7	Corneal stroma; Surgical flaps;Cornea;Corneal topography;Photorefractive keratectomy; Astigmatism;	Corneal Surgery, Laser

Strategic diagram

Relying on cluster centrality and density of the 55 themes (7 clusters) in Table 4, a strategic diagram was constructed according to internal and external cohesion of themes (Figure 5). "A strategic diagram is mostly used to describe the internal relations within a cluster, as well as the interactions among different fields" (Hu, Zhang, 2015).

According to Table 4, the clusters 6, 2, 4, and 7, respectively, have higher centralities. It points out that the clusters have a crucial position in the literature regarding laser and the clusters 1, 5, and 3 have a lower centrality. These are considered as marginal clusters of laser.

Table 4
The centrality and density of seven clusters

No. Cluster	Name of clusters	Density	Centrality
1	Photo chemotherapy	303	100
2	skin diseases with Emphasis on Lasers, gas	56.8727	71.9
3	Laser Effects	14.332	14.9199
4	Laser dentistry	68.3333	65.2
5	Lasers, solid-state	1030	100
6	Corneal Surgery, Laser	678	286.25
7	Cornea	48.3333	42.8036

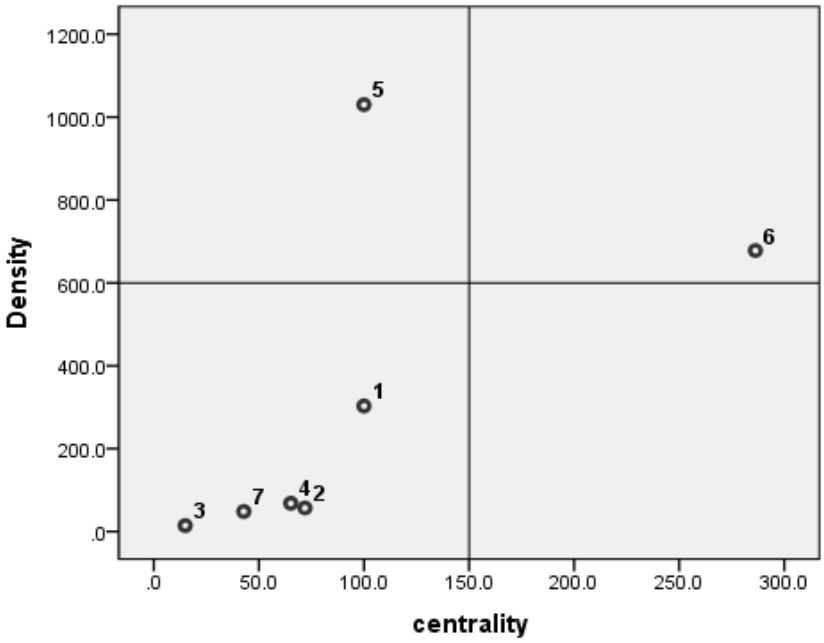

Figure 5. The strategic diagram of seven clusters.

Figure 5 illustrates the strategic diagram of clusters derived from co-word analysis in the field of laser. The origin of the diagram was set on points 600.0 and 150.0 based on the average cluster centrality and density. As already mentioned, the strategic diagram divides the clusters into four quadrants. "Themes with high density in quadrant 1 are well-developed and are core. Research topics in quadrant 2 are not central but well-developed. Quadrant 3 contains themes with weak density and inadequate centrality, and these are considered to be either appearing or vanishing. The themes in Quadrant 4 contain themes that are central in the network but lacking internal maturation".

As Figure 5 shows, cluster 6 falls in part 1 and displays higher centrality and density than other clusters. This cluster is the mainstream issues in laser field. Cluster 6 includes keywords such as "Myopia", "Keratomileusis, laser in situ", "Refraction, ocular", "Lasers, excimer" and "Visual acuity". Cluster 5 focuses on keywords including "Lasers, solid-state" and "Laser therapy". This cluster is developed while isolated clusters 1, 2, 3, 4, and 7 fall in the part 3 and have lower density and centrality; therefore, these clusters are peripheral and undeveloped. This implies that these clusters are not axial but are developing. For example, the keywords in Cluster 4 include "Surface properties", "Materials testing", "Microscopy, electron, scanning", "Dentin", "Dental bonding", "Dental enamel", and "In vitro techniques". Another finding is that no cluster was placed in part 4 of the diagram.

Discussion

The data driven approach in this study used co-word analysis to determine the major topics of researches in the laser field during the past 10 years and to understand the main research focus, the correlation between topics, and the trends in the field. The growth rates for scientific papers on the laser field had a steady increase from 2009 to 2018. "The increase in publication activity may be due to the new developments in the field of laser science and technology (Garg & Padhi, 1998).

About 20% of papers were published in five journals – Lasers in Medical Science, Journal

of Refractive Surgery, Journal of Cataract and Refractive Surgery, photo medicine and laser surgery, and Dermatologic surgery.

"Lasers, solid-state" was the most frequently-used word in this research. Research into solid-state lasers has continued for more than 50 years. "Gradually significant progress has been reached in obtaining new emission wavelengths and tunable sources of laser radiation. A specific feature of solid-state lasers is the ability to obtain a wide variety of operation modes and output parameters of laser radiation. That is the basis of the huge diversity of different uses of solid-state lasers in medicine" (Jelínková, 2013).

Among the most frequent keywords in the field of laser, "Laser Therapy" and "Lasers, Excimer" are ranked second and third respectively. "Excimer lasers" are facing strong competition from solid-state lasers, although they still offer the most efficient access to the ultraviolet spectral region—with high energies, high peak and average powers in pulsed operation. Excimer lasers, along with nitrogen lasers, are the most popular gas lasers generating radiation in the ultraviolet range" (ibid). "Laser therapy" consists of any medical use of lasers for purposes designed to improve the state of patients. Lasers can be used for many medical purposes. Because the laser beam is small and precise, it allows healthcare providers to treat the disease without injuring the surrounding area. The findings of many researches mandate the conclusion that laser therapy is a highly effective therapeutic armamentarium (Enwemeka, Parker, Dowdy, Harkness, Harkness, & Woodruff, 2004; Woodruff et al., 2004). Therefore, it is no surprise that "laser therapy" was a hot keyword.

By analyzing the topics attributed to the documents (keywords), a wide range of scattered data was located in three groups and seven clusters. The topics of these clusters are: "Photo Chemotherapy", "skin diseases with Emphasis on Lasers, gas", "Laser Effects", "Laser dentistry", "Lasers, solid-state", "Lasers, Excimer" , and "Corneal Surgery, Laser". The clusters created with common features within each group have structural relationships with each other, and clusters represent a research director of the subject. The main axis of the subjects were clusters 6 and 7 in the third group: "Corneal Surgery, Laser". The cornea is the transparent tissue that covers the front of the eye. It helps to control focusing. Vision correction surgery, also called refractive and laser eye surgery, refers to any surgical procedure used to fix vision problems. Recent years have witnessed huge advances in this field. Refractive and laser eye surgery allow many patients to see better than any other time in their lives (Pietilä et al., 2016).

Analysis of clusters showed that researchers have emphasized the use of laser in the treatment of eye and skin diseases. Further analysis of the data indicates that researches mainly concentrate on experimental aspects of laser. In other words, emphasis on theoretical aspects of laser is little. This finding is consistent with previous research (Garg & Padhi, 1998).

The application of laser in other branches of medicine such as cardiology and oncology were not considered. One of the reasons for such a result is that, in bibliometrics, researches dictated that the major articles were published in ophthalmology and dermatology journals (Jain & Garg, 1992; Garg & Padhi, 1998; Kalaiselvi & Gopalakrishnan, 2017).

As a result, the strategic diagram was employed to complement hierarchical clustering in the co-word analysis. As shown in Fig. 4, quadrant I includes Cluster 6, "Myopia; Keratomileusis, laser in situ; Refraction, ocular; Lasers, excimer; and Visual acuity that are the most comprehensive subject areas in laser and that are more developed and tend to be mature. This cluster is broadly linked with other clusters. Keywords "Lasers, solid-state" and "Laser therapy" (cluster 5) are in the second quadrant with low centrality and high density, which have

a close internal connection. These topics are well-developed and mature. They are potential research areas in the laser field.

Many clusters including “Photo chemotherapy”, “skin diseases with Emphasis on Lasers, gas”, Laser Effects”, and “Laser dentistry are located in quadrant 3. Concerning the placement of these themes in the strategic diagram, one can claim that these themes did not show established internal and external relations in the field and remained underdeveloped. These clusters of keywords are not very related to the keywords in other clusters. Therefore, they are topics that may be emerging or disappearing. These topics are almost related to each other. In other words, “laser Effects, can be defined how laser exerts its medical effects on treating in the medical field (skin, dentistry, eye, and photo chemotherapy). The effects of laser brings about scientific maturity to the medical laser” (Abuarra et al., 2012).

It is necessary to mention that this study examined the research on PubMed database. However, using other databases like Scopus and WoS may produce different results.

Conclusion

This study was conducted as a scientometrics review about the knowledge structure of laser field from 2009 to 2018. The overall context of issues, which were collected by the research on laser, is shown by the co-word networks. Due to the frequency of keywords along with the clusters obtained, it seems that the most distinguished research approach was experimentally oriented, especially on subjects like Cornea, dermatology, and dentistry. The application of laser in other branches of medicine such as cardiology, oncology, etc. was not considered. It is thus suggested that researchers can focus on topics that are not addressed in the laser field. There are several relevant studies in other publication formats (clinical trial, review, etc.) that may change the results of this research. Therefore, other bibliometric analyses can be done on them. Furthermore, applying other scientometric methods like citation analysis or co-authorship can complement this study.The results form a solid academic foundation that gives insight to researchers and aids more discussions and questions about the field in general.

Acknowledgments

The author appreciates the support of Mr. Ali Taherizadeh (MA in English literature) for editing.

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