

# Science-Technology Linkage in the Field of Medical and Laboratory Equipment

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## ABSTRACT

The study aimed to investigate the relationship between science and technology in the field of medical and laboratory equipment registered at the United State Patent and Trademark Office database in the period 1984-2014. This research carried out as a descriptive-analytical study using scientometrics techniques. The statistical population is all patents of medical and laboratory equipment registered at the US Patent and Trademark Office during the period from 1984 to 2014, as well as all articles indexed in the period studied in the Web of Science. As a result of this search, 13424 patents and 16877 articles were retrieved. The number of patents and scientific articles published in the field of medical and laboratory equipment rose steadily between 1984 and 2014. Also, the number of citations to patents and scientific papers of this research area has grown exponentially in the given period. Citation rates for patents of medical and laboratory equipment area to US patents are much higher than their citations to non-US patents and other types of records. The scientific potential of medical and laboratory equipment is far more than technical capacity and researchers in the field of medical and laboratory equipment tend to cite to scientific articles rather than patents. This indicates the reliance of technology to science in the field of medical and laboratory equipment. Actually, the increasing role of scientific discoveries, which is accompanied by an increase in the number of citations to scientific documents, has led to the development of applied technologies in this field.

**Keywords:** Medical and laboratory equipment, Science and technology linkage, Science development, Technology development, Technology metrics.

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## INTRODUCTION

Due to the recent rise in international competition, governments are implementing technological policies to guide the future of research and development, innovation and the promotion of industrial technologies. In fact, government support for research and development programs is needed to increase national competitiveness and expand knowledge and technology, since these activities require cost and state-owned infrastructure.<sup>[1]</sup>

Among the indicators available to evaluate technology outputs, patent-based indicators are an appropriate indicator for assessing the outcomes of technological activities in countries. In the field of Industry and technology, patents have profitable and fruitful information about innovation and knowledge flowed between them.<sup>[2]</sup> Analysis of patents is a method that can be used to convert inventive data into useful

information about the status of technological development, the competitive outlook of the market, the position and structure of technology, business strategies, research and development planning and intellectual property management. Also, the analysis of patent patents can be used to analyze competitors and the process of technological change at the national and international levels and to estimate the strengths and weaknesses of rival technologies and the assessment of the potential of foreign markets.<sup>[3]</sup> Patents also include a wide range of exact knowledge domains and with the development of new technologies, new terms are constantly emerging from the various fields of science.<sup>[4]</sup>

The scientific mapping of patents and articles published in various fields of science can be indicative of structural relationships between S&T. Through the processing, extraction and sorting of information, researchers can conduct scientific mapping that allow researchers to analyze, way finding and display knowledge.<sup>[5]</sup> In fact, the interactive link between S&T is the key to innovation. In order to achieve innovative advances in technology, experts have integrated S&T into emerging areas. Although articles and patents alone cannot be indicative of general scientific advances in the field of S&T, but through them, we can measure the overall

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process of initial efforts through the quantity of articles and obtain accurate and sufficient information about technological activities via inventions. Hence, articles and patents can be used as indicators of technical and scientific activities.<sup>[6]</sup>

Since S&T are the basis for the sustainable development of each country, their assessment at the national and international levels has been considered as a growing process in recent years. Among the various research areas, the field of medical and laboratory equipment has been considered due to its high profitability in the economic dimension and engaging with human health. Also, it is impossible to develop medical science without medical and laboratory equipment and the growth of this science can be attributed to the existence of medical and laboratory equipment. The main question of the present research is how the relationship between articles and patents in the field of medical and laboratory equipment between 1984-2014. Therefore, researchers are trying to investigate the process of growth of articles and patent and the growth process of citations of medical and laboratory equipment experts and measures linked to S&T and measures of academic ability and technical capacity to examine the link between S&T in the field of medical and laboratory equipment. This study seem necessary because of the importance of this field, no research has ever been done in the field of medical and laboratory equipment. Finally, considering the importance of scientific articles as an appropriate measure for assessing the progress of science and patent as an appropriate measure for assessing the progress of technology, the analysis on them can provide a report on the scientific and technical state of medical and laboratory equipment and ultimately, moving on the path to more science and technology's effectiveness. The most important feature of this research that distinguishes it from other research, besides the topic novelty, is the statistical population in which has tried to work with a comprehensive search strategy that includes all the inventions made by inventors and articles in the field of medical and laboratory equipment during the period from 1984 to 2014.

Therefore, considering the importance of patents in determining the share of countries' production in the development of S&T, as well as the competitiveness of countries to obtain a higher status in this regard, it seems that conducting this research is essential for maintaining the health of human societies. Investigating the relationship between S&T in the field of medical and laboratory equipment can lead to the movement of many national and international researchers towards the commercialization of science. Finally, this research can demonstrate the scientific and technical status of countries in the world at the given time. As a result of quantitative evaluation of scientific outputs in this research area, it can help planners to use the most from human and financial resources at the lowest cost, as well as in optimizing their country's economic and social structure will be effective.

This research can encourage researchers in the field of medical and laboratory equipment to make further efforts and create a healthier competitive environment among them.

## LITERATURE REVIEW

Naomi and Takanori<sup>[7]</sup> conducted a research entitled "Science linkages between scientific articles and patents for leading scientists in the life and medical sciences field: The case of Japan". The findings showed that the highest citation of the article-article is 4 years, while this amount is 6 years for the article -patent. In addition, the quality of the articles is crucial to be cited by patents. The citation to patents requires more time than citation to scientific papers. Also, the findings indicated that articles with high quality and high citation had a great impact on the development of patents. Overall, the results showed that the distribution of scientific knowledge and technological activities take a long time; however, the expansion of collaboration between industry and the university could be helpful in this regard and shorten the time lag. Also, academic high- quality papers are highly cited by patents. So, highly cited articles are useful for the development of areas of technology.

Huang *et al.*<sup>[6]</sup> carried out a study titled "Increasing S&T linkage in fuel cells: A cross citation analysis of papers and patents". The findings of this study showed that there is a growing convergence between S&T. The results of this study showed that the number of citations in articles and patents was not high, but gradually increased since 2003. The average number of citations of articles in each patent has been increasing annually since 2006, indicating an increase in the number of citations between articles and patents. Also, in articles, the number of patents cited was much lower than other types of citations. Accordingly, the results indicated that the annual growth rate of science is higher than that of technology.

Wong and Wang<sup>[8]</sup> conducted a research entitled "Trajectories of S&T and their co-evolution in BRICS: Insights from publication and patent analysis". The results of this study showed that the growth of scientific production and patents in the studied countries was very appropriate during the mentioned period. Among the mentioned countries, Russia and India are expected to reach maturity in S&T sooner than other countries in the years 2026-2027 and about ten years later, China and Brazil will achieve such a place and in the end, it is expected that South Africa 65 years after Russia and India and about 50 years after China and Brazil in the field of S&T to reach maturity. South Africa, unlike the other four countries, has a relatively stable growth pattern or a low growth rate. However, the difference in growth paths in patents is less pronounced than in scientific publications.

Noruzi and Abdekhoda<sup>[9]</sup> conducted a research entitled “Mapping Iranian patents based on International Patent Classification (IPC), from 1976 to 2011”. The aim of this study is to map the past and current trends in patenting activities with a view to better understanding and tracking the changing nature of S&T in Iran. The patenting activity in the Iran was investigated for the period 1976–2011, based on the USPTO, WIPO and EPO. Analytical results demonstrate that between 1976 and 2011, 212 patents have been registered by Iranian inventors in the three above-mentioned databases. The average number of Iranian patents registered per year has increased significantly from 25 in 1976–1980 period to 119 in 2006–2011. It was noted that the highest number of registered patents (27 %) were in “chemistry, metallurgy” area of International Patent Classification (IPC), followed by “human necessities” (18 %), “electricity” (17 %) and “performing operations; transporting” (15 %). Overall, it can be concluded that patent-activities are highly country-specific, the results indicate that Iran is focused on “chemistry, metallurgy” technology.

Also, other researchers such as Finardi<sup>[10]</sup> “Time relations between scientific production and patenting of knowledge: the case of nanotechnologies”; Szu-chia<sup>[11]</sup> “Scientific linkage of science research and technology development: A case of genetic engineering research”; Guan and He<sup>[12]</sup> “Patent-bibliometric analysis on the Chinese science- technology linkages”; Murray<sup>[13]</sup> “Innovation as co-evolution of scientific and technological networks: exploring tissue engineering”; Meyer<sup>[14]</sup> “Patent Citation Analysis in a novel field of Technology: An Exploration of nano-science and nano-technology” studied related issues. Overall, the review of the conducted research shows that although there is a lot of research in the field of citation analysis of patents and the importance of citations in patents has proved, but on the linkage between S&T has not been carried out any research in the field of medical and laboratory devices. Therefore, it was essential to carry out a research that examined the linkage between S&T in the medical and laboratory devices area and to demonstrate scientific and technical potential in this field.

The research questions are:

1. What is the growth rate of articles and patents in the field of medical and laboratory equipment specialists in the Web of Science and the US Patent and Trademark Office database in the period 1984–2014?
2. What is the growth rate of citations in articles and patents in the field of medical and laboratory equipment in the Web of Science and the US Patent and Trademark Office database in the period 1984–2014?
3. What are the distribution of citations in patents in the field of medical and laboratory equipment to patents (separated

by American and non-American patents) and other types of documents?

4. What is the metrics rate of linkage between S&T in patents in the field of medical and laboratory equipment at the US Patent and Trademark Office database in the period 1984–2014?

5. What is the metrics rate of scientific power and technical capacity in patents in the field of medical and laboratory equipment at the US Patent and Trademark Office database in the period 1984–2014?

## MATERIALS AND METHODS

This research is a kind of scientometric studies and has been done using citation analysis method. The subjects of the present study are all patents of medical and laboratory equipment area registered at the US Patent and Trademark Office during the period from 1984 to 2014, as well as all articles in this area of research indexed in Web of Science database in the given time. As a result of this search, 13424 patents and 16877 articles were retrieved.

Since in some countries, the amount of scientific production indexed in credible databases such as the Web of Science, under the supervision of Thomson Reuters, is one of the indicators for allocating funds and evaluate the scientific rankings of countries, researchers, institutes and universities around the world. Therefore, the Web of Science database was selected for review. The reason for choosing the US Patent and Trademark Office database is that it is one of the most comprehensive databases in the field of collecting and filing patent permits worldwide and since the inventor is required to disclose all his information in this database has more credibility than similar databases such as the other database, in which the citation data recorded by the evaluator may be invented without the knowledge of the inventor.<sup>[15]</sup>

In this study, researchers selected category D24, which is the category of medical and laboratory equipment at the US Patent and Trademark Office database, due to the increasing importance of this scientific field and its close connection with human health. It should be noted that patents are divided into three categories of utility, design and plant patents. Patents in the field of medical and laboratory equipment were of a utility and design type. Therefore, researchers decided to consider both patent types in their analysis. The results of the data collection showed that among the total retrieved patents, 27316 patents were of a design type and 3937 patents were utility type. Then, the researchers decided to remove the retrieved patents file, which is in the form of an image and lack of any kind of information, as well as patents that have an incorrect or incomplete download link from the target statistical population. After applying these processes, a total

of 13424 patents remained for investigating. Researchers in the Web of Science database searched for keywords related to medical and laboratory equipment in the title search between 1984 and 2014. The searched keywords in the title search of US Patent and Trademark Office database are “medical and laboratory equipment”. The searched keywords in the title search of the Web of Science database are as follows:

ti=(medical equipment\*) OR ti=(Medical supplies\*) OR ti=(Medical instrument\*) OR ti=(Medical apparatus\*) OR ti=(Medical inventor\*) OR ti=(Medical technology\*) OR ti=(Medical material\*) OR ti=(Medical kit\*) OR ti=(Medical innovation\*) OR ti=(Medical device\*) OR ti=(Clinical equipment\*) OR ti=(Clinical supplies\*) OR ti=(Clinical instrument\*) OR ti=(Clinical apparatus\*) OR ti=(Clinical inventor\*) OR ti=(Clinical technology\*) OR ti=(Clinical material\*) OR ti=(Clinical kit\*) OR ti=(Clinical innovation\*) OR ti=(Clinical device\*) OR ti=(Laboratory equipment\*) OR ti=(Laboratory supplies\*) OR ti=(Laboratory instrument\*) OR ti=(Laboratory apparatus\*) OR ti=(Laboratory inventor\*) OR ti=(Laboratory technology\*) OR ti=(Laboratory material\*) OR ti=(Laboratory kit\*) OR ti=(Laboratory innovation\*) OR ti=(Laboratory device\*) OR ti=(standard medical equipment\*) OR ti=(engineering of medical equipment\*) OR ti=(maintenance of medical equipment\*) OR ti=(therapeutic equipment\*) OR ti=(operating room equipment\*)

This search retrieved all records that published in any language or any document form (article, review, etc.) between 1984 and 2014. As a result of this search, 16,877 records were retrieved. For analyzing the data, the special formulas of the growth rate, scientific potential, technical potential and linkage with science were performed using Excel software. The following formula is used to calculate the growth rate:

$$1 - 2^R = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1}$$

In the above formula,  $1 - 2^R$  is the relative growth rate for a given time period,  $\text{Log}_e W_1$  is the logarithm of the initial number of patents,  $\text{Log}_e W_2$  is the logarithm of the final number of patents in the desired time and  $T_1 - T_2$ , is the difference between the two periods of time.

## RESULTS

1. What is the growth rate of articles and patents in the field of medical and laboratory equipment specialists in the Web of Science and the US Patent and Trademark Office database in the period 1984-2014?

Figure 1 shows the annual growth trend of specialists' patents for medical and laboratory equipment area at the US Patent

1. The sign \* is used to consider the singular numerator and the sum of the keywords while searching in the Web of Science database

and Trademark Office database during 1984-2014. The findings demonstrate that the growth chart has been growing in the period from 1984 to 2014 (growth rate of 5%). Patents for medical and laboratory equipment at the US Patent and Trademark Office in 2005 resulted in a reduction of nearly 200 patents (19% growth rate) over the previous year. Since then, the upward trend in patents has continued in 2008 (11% growth rate). In 2009, we are faced with a sharp decline in the production of patents in this area, as far as the number of patents for medical and laboratory equipment decreased from 983 in 2008 to 20 patents in 2009 (Growth rate of 169%) and then the production of patents in this area has not increased significantly. Given that the patent process takes at least three years, it can be deduced that the decline in the number of patents for medical and laboratory equipment in the final years cannot be a sign of deterioration and the saturation of technology in this field of science. In general, the average growth rate of patents for medical and laboratory equipment in the 30-year period was obtained based on the relevant formulas of the growth rate of 2.5%.

In the following, Figure 2 indicates the annual growth rate of researchers' articles for medical and laboratory field in the Web of Science database. The findings show that the growth rate has increased steadily between 1984 and 2014 (growth rate of 8%). Researchers' articles in the field of medical and laboratory equipment reached a high point in the Web of Science database in 1991 (growth rate of 7%) and almost every 5 years has grown negatively compared to previous years and has suffered a decline in articles production. In the rest of the cases, papers in this area have grown steadily and in general, during the years 1984 to 2014, the production of articles in this area has increased. In general, the average growth rate of articles in the field of medical and laboratory equipment in the 30-year period was obtained 8.3% based on the relevant formulas of growth rate.

2. What is the growth rate of citations in articles and patents in the field of medical and laboratory equipment in the Web of Science and the US Patent and Trademark Office database in the period 1984-2014?

Figure 3 illustrates the annual growth rate of citations in patents for medical and laboratory equipment field at the US Patent and Trademark Office. The findings show that the growth rate of patents citations for medical and laboratory equipment from 1984 to 2014 has steeply increased (growth rate of 6%). The findings indicate that the number of patents citations for medical and laboratory equipment field at the US Patent and Trademark Office has risen up to 2008 (7% growth rate), which this phenomenon can be influenced by the increased attention paid to the importance of citations in the scientific valuation of patents. But in 2009, there was a sudden drop in the number of citations (a growth rate of

145%), which could be attributed to the decline in the number of patents in 2009 (20 patents) compared to 2008 (983 patents), as in 2005, the reduction in the number of patents for medical and laboratory equipment has led to a decrease in citations. In total, the average annual growth rate of citations in patents in the field of medical and laboratory equipment for the period of 30 years, was obtained 6.1% based on the relevant formulas of growth rate.

Figure 4 shows the annual growth rate of citations to articles in medical and laboratory equipment field in the Web of Science. The number of citations in articles in the field of medical and laboratory equipment in the Web of Science database has not been steadily decreasing or increasing and has steadily been changing, but in 2006 and 2009, the number of citations dropped sharply. In total, the average annual growth rate of citations in articles of medical and laboratory equipment in the 30-year period was calculated based on the corresponding formulas of the growth rate of 8.3%.

3. What is the distribution of citations in patents in the field of medical and laboratory equipment to patents (separated by American and non-American patents) and other types of documents?

Figure 5 shows the annual growth rate of citations to patents for medical and laboratory equipment compared to the US, non-US patents and other types of records during the years 1984 to 2014. The findings indicate that the annual growth

rate of citations to the US patents reached its highest point in 2008 (growth rate of 7%) and suddenly dropped sharply in 2009 (Growth rate of -1%) and this citation drop process for patents has continued until 2014 and beyond. In total, the average annual growth rate of citations in US patents for medical and laboratory equipment over the 30-year period was obtained 6.1% based on the relevant formulas of growth rate. Citations to non-US patents reached the highest point in 2008 (growth rate of 5%) and suddenly with a severe drop (growth rate of -2%) and this reduction process of the number of citations to Non-US patents have continued until 2014 and beyond. In total, the average annual growth rate of citations in non-US patents for medical and laboratory equipment in the 30-year period was calculated based on the corresponding formulas of the growth rate of 6.6%. The annual growth rate of citations to other types of records during the years 1984 to 2014 has a lot of ups and downs. Citation to other types of documents reached its highest point in 2000 and 2003 and after these years, we are faced with the process of decreasing citation to other types of documents by 2014 and beyond.

In general, the average annual growth rate of citations in other types of medical and laboratory equipment records in the 30-year period was based on the relevant formulas of the growth rate of 5.7%. Overall, the findings showed that the annual growth of citations in patents for medical and laboratory equipment led to US and non-US patents, has followed similar behavior and has the same ups and downs but

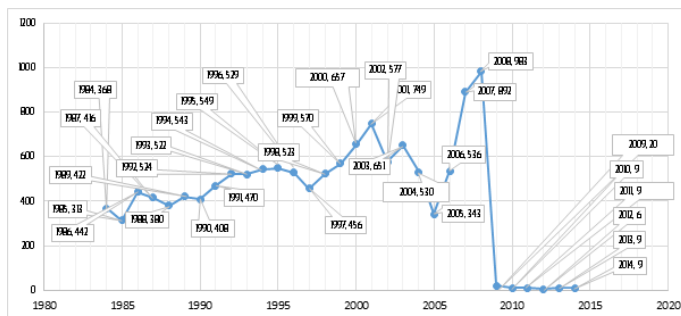


Figure 1: Annual growth rate of experts' patents of medical and laboratory equipment field at the US patent and trademark office.

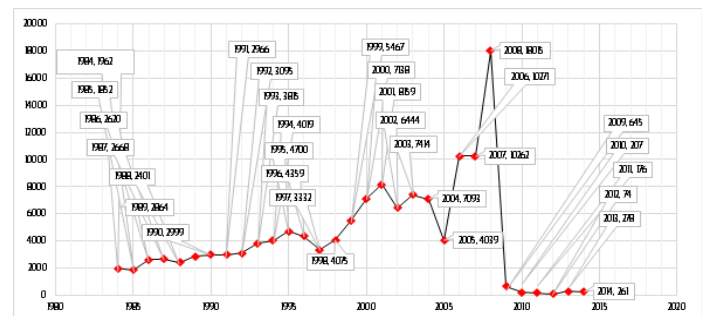


Figure 3: Annual growth rate of citations for medical and laboratory equipment field at the US patent and trademark office.

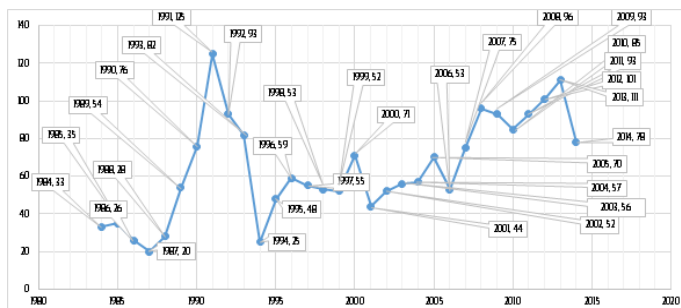


Figure 2: Annual growth rate of researchers' articles for medical and laboratory equipment field in web of science

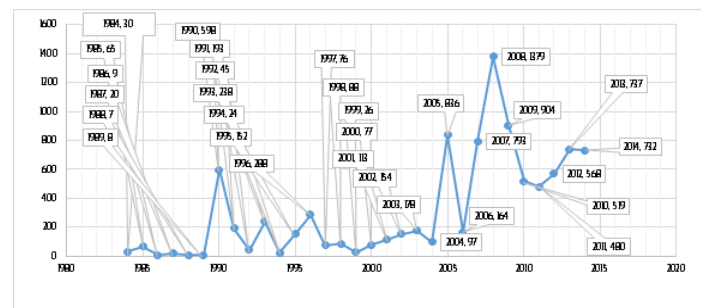


Figure 4: Annual growth rate of citations in articles for medical and laboratory equipment field in the web of science.

with a huge difference. This is despite the fact that citations to other types of records in different years are subject to more changes and do not follow the process of citation to patents. As shown in Figure 5, the number of citations of patents for medical and laboratory equipment to US patents far exceeds their citations to non-US patents and other types of records. But the annual growth of citations to US and non-US patents and other types of records has been subject to many changes.

4. What is the metrics rate of linkage between S&T in patents in the field of medical and laboratory equipment at the US Patent and Trademark Office database in the period 1984-2014?

In this part of the research, the link with science in patents of medical and laboratory equipment according to the formula provided by Narin,<sup>[16]</sup> equal to dividing the number of citations of patents into scientific documents on the total number of patents in this area, which is obtained for the whole study period equal to 94.26 %. The scientific potential is calculated of the multiplication of science linkage index in the total number of patents, which is obtained for the field of medical and laboratory equipment 1265346.126. The formula for calculating the above indicators is as follows:

$$\text{Science linkage} = \frac{\text{Citation to scientific records in patents}}{\text{Total citations to patents}} \times 100$$

$$\text{Science linkage with medical and laboratory equipment field} = \frac{126507}{134203} \times 100 = 94.26$$

The total number of patents  $\times$  Science = Scientific potential

Scientific potential in the field of medical and laboratory equipment = 94.26 13424 = 1265346.24

5. What is the metrics rate of scientific potential and technical capacity in patents in the field of medical and laboratory equipment at the US Patent and Trademark Office database in the period 1984-2014?

Citation to patents reflects the extent to which these resources are used from previous technologies. In the scientific literature,

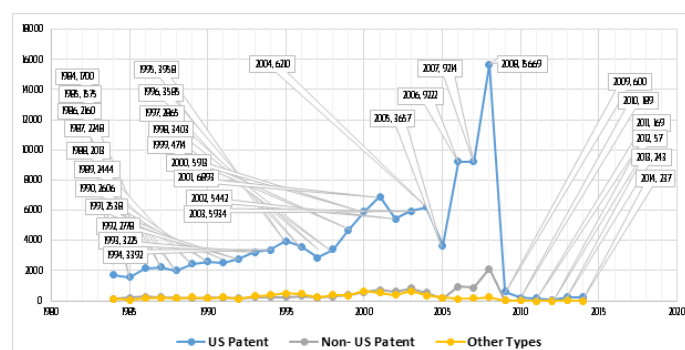


Figure 5: Annual growth rate of citations to patents separated by US and non-US patents and other types of documents.

the scientific citation to patents has been considered as an indicator of the linkage with the technology. Accordingly, the technical linkage in patents for medical and laboratory equipment field has been calculated by dividing the total number of citation in the technical documentation into the total number of citations, which is equal to 0.057% for the whole review period. The technical potential was also calculated from the multiplication of linkage with technology in the total number of patents, which is equal to 765.168. The formula for calculating the above indicators is as follows:

$$\text{Science linkage} = \frac{\text{Citation to technical documents in patents}}{\text{Total citations to patents}} \times 100$$

$$\text{Science linkage with medical and laboratory equipment field} = \frac{7696}{134203} \times 100 = 0.057$$

The total number of patents  $\times$  Science = Scientific potential

Scientific potential in the field of medical and laboratory equipment = 13424 = 765.168

## DISCUSSION

The results of this study revealed that the number of patents and scientific articles in the field of medical and laboratory equipment has been growing in this period. The results obtained in the research are consistent with the results of Huang *et al.* (2015), Wong and Wang (2015), Noruzi and Abdekhoda (2012), Finardi (2011), Szu-chia (2010), Guan and He (2007). In their research, they also pointed to the increasing rate of scientific articles and patents in the areas studied. In general, factors such as the lack of impact on patents in the economies of the countries, the low quality of some inventions, the allocation of very few funds to institutions and research centers, the lack of support of inventors in most countries, high costs and fees of patents in most countries and so on, greatly reduce the interest and efforts of inventors to register their patents. It is therefore desirable for authorities around the world to avoid insisting on misleading patent policies and take serious steps to improve this system and its scientific management in the framework of national and international innovation systems. Therefore, according to the results of this study, the necessity of encouraging the inventors of medical and laboratory equipment area to increase their patents on international databases and global participation. Also, governments should, as far as possible, take on a portion of the patent fees of the inventors in various fields of science in order to reduce both the heavy costs borne by the inventors and somehow encourage inventors for more effort in the field of patents. In fact, encouraging innovation, marketing for inventions and encouraging the disclosure of inventions are key prerequisites for the development of national and international technology and innovation, which will be far from reaching the long-term goals of national and international perspectives in this field without doing them.

Patents are very important in scientometric studies. Therefore, today the attention of most S&T evaluators has been focused on analyzing citations. This technique is based on the fact that scientists are forced to refer to earlier work and cite them to carry out their scientific and research work. Therefore, the results of the study of patents citations and scientific articles in the field of medical and laboratory equipment during the desired time indicate an upward trend. The results of this part of the study are consistent with the findings of Fukuzawa and Ida (2016), Huang *et al.* (2015), Wong and Wang (2015), Noruzi and Abdekhoda (2012), Finardi (2011) and Naomi and Takanori (2016) and Meyer (2001).

In fact, the reasons for the increase in the number of citations of patents for medical and laboratory equipment to US patents compared to their citations to non-US patents and other types of records are creditable and high quality of patents for American inventors. The strong position of the United States in the world, the highest national wealth, the strengthening of the infrastructure of scientific and technological institutions, access to advanced technologies, the creation of marketing and sales opportunities for inventions and the allocation of large budgets in this field, improved the quality of patents of US inventors. However, such facilities and infrastructures are not available in all countries. Therefore, this issue has reduced the reliability and quality of articles and patents of researchers and authors of other countries, which has led to a slower growth of citations of patents for medical and laboratory equipment field to non-US patents and other types of records. Therefore, it is due to the dramatic difference between the US and other countries in terms of technology infrastructure and research budgets and as long as no measures are taken to reduce these differences, comparison of scientific articles and patents of American with other countries of the world does not seem logical.

Other research findings also showed that the scientific potential of medical and laboratory equipment is far more than technical capacity and researchers in the field of medical and laboratory equipment tend to cite to scientific articles rather than patents. This indicates the reliance of technology to science in the field of medical and laboratory equipment. Actually, the increasing role of scientific discoveries, which is accompanied by an increase in the number of citations to scientific documents, has led to the development of applied technologies in this field. On the other hand, it can be said that the publication of patents in some areas takes a long time and the lack of access to a sufficient number of these documents leads to the use of sources other than patents. Therefore, it can be argued that the technology of medical and laboratory equipment is largely based on scientific advances in this field. The results of this study are consistent with the findings of Fukuzawa and Ida (2016), Huang *et al.* (2015), Szu-Chia (2010), Guan and He

(2007), Meyer (2001). They also stated in their research that the scientific potential in the areas studied is far more than technical potential. However, the results of the present study are inconsistent with the results of Finardi's research (2011). In his research, he stated that the technical potential in the field studied was far more than scientific potential. Therefore, in the field of medical and laboratory equipment, along with attention to science based on scientific articles, patents that indicate technology in this field should be paid more attention, as in this field of science simultaneously with the increase of scientific capability, the technical potential is also promoted. It should be noted that by increasing the technical potential in the field of medical and laboratory equipment, the context will be further developed for the commercialization of science for authors and researchers. Therefore, it is necessary to provide the context for the improvement of technical potential and scientific potential simultaneously in the field of medical and laboratory equipment and provide appropriate measures to resolve the problems in this area, especially in the field of technology.

However, some restrictions may affect the research. In this research, the articles of web of science and patents that registered at the US Patent and Trademark Office data base were analyzed, therefore, some articles and patents that have been indexed in other database may have left the research community, which is one of the limitation of this research.

## CONCLUSION

Therefore, the analysis of the results of reviewing the articles and patents of this scientific field from any point of view may not be universally accepted, but the process presented in this study could lead to a better and more accurate understanding of the field of medical and laboratory equipment and ultimately enhances and better manage research in this field. The field of medical and laboratory equipment, like all S&T, has undergone many changes and advances in this century and it is also adding to the acceleration of these changes day by day. Considering the great importance of medical and laboratory equipment technology, the identification of the growth process of articles and patent and the process of development of citations in this field and examination of the linkage of S&T seemed necessary, because according to the importance of this field of research has been done in this area.

Finally, it can be argued that the advancement of S&T and developments that were created in various scientific fields, especially from the 18th and 19th centuries onwards, strengthened the fact that the development of S&T could make important changes in the economic and social context, which will be able to make fundamental changes in the future. In the twentieth century, the relationship between S&T became more apparent. Governments, more than ever,

turned to support science, research and exploitation and this linkage became stronger throughout the twentieth century. Therefore, it can be argued that the field of medical and laboratory equipment is largely based on scientific advances and products. It should be noted that the relationship between S&T is a two-way relationship and the relationship between S&T is a changing relationship, depending on the circumstances, it may vary from one domain to another or from one time to another. Therefore, the recognition of the concepts of S&T and the study of the relationship between these two concepts for scientific and economic policy is an undeniable necessity. Accordingly, it is recommended that in macro policy making of countries, the relationship between the university and the industry should be further developed. S&T parks, knowledge-based companies and communication with industry offices in universities can play an important role in this area by optimizing the conditions.

The results of this study can provide potential for the development medical equipment and explore the needs of the field. Also, the results of this research could encourage thinkers to provide their creativity in the presence of engineers, physicians and capital owners and provide the basis for converting the idea into a product in the field of medical and laboratory equipment.

### Suggestions for Further Research

- According to the results obtained, a decrease in the number of patents in the field of medical and laboratory equipment has decreased since 2008. Therefore, it is suggested that a study investigate the causes of the sudden drop in patents in this field from 2008 onwards to determine which causes or factors have been affected in this regard.

- According to the results, which show overcoming the scientific potential on the technical potential of medical and laboratory equipment field, it is suggested that the main reason for this problem be identified in a research. Also, to clarify the issue, further research is needed using the data available in other databases, as well as in other types of documents or using other scientometrics indicators and other science visualization software, can complement this research.

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### CONFLICT OF INTEREST

The authors declare no conflict of interest.

### Ethical approval

This study was approved at Kharazmi University with the code of ethics 2481589.

### Authors' Contributions

All authors met the criteria of authorship based on the recommendations of the international committee of medical journal editors.

### ABBREVIATIONS

**S&T:** Science and Technology.

### REFERENCES

1. Cheng-hsin C, Yi-ching L, Rung-tai W. Patent Analysis for the Formulation of Technology Policy: Evidence from 4G LTE Industry. Proceedings of the 50<sup>th</sup> Hawaii International Conference on System Science. 2017;4413-22. Doi: 10.24251/HICSS.2017.535.
2. Hur W. The patterns of knowledge spillovers across technology sectors evidenced in patent citation networks. *Scientometrics*. 2017;111(2):595-619. Doi: 10.1007/s11192-017-2329-7.
3. Castriotta M, Chiara DGM. Disentangling the automotive technology structure: A patent co-citation analysis. *Scientometric*. 2016;107(2):819-37. Doi: doi.org/10.1007/s11192-016-1862-0.
4. Hu J, Li S, Yao Y, Yu L, Yang G, Hu J. Patent Keyword Extraction Algorithm Based on Distributed Representation for Patent Classification. *Entropy*. 2018;20(2):104-25. Doi: 10.3390/e20020104.
5. Kay L, Newman N, Youtie J, Porter A, Rafols I. Patent overlay mapping: Visualizing technological distance. *Association for Information Science and Technology*. 2014;65(12):2432-43. Doi: 10.1002/asi.23146.
6. Huang M, Yang H, Chen D. Increasing science and technology linkage in fuel cells: A cross citation analysis of papers and patents. *Informetrics*. 2015;9(2):237-49. Doi: 10.1016/j.joi.2015.02.001.
7. Naomi F, Takanori I. Science linkages between scientific articles and patents for leading scientists in the life and medical sciences field: The case of Japan. *Scientometrics*. 2016;106(2):629-44. Doi: 10.1007/s11192-015-1795-z.
8. Wong C, Wang L. Trajectories of science and technology and their co-evolution in BRICS: Insights from publication and patent analysis. *Informetrics*. 2015;9(1):90-101. Doi: 10.1016/j.joi.2014.11.006
9. Noruzi A, Abdekhoda M. Mapping Iranian patents based on International Patent Classification (IPC), from 1976 to 2011. *Scientometric*. 2012;93(3):847-56. Doi: 10.1007/s11192-012-0743-4.
10. Finardi U. Time relations between scientific production and patenting of knowledge: The case of nanotechnologies. *Scientometric*. 2011;89(1):37-50. Doi: 10.1007/s11192-011-0443-5.
11. Szu-chia S. Scientific linkage of science research and technology development: A case of genetic engineering research. *Scientometrics*. 2010;82(1):109-20. Doi: 10.1007/s11192-009-0036-8.
12. Guan J, He Y. Patent-bibliometric analysis on the Chinese science-technology linkages. *Scientometrics*. 2007;72(3):403-25. Doi: 10.1007/s11192-007-1741-1.
13. Murray F. Innovation as co-evolution of scientific and technological networks: Exploring tissue engineering. *Research Policy*. 2002;31(8):1389-403. Doi: 10.1016/S0048-7333(02)00070-7.
14. Meyer M. Patent Citation Analysis in a novel field of Technology: An Exploration of nano-science and nano-technology. *Scientometrics*. 2001;51(1):163-83. doi: 10.1023/A:1010572914033.
15. Mansour A, Osareh F. Surveying the value of knowledge resources based on the importance factor (backward-looking factor, forward-looking factor): Case study of patents. *Iranian Research Institute Iranian for Science and Technology*. 2014;29(3):657-84. <http://ijpm.irandoc.ac.ir/article-1-2438-en.html>.
16. Narin F. Tech-line background paper. CHI Research, Inc., Haddon Heights, NJ. 2000. downloadable at: [www.Chiresearch.com](http://www.Chiresearch.com).