A REVIEW OF MALAYSIAN EXPERIENCE IN TISSUE ENGINEERING RESEARCH AND DEVELOPMENT: AN ONLINE DATABASE STUDY USING SCOPUS

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ABSTRACT

Tissue engineering (TE) research serves to overcome the major obstacles in organ transplantation. This paper summarizes the progress of TE in Malaysia. The online database of Elsevier's SCOPUS was accessed. Publications related to TE from 1960 till 2017 were scrutinized. The results show an increasing trend in tissue engineering research and development in Malaysia. The search result identified and examined 264 original article publications. It is hoped that the outcomes of this study could serve as a point of reference for researchers on the status of TE research and development in Malaysia. The findings of this study could assist TE researchers in Malaysia to identify the strengths, weaknesses, opportunities and obstacles towards further enhancement in their activities. Consolidating, realigning and re-strategizing those initiatives should also be seen within the context of nurturing potential and budding researchers in TE.

KEYWORDS: tissue engineering progress; research and development; Malaysia; publication; online database

INTRODUCTION

"Historically there has always been a shortfall in the supply of organs and tissues. The success of transplantation has increased demand, thus increasing the gap even more. The shortage of organs for transplantation has led to greater use of organs from living donors…" (Ministry of Health Malaysia, 2007). The policy statement has challenged Malaysian researchers to venture into tissue engineering field. Based on current updates provided by the Transplant Unit, Medical Development Division and National Transplant Resource Centre, Ministry of Health (MOH) Malaysia, there are more than 20,000 patients who are waiting for benefit from a transplant (Table 1). From these recent updates, the numbers of

waiting patients for transplantation are more than 30 times higher than the actual organ donors (Muhammad Aa'zamuddin & Munirah, 2016).

Table 1 Organ donation waiting list as of March 2018

Organ	Numbers of patients
Kidneys	21,492
Liver	Adult: 7 | Child: 0
Heart	5
Lungs	4
Heart & Lungs	5
Total	21,513

Tissue engineering (TE) being part of regenerative medicine is regarded as a revolution in biomedical technology. It has the ability to overcome the issue of insufficient organ/tissue supply. TE offers alternative treatment modalities for damaged organs or tissues. This restorative technique aims at reconstructing human tissues/organs for transplantation. The technology applies the approaches of cell-based therapy and autologous transplant. TE is advancing towards the application of functional tissue, from laboratory works to clinical setting (Rozlin, Muhammad Aa'zamuddin, Norhamiza, Noorhidayah, & Munirah, 2015).

Biomedical research including TE has been championed by the developed countries. TE research conducted in developing countries like Malaysia have become significantly important as the regenerative medicine therapy has become a necessity. In 2004, it was noted that the first conference relating to TE was held in Kuala Lumpur. This was followed by the establishment of Tissue Engineering and Regenerative Medicine Society of Malaysia (TESMA) in the same year. The events united researchers with different research interests throughout the country to discuss on the ideas and principles of TE (Ruszymah, 2006).

The study on the progress of TE research activities in Malaysia is yet to be explored. Thus, a descriptive bibliometric study of published articles indexed in Elsevier's SCOPUS (Scopus) related to TE comprised of Malaysian authors was conducted to fill the gap. The bibliometric study can be used as a tool to reflect on the current progress and also to anticipate the future directions (Song et al., 2015) of TE. Scopus was chosen as the local academicians were prone to publish in bibliographic database as emphasized by their universities management (Zainal & Zainab, 2011). This study summarizes the progress of TE research in Malaysia between 1960 and 2017 as shown by original articles published in journals. The results provide an updated ranking list of the corresponding authors and institutions investigating TE in Malaysia.

MATERIALS AND METHODS

The study was done by searching for and extracting publications in Scopus that were published between 1960 to 2017. The data were confined to those articles with the corresponding author's affiliation of country name and institutional address in Malaysia. The study was carried out by identifying keyword associated to TE research. The range of years was set as All Years to Present. The keyword of "tissue engineering" was inserted in the field of Article Title, Abstract and Keywords. It is noted that the keywords used are not exhaustive but sufficient for the purpose of the study. The "Malaysia" keyword was used for the field of Affiliation Country.

Zainuddin and Radzi (2013) cited Trevelyan, Cook, and Fisher who reiterated that ninety-nine percent of audience will browse only the title and abstract of an article, with the majority reading only the title of the publications, before deciding to read the publication or otherwise. The search was limited to the journal article type of document as researchers preferred to publish their research results through journals (Salina & Shaheen, 2001). The methodological quality of the articles was not assessed. Descriptive analyses of data collected were done to generate the following information: (a) Total publication productivity in TE; (b) Local institutional contributions; (c) Core journals used by local TE researchers to publish; (d) The authorship pattern and productivity. The database search was conducted in December 2017. Microsoft Excel was used to generate ranked list of productive authors, institutions and journals. The correspondent addresses were screened to identify the Malaysian corresponding author. If the address was blank, the first author was assumed to be the corresponding author of the document. Different names for the same author were standardized to one name. For example, Idrus, R.B.H., Ruszymah, B.H.I., Bt Hj Idrus, R., Hj Idrus, R.B., Bt. Hj Idrus, R., Hj Idrus, R. B., Ruszymah, B. H. I. and Idrus, R. were standardized to Ruszymah, B.H.I.

RESULTS

Total publication productivity in TE

A total of 501 publications were retrieved. However, only 384 documents were affiliated to Malaysian corresponding authors' affiliation and related to TE (Figure 1). All documents were found to be written in English. The document types were identified as original article with 264 publications, conference paper (56), review (30), book chapter (14), article in press (3), editorial (3), book (2), note (2), erratum (1) and letter (1) as shown in Figure 1.

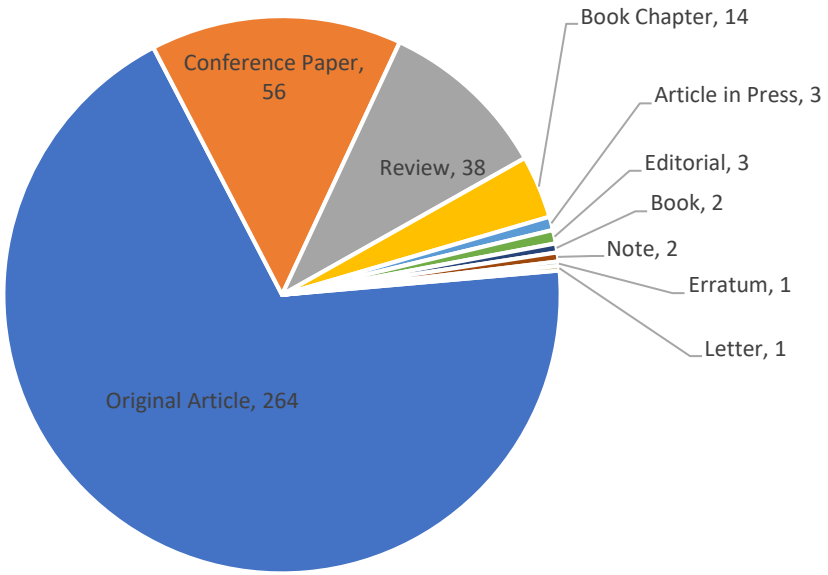

Figure 1 Type of documents

This study focused on the experimentation part of TE which is the 264 original articles of TE empirical research. An original article published in 2018 was treated as 2017 publication. R^2 coefficient of determination was produced using the Microsoft Excel to measure how well the regression line approximates the real data points of TE research progress with zero intercept. The value of 1 indicates that the regression line perfectly fits the data. In this study, the trendline of $R^2 = 0.7451$ indicated an upward trend since 2005, which is the first original article related to TE is published in 2005 in Scopus (Figure 2). Statistically, this trend is expected to continue in the coming years.

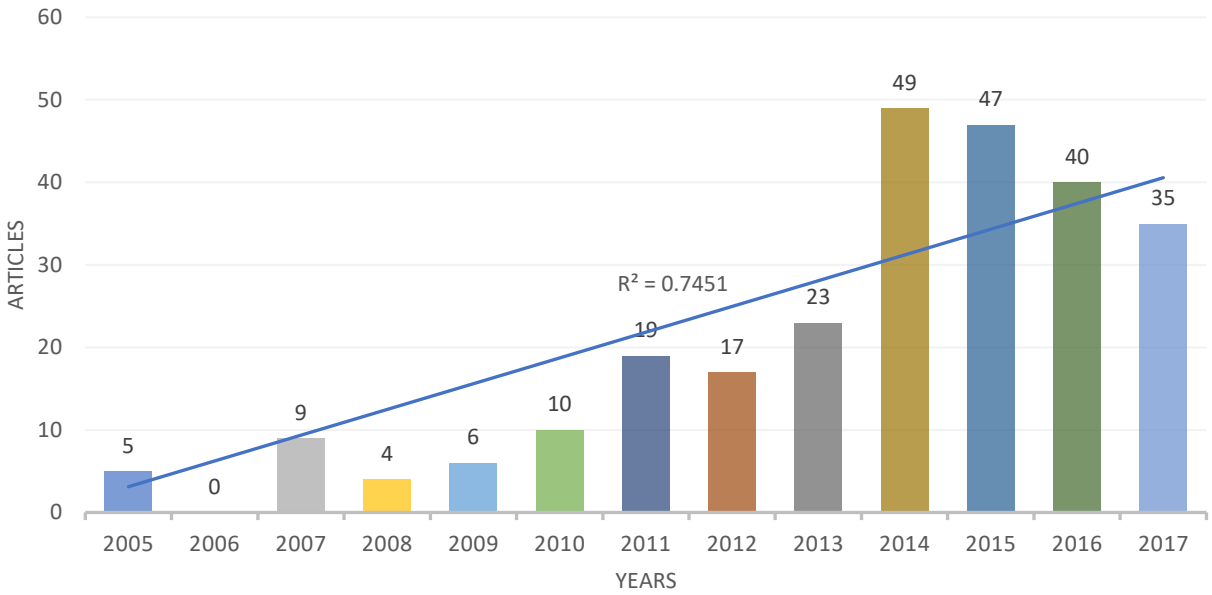

Figure 2 Trend of original article publications by years

Productivity of local institutions based on the corresponding authors affiliations

Out of 264 publications, the corresponding authors were from 21 institutions. Public Institutions of Higher Learning (PIHLs) covers 95% of the publications. This suggests that PIHLs are actively doing research in TE. The five most productive PIHLs were Universiti Kebangsaan Malaysia (26.9% of total publications), Universiti Malaya (26.1%), Universiti Teknologi Malaysia (19.7%), Universiti Sains Malaysia (8.3%) and University Putra Malaysia (3.8%) as depicted in Table 2. Other 16 institutions produced less than 10 publications respectively.

Core journals publications

There was a total of 144 journal titles contributed to the 264 original articles in this study. Table 3 shows list ranking of journals publishing Malaysian-affiliated TE articles. Journals that published five (5) related articles and above were *Journal of Biomedical Materials Research Part A* (10 publications), *Materials Science and Engineering C* (9), *Journal of Nanomaterials* (7), *Jurnal Teknologi* (7), *ARPN Journal of Engineering and Applied Sciences* (5), *International Journal of Pediatric Otorhinolaryngology* (5), *Materials Letters* (5), *PLoS ONE* (5) and *Medical Journal of Malaysia* (5). For other publications, there were, seven (7) journal titles published four (4) articles each, 13 journal titles published three (3) articles each, 24 journal titles published two (2) articles each and 91 journal titles published one (1) article only.

Table 2 The productivity of local institutions in TE study

Correspondence Institution	Publication(s)	Percentage (%)
Universiti Kebangsaan Malaysia	71	26.9
Universiti Malaya	69	26.1
Universiti Teknologi Malaysia	52	19.7
Universiti Sains Malaysia	22	8.3
Universiti Putra Malaysia	10	3.8
Universiti Malaysia Pahang	8	3.0
International Islamic University Malaysia	8	3.0
Universiti Malaysia Perlis	3	1.1
Universiti Tun Hussein Onn	3	1.1
Universiti Teknologi MARA	1	0.4
Universiti Malaysia Terengganu	1	0.4
Universiti Pendidikan Sultan Idris	1	0.4
Universiti Sains Islam Malaysia	1	0.4
Universiti Teknikal Malaysia Melaka	1	0.4
University of Nottingham Malaysia	4	1.5
Monash University Malaysia	2	0.8
Advanced Materials Research Centre	2	0.8
Malaysian Institute of Pharmaceuticals and Nutraceuticals	2	0.8
Institute for Medical Research	1	0.4
Taylors' University	1	0.4
Universiti Tenaga Nasional	1	0.4
Total	**264**	**100.0**

The corresponding authorship productivity

The nine most identified productive authors with number of publications are as follow; Ruszymah, B.H.I. (54 publications), Sultana, N. (20), Kamarul, T. (10), Munirah, S. (6), Raghavendran, H.B. (5), Zubairi, S.I. (4), Chai, W.L. (4), Zulkifli, F.H. (4) and Idris, A. (4) as shown in Table 4. The other 124 corresponding authors produced less than four (4) publications respectively. Collectively, they produced 1.98 papers per year.

Table 3 The identified journal titles with the most number of publications in Malaysian TE research

Journal Title	Publications
Journal of Biomedical Materials Research - Part A	10
Materials Science and Engineering C	9
Journal of Nanomaterials	7
Jurnal Teknologi	7
ARPN Journal of Engineering and Applied Sciences	5
International Journal of Pediatric Otorhinolaryngology	5
Materials Letters	5
PLoS ONE	5
Medical Journal of Malaysia	5

DISCUSSION

This study is limited to 264 original article publications collected from Scopus which encompassed Malaysian correspondents' affiliation address. Therefore, it cannot be generalized to TE literature covered by other databases such as Google Scholar, Web of Science and non-indexed journals. However, the study does give a straightforward review about the characteristics of the Malaysian TE articles published in the international database. Scopus search engine is among the best available tools to track and analyse citations and compare citations to different researchers and institutions (Aryati & Willett, 2011; Zyoud, Al-jabi, Sweileh, & Awang, 2014). MEDLINE is an important citation resource for clinicians and biomedical researchers and it is fully covered by SCOPUS (Falagas, Pitsouni, Malietzis, & Georgios, 2008).

Information on trends and productivity reveals the intellectual output of TE works published in SCOPUS. It is useful for TE scientists to evaluate the performance of TE researches in Malaysia to further plan their incoming project. Based on Figure 1, it seems that the idea of TE in Malaysia is being published in Scopus as early as 2005 after the conference and TESMA official establishment in 2004. The surge of TE-related papers publication can be noted after 2007 which may have been boosted by the interest among the medical researchers in Malaysia. While it can be statistically anticipated that the performance of TE research will be further enhanced, external forces within the Malaysian economic scenario and the Malaysian Budget 2016 recalibration might slow down the expected progress (Bank Negara Malaysia, 2016). However, the initiative taken by the Malaysian government to intensify the higher education in 2018 budget may improve the TE research productivity. On 27th October 2017, the government has announced the allocation of RM 400 million for research and development grants to higher education institutions compared to RM 235 million in the previous year budget (Bank Negara Malaysia, 2017; Ministry of Finance, 2017; Ministry of Higher Education, 2017).

Interestingly, the results suggest that most of the TE publications are championed by five public universities which are designated by Malaysian government as research universities. In the same year of the TE establishment in Malaysia, 2004, Malaysian universities had been invited to apply for "research university" status by the Ministry of Higher Education (Aryati & Willett, 2011). These universities are funded to focus on research, innovations and publications in the field of science, medicine and technology. It can be appreciated that research universities have allocated more budget on TE research as compared to other local universities. Future study can be conducted to identify the allocation used by the researchers to identify the sources of the funding, i.e. university grants, ministry grants or private grants. TE research may be stimulated in other non-research universities by ensuring those institutions and TE research groups are well-funded by the government. However,

Table 4 The 9 most identified productive authors with number of publications in TE research

Corresponding Author	Publications
Ruszymah, B.H.I.	39
Sultana, N.	20
Kamarul, T.	10
Munirah, S.	6
Raghavendran, H.B.	5
Zubairi, S.I.	4
Chai, W.L.	4
Zulkifli, F.H.	4
Idris, A.	4

specific terms and condition such as the ability to conduct high-quality research in a cost-effective manner may be imposed on them (Aryati & Willett, 2011).

On the other hand, it can be noted that other neighbouring countries around Malaysia are also embarking in TE researches. These include, but not limited to, the establishment of research institutions related to the field. In Thailand, a research cluster has been set up in Chiang Mai University namely *Thailand Excellence Center for Tissue Engineering and Stem Cells* (Chiang Mai University, n.d.). *Stem Cells and Tissue Engineering Research Center* has been founded in Indonesia which consists of integrated interdisciplinary research laboratories and houses clinician and researchers (Indonesian Medical Education and Research Institute, n.d.). Moreover, Singapore institutions have established TE laboratories and programs to produce high quality of research outcomes (National University Hospital, n.d.; National University of Singapore, n.d.; Singapore Eye Research Institute, n.d.). Perhaps, the researchers in Southeast Asia may build collaborative teams in conducting studies to enhance the knowledge and skills of the field in the region.

There are several Malaysian journals that had been chosen by TE researchers to publish their papers. These include *Jurnal Teknologi* and *Medical Journal of Malaysia* (Table 4). The limitation of this study is the non-inclusion of *Regenerative Research* that is the official journal of TESMA in the search. The reason is because the journal is yet to be indexed in SCOPUS. Therefore, it is possible that the number of publications analysed in this study did not exactly represent all TE research activities in Malaysia. From this study, it can also be noted that TE researchers prefers to publish in international journals which have been indexed in SCOPUS. In Malaysian universities, promotional criteria require academicians to show their active involvement in research by publishing academic papers. The analysis of the names of productive authors becomes necessary as the Research Management Centre of the universities frequently being asked by university administrators to provide such evidence (Zyoud et al., 2014).

This paper reports on the most prolific local authors publication patterns, indicating their active roles as writers in TE. The pattern of productive authors may indicate that only a small number of authors are highly contributing to TE field. However, it was common to note the presence of many authors in one TE publication also known as "mega-authorship" replicates the works in laboratory or field (Subramanyam, 1983). It is suggested that the main researcher who is responsible for the publication was named the first author as suggested by Zuckerman, (1968). It can be seen from the authorship pattern of Malaysian publications in TE research that majority of the researches involves one-time contributor which was supported by a study done by Zainal and Zainab in 2011. This pattern substantiates with Lotka's law of scientific productivity which postulates that in any field, only a small number of authors are highly productive (Coile, 1977). Thus, there is a need to increase the researchers in this field as to maintain the momentum of TE research. On the other hand, there is a conception of developed countries are more affluent in biomedical research compared to the developing country.

This might cause deficit in publicity of TE research conducted in Malaysia which can be attributed to the lack of attention on TE research undertakings (Shani, Sangeetha, & Kamarul, 2012).

CONCLUSION

This paper has described the first attempt to summarize the progress of TE research in Malaysia using descriptive bibliometric methods. Searches of the Scopus database identified a total of 264 original article publications affiliated to Malaysian correspondents' address that were chosen for analysis. The study reveals the development of TE activities in Malaysia based on the articles publication in the popular online database. Based on the study, certain prominent researchers and institutions are actively upholding the TE research. This can serve as a reference for researchers in Malaysia setting to identify the strengths, weaknesses, opportunities and obstacles towards further enhancement in TE study. More effort is needed to bridge the gap in TE application and to promote better evaluation of TE research in Malaysia. Comparative review between countries which actively doing research on TE shall be done to further clarify the status of TE research in Malaysia.

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