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Fecal microbiota transplantation research output from 2004 to 2017: a bibliometric analysis

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Background: Fecal microbiota transplantation (FMT) is an emerging therapy against Clostridium difficile infection (CDI) and inflammatory bowel disease (IBD). Although the therapy has gained prominence, there has been no bibliometric analysis of FMT. Methods: Studies published from 2004 to 2017 were extracted from the Science Citation Index Expanded. Bibliometric analysis were used to evaluate the number or cooperation of publications, countries, citations, references, journals, authors, institutions and keywords. Results: A total of 796 items were included, showing an increasing trend annually. Publications mainly came from 10 countries, led by the US (n = 363). In the top 100 articles ranked by the number of citations (range 47-1158), American Journal of Gastroenterology (2017 IF = 10.231) took the top spot. The co-citation network had 7 co-citation clusters headed by ‘recurrent Clostridium difficile infection’. The top 7 keywords with the strongest citation bursts had three parts, ‘microbiota’, ‘diarrhea’, and ‘case series’. All keywords were divided into four domains, ‘disease’, ‘nosogenesis’, ‘trial’, and ‘therapy’. Conclusions: This study shows the research performance of FMT from 2004 to 2017 and helps investigators master the trend of FMT, which is also an ongoing hotspot of research.
Fecal microbiota transplantation research output from 2004 to 2017: a bibliometric analysis

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ABSTRACT

**Background:** Fecal microbiota transplantation (FMT) is an emerging therapy against *Clostridium difficile* infection (CDI) and inflammatory bowel disease (IBD). Although the therapy has gained prominence, there has been no bibliometric analysis of FMT.

**Methods:** Studies published from 2004 to 2017 were extracted from the Science Citation Index Expanded. Bibliometric analysis was used to evaluate the number or cooperation of publications, countries, citations, references, journals, authors, institutions and keywords.

**Results:** A total of 796 items were included, showing an increasing trend annually. Publications mainly came from 10 countries, led by the US (n = 363). In the top 100 articles ranked by the number of citations (range 47-1158), American Journal of Gastroenterology (2017 IF = 10.231) took the top spot. The co-citation network had 7 co-citation clusters headed by ‘recurrent *Clostridium difficile* infection’. The top 7 keywords with the strongest citation bursts had three parts, ‘microbiota’, ‘diarrhea’, and ‘case series’. All keywords were divided into four domains, ‘disease’, ‘nosogenesis’, ‘trial’, and ‘therapy’.

**Conclusions:** This study shows the research performance of FMT from 2004 to 2017 and helps investigators master the trend of FMT, which is also an ongoing hotspot of research.

**Subjects:** Gastroenterology and Hepatology, Global Health, Statistics

**Keywords:** Fecal microbiota transplantation; bibliometric analysis; citations; *Clostridium difficile* infection; inflammatory bowel disease
INTRODUCTION

Fecal microbiota transplantation (FMT) is a therapeutic method by the infusing fecal suspensions from a healthy individual into the gastrointestinal tract (Kelly et al., 2016). Zhang et al. noted that GE Hong pioneered the use of feces to treat human diseases in the Eastern Jin Dynasty (300 ~ 400 AD). (Zhang et al., 2012) FMT has received public attention over the past decade because it has been shown to be a highly effective treatment of *Clostridium difficile* infection (CDI) and inflammatory bowel disease (IBD) over the past decade (Khoruts et al., 2016; Khoruts et al., 2015).

In 2013, FMT was included in the CDI treatment guidelines which clearly stipulated that FMT should be considered for patients with a third recurrence of CDI (Surawicz et al., 2013). It was pointed out that recurrent CDI is difficult to treat, and the failure rate of antibiotic therapy was relatively high. Moreover, it has been reported that more than 300 cases of recurrent CDI were effectively treated using FMT (van Nood E et al., 2013). FMT not only has a remarkable cure rate, but is also a safe and acceptable treatment option (Brandt et al., 2012a). However, little systematic analysis of FMT has been performed (Hourigan et al., 2015).

Quantitative studies of the literature had been performed for nearly one hundred years, during which bibliometric methods have been developed and matured. Traditional bibliometric methods had been used to evaluate the variations of particular areas by assessing the productivity of countries, institutions, authors and journals.

In the current study, we analyzed those were quoted above and provided additional analysis including keywords of those studies and the clusters of citations (Choi & Kim, 2018; Miao et al., 2017a; Suk et al., 2011). Multiple analytical tools were used to map the trends of FMT research.
from 2004 to 2017. This analysis will assist researchers in understanding the literature available regarding FMT, and help determine the future directions for future study of FMT.

**MATERIALS & METHODS**

**Search strategy**

Data were acquired from the Science Citation Index Expanded (SCI-E) of the Web of Science Core Collection (WoSCC) of Thomson Reuters (Philadelphia, Pennsylvania, the United States) on April 22, 2018. The data were downloaded from the public database so that there were no ethical issues. The searching included literature published from 2004 to 2017, and used the following keywords and terms: ‘Fecal bacteria transplantation$’ or ‘Intestinal Microbiota Transfer$’ or ‘Fecal Transplantation$’ or ‘Fecal Transplant$’ or ‘Donor Feces Infusion$’. All electronic searches were performed on the same day, April 22, 2018, to avoid changes in citation rates. The year 2018 was excluded because database entries for the year would not be complete at the time of the search. When all data were collected, the results were arranged according to the ‘Times cited’.

**Study selection**

All data were collected by two independent reviewers (Y. Li and Y.S. Huang), by reading the titles and abstracts acquired from SCI-E of the WoSCC database. When necessary, the full text was downloaded from PubMed or other databases. Articles were included only if the main topic was FMT, and the language was English. Exclusion criteria were: (1) the main topic of the article was
not about FMT; (2) the abstract of the article couldn’t be acquired from WoSCC; (3) the article was a duplicate. Any differences between the two reviewers were settled through discussion with a third reviewer.

Assessment of the articles and journals
Two researchers (Y.S. Huang and J. Zhao) reviewed the selected articles, and the following data were identified and recorded for analysis: (1) titles, (2) authors, (3) citation number, (4) keywords, (5) publication year, (6) topics (7) funding and (8) countries of origin. Furthermore, the journal names and impact factors (IFs) were also recorded. Journal IFs of the journals were specifically referenced to the 2017 edition of the Journal Citation Reports (JCR).

Statistical analysis
Data were converted to txt format and imported into CiteSpaceV, GraphPad Prism 5, and the Online Analysis platform of Literature Metrology (http://bibliometric.com/). Data were then analyzed quantitatively and qualitatively. CiteSpaceV was used to analyze the cooperation between keywords, institutions, cited reference, and authorship. GraphPad Prism 5 software was used to evaluate the strength and direction of the linear relations between the number of years since publication, authors, institutions, countries and the number of citations in the top 100 (T100) cited articles. It was also used to analyze the correlation of article citations between different databases (WoSCC and Scopus). All probability values were two-tailed, and the threshold for significance was set at $P < 0.05$. Using the Online Analysis platform of Literature Metrology, the number of
included articles and the number of national articles published each year were reported. The
analysis also showed the number of the top 17 keywords in each year.

RESULTS

Total numbers of published items

It was absolutely necessary to consider the number of published items on FMT as an index of
research productivity. From 2004 to 2017, a total of 2,062 publications on FMT were registered in
WoSCC and were screened of the 2,062 publications, 1,266 papers were excluded due to
uncorrelated to FMT in 809 papers. In 125 articles the main content was irrelevant to FMT, the
abstracts were inaccessible for 302 papers and 2 papers duplicates with other articles. Twenty-
eight articles that were not in English writing were also excluded. Thus, 796 articles on FMT from
2004 to 2017 were included in the analysis (Figure 1). One article was published in 2004 (n = 1),
and it was in 2011 (n = 15) and 2012 (n = 31) when the numbers of published articles each year
began to increase dramatically. The yearly number of published articles reached a peak in 2017 (n
= 248) (Figure 2(A)).

Distribution by countries

The 796 publications on FMT were primarily published by ten countries/regions (n = 722, 90.70%)
(Figure 2(B)). The greatest number of publications came from the United States (n = 363, 50.28%),
followed by China (72, 9.97%), Canada (69, 9.56%), and Germany (41, 5.68%). The United States
was the only country with a dynamic growth in the number of published articles over last five
An analysis of international cooperation is shown in Figure 2(C); the most frequent operation was between the United States and Canada, followed by the US and UK.

**Distribution by citations**

Of the 796 selected articles, the top 100 articles ranked by the number of citations (Table 1, Supplementary Table S1). The median number of citations was 95 (range 47-1158), and three papers were cited over 500 times. The citation index (median 21.17, range 7.18-231.60) was correlated with the number of citations ($r^2 = 0.83$, $P < 0.01$) per article in the Web of Science database. In addition, the number of citations and citations index per article were strongly correlated in the Scopus database (Figure 3: $r^2 = 0.84$, $P < 0.01$) (Supplementary Figure S1). The T100 articles were published from 2007 to 2016, with the most articles published in 2015 (n = 22), followed by 2013 (n = 20; Figure 3). Interestingly, the number of citations in 2013 (n = 4,136) was the highest, followed by 2015 (n = 2774).

To identify factors that might influence the number of citations of the T100 articles, we analyzed possible correlations between the number of citations and the number of countries, funding, years since publication, and authors using GraphPad Prism 5 (Figure 3). There was a strong correlation between the number of citations and the number of authors ($r^2 = 0.05$, $P < 0.05$). However, no significant correlations were present between the number of countries ($r^2 = 0.01$, $P = 0.46$), institutions ($r^2 = 0.01$, $P = 0.27$), and years since publication ($r^2 = 0.01$, $P = 0.27$).

**Analysis of references**
Analysis of cited references is crucial to bibliometric analysis, as the scientific relevance of publications can be evaluated by the map of co-cited references. Using CiteSpaceV, the co-citation network was divided into 7 co-citation clusters (Figure 4(A)). The modularity Q score was 0.54, and the silhouette score was 0.32. These clusters were labeled by index terms from their own citers. The largest cluster was cluster #0 labeled as ‘recurrent *Clostridium difficile* infection,’ followed by cluster #1, labeled as ‘*Clostridium difficile* infection.’ (Supplementary Table S2)

**Distribution by journals**

The 796 articles were published by 294 journals. The top 100 were from 52 journals (Table 2, Supplemental Table 3). According to the Journal Citation Reports (JCR) 2017 standards, the American Journal of Gastroenterology (2017 IF = 10.231) made contributions to the largest number of articles on FMT (10 articles, 10.00%), followed by Gastroenterology (2017 IF = 20.773; 8 articles, 8.00%), Journal of Clinical Gastroenterology (2017 IF = 2.968; 8 articles, 8.00%), and Clinical Infectious Diseases (2017 IF = 9.117; 4 articles, 4.00%).

**Distribution by authors**

There were more than 3,000 authors who contributed to the publications on FMT. The network maps of the authors and co-cited authors produced by CitespaceV are shown in Figure 4(B)& (C). Kassam Z had the greatest number of articles (n = 33), followed by Khoruts A (n = 32) and Kelly CR (n = 21). The top five cited authors were Khoruts A (n = 755), by Brandt LJ (n = 720), de Vos WM (n = 557), and Nieuwdorp M (n = 509) (Table 3&4).
**Distribution by institutions**

The publications on FMT were from 933 institutions, and extensive cooperation was carried out between institutions (Figure 4(D)). The top five institutions ranked by the number of articles published 253 articles, about 31.78% of the total. The University of Texas MD Anderson Cancer Center (n = 9, 12.44%) published the greatest number, followed by the University of Washington (n = 58, 7.23%), McMaster University (n = 34, 4.27%), Emory University (n = 32, 4.02%), and the University of Alabama at Birmingham (n = 30, 3.77%) (Table 5).

**Analysis of keywords**

An approximation of research trends was found by analyzing the top 17 keywords (Figure 2(D)). Almost all the keywords appeared rising and falling fluctuations but an ascendant trend. The keywords of ‘fecal microbiota transplantation’ and ‘Clostridium difficile’ were the first and second most frequent in the last five years of the study period. Except for searching keywords which were ‘fecal microbiota transplantation, ‘fecal transplantation’, and ‘facal transplant’, the three most frequent keywords were ‘Clostridium difficile’, ‘microbiome’, and ‘inflammatory bowel disease’. These three words are also the main therapeutic directions of all FMT researches in the world.

The top 7 keywords with the strongest citation bursts were extracted by CiteSpaceV (Table 6). The blue line represents the time interval and the red line represents the duration of a burst keyword, suggesting the beginning and the end of the time interval of each burst. The top keyword was ‘flora’ (10.56, 2011-2014), followed by ‘bacteriotherapy’ (7.69, 2009-2013) and ‘diarrhea’
There were 722 different keywords in the 796 publications. All keywords with the same meaning were merged into one keyword. After data standardization, 481 keywords were selected as core keywords. Among them, 59 keywords appeared more than three times whose frequency of occurrence were 70.24% so that they were selected as core keywords. The classification results in Table 7 are shown in four domains: disease, nosogenesis, trial, and therapy. Among the 59 core keywords, the highest percentage was in the disease domain (40.49%), followed by the therapy domain (41.44%), the nosogenesis domain (14.63%) and the trial domain (3.77%). The transplantation topic in the therapy domain contained the highest percentage (33.30%) of core keywords, which were ‘fecal microbiota transplantation’ ‘microbiome’ ‘stool transplantation’ ‘bacterial consortium transplantation’ ‘bacteriotherapy’ ‘gut microbiome transplantation’ and ‘transplantation’. In the disease domain, infection topics (16.79%) occurred most frequently. Microbiota topics (11.13%) occurred most frequently in the nosogenesis domain. The subject topic in the trial domain accounted for 2.42%.

DISCUSSION

Total number of published items

This was the first bibliometric analysis of FMT. The yearly number of publications rapidly increased from one article in 2004 to 248 articles in 2017, with an average annual increase of 17.35% over the last 5 years of the study period. Compared with the total scientific output in the WoSCC database, its average annual growth rate was 3.84% between 2004 and 2017. The
increasing incidences of CDI and IBD might explain the increase in the numbers of publication from 2004 to 2017 (Rohlke & Stollman, 2012; Kelly et al., 2012). In addition, the increasing number of output indexed in the WoSCC database might have also made a contribution to the increase in the number of publications. A conclusion can be drawn from the rapid development of FMT, whose research was only in its infancy but promising and potential.

Country of origin and institutions

The top 10 countries/regions in which FMT studies were performed accounted for for 90.70% of the total number of publications. China was the only developing country among these 10 countries/regions, indicating that China has made great progress in the FMT research recently. It is not surprising that developed countries produced the greatest numbers of publications (Van Rossum et al., 2010; Halpenny et al., 2010). The United States, which produced 363 publications (45.60%), demonstrated a leading role in FMT research. This might be related to the high incidence of CDI and IBD in the United States (Orenstein et al., 2013). It might also be related to the financial resources devoted to scientific study in the United States. In addition, the United States played a key role in promoting international cooperation, with the strongest international cooperation between the United States and Canada, followed by between the United States and the United Kingdom. As regard to the cooperation of institution, the top five institutions were ranked by the number of articles, among which 4 institutions subordinated to the United States. This conclusion was consistent with the dominance of the United States. A conclusion could be drawn that the increasing incidence of CDI and IBD has promoted research of FMT in this field.
Citation count and possible factors influencing citations

Based on the clarity of network structure and clustering, two indexes were proposed by CitespaceV: the modularity Q score and the mean silhouette score. Modularity and silhouette metrics provided useful quality indicators of clustering and network decomposition. A low modularity means that a network couldn’t be reduced to a cluster with clear boundaries, while a high modularity suggests a well-structured network. The silhouette metric is helpful for estimate the uncertainty involved in identifying the nature of a cluster (Chen et al., 2010). The co-citation network was divided into 7 co-citation clusters with a modularity of 0.54 and a silhouette of 0.32. This result suggested, the inter-cluster connections are considerable, but not overwhelming and are diverse and heterogeneous.

Citation counting, a proxy measure of research quality, can help authors understand the characteristics inherent in highly cited studies and provided a new perspective on specific areas (Yan et al., 2011; Fu & Aliferis, 2008). However, there has been no citation analysis of FMT until now. Of 796 selected articles, we focus on the top 100 articles arranged by the number of citations. Interestingly, there was no output in 2017. It’s likely that ‘older’ articles have a longer citable period and attained more citations, and as such accumulative citation frequency will be higher (Liu et al., 2016). To further examine this, we assessed the correlation between years since publication and citation count. However, no obvious correlation was found. In addition, we replaced citation count with citation index to decrease the effect of publication time. The results indicated that citation count and citation index exhibited a substantial correlation, indicating that
publication time has very little influence on citations. In addition, we analyzed the citations of the top 100 publications in Scopus. A strong relationship between citation index in WoSCC and citation index in Scopus was found, so does the relationship between citations and citation index in Scopus, which ruled out the impact of the database on citations.

**Journals**

The IFs of journals were one of the strongest indicators for citations in some way owing to the attraction of high IF journals to the scientific community (Garfield, 2003). The top-cited articles are usually published in high IF journals. The top 100 articles ranked by the number of citation were published in 52 journals, one of which was excepted, because its IF was not found in the JCR. The median IF of these publications was 6.96, and the IFs of 18 (35.29%) publications were greater than 10.00. These results suggest that it was challenging to published articles on FMT in high IF journals. Meanwhile, it implied the quality of output in this subject area.

**Authorship**

Ranked by the number of articles they owned, the top five authors identified in this analysis published at least 22 articles. They were consequently regarded as ‘prolific authors’. The top five authors contributed to at least 472 citations. Surprisingly, there was one author in both analyses where this author not only did well in the number of publications but also the quality of publications. The co-cited authors who had at least 200 co-citation counts, included Van Nood E and Borody TJ. Although neither of them belonged to the category of prolific authors, they played
pivotal roles in FMT research; particularly, Van Nood E, who was also the first author of the article with the highest number of citations.

Keywords and research fields

In recent years, there has been great interest in the use of FMT for therapy of gastrointestinal and non-gastrointestinal diseases, mainly for CDI and IBD. In most countries/regions, the incidence of IBD is increasing or at a relatively high stable level. Furthermore, IBD patients have a nearly threefold higher risk for CDI compared with the general population (Rodemann et al., 2007). Nevertheless, some patients became refractory to standard therapy and suffer from a poor quality of life. Evidence suggested that FMT was a potential, effective and safe therapy for recurrent, refractory, or severe CDI and IBD, at least when standard treatments had failed (Anderson et al., 2012; Kelly et al., 2014a). The goal of this bibliometric analysis was to provide an overview of FMT’s research, and guide future studies.

According to the 59 core keywords identified, 4 domains were classified. The disease domain had the highest percentage and the trial domain the lowest. Within the disease domain, the topics of infection and inflammatory have the highest ratio. In this regard, it might relate to the therapy principle of FMT. Evidence has suggested that there is a reduced diversity of luminal microbiota and increased mucosal adherent bacteria in IBD and CDI (Nagalingam & Lynch, 2012). Changes in gut microbiota led to a serious imbalance of host physiology and immune homeostasis, which ultimately results in infection and inflammation. Brandt et al (Brandt et al., 2012b) noted that FMT was a promising therapeutic strategy because it manipulated the microbiota, based on
gastrointestinal microbiota’s role in driving disorders. Interestingly, the topic of emotion taken up
a certain proportion, which was an indication that FMT could be used to treat mental illness.

In the therapy domain, the topic of transplantation occupied the largest portion and other
major treatments of IBD and CDI were also listed. In general, the standard therapy for CDI and
IBD included steroids, amino-salicylates, immunosuppressants, and various biological therapies,
most of which are not effective and place a heavy economic burden on patients (Talley et al., 2011;
Kappelman et al., 2008). Some patients become refractory to standard management and suffer
significant adverse side effects with a poor quality of life (Mcfarland, 2005). Konijeti et al (Konijeti
et al., 2014) indicated that FMT was the most cost-effective initial strategy for management of
recurrent CDI. FMT can thus reduce the financial burden of patients, and result in a substantial
increase in quality of life (Merlo et al., 2016).

The domains mentioned above clarified research hotspots clear, and burst keywords can be
considered indicators of research frontiers over time (Yin et al., 2016). The blue line represents the
time interval and the red line represents the duration of a burst keyword. There were 7 keywords
with the strongest citation bursts. After taking similar burst keywords into consideration, they were
divided into three categories: (i) Microbiota: The presence of normal, healthy, intestinal microbiota
was now considered to offer protection against CDI and IBD. However, the repeated use of
immunosuppressants and other therapy with drugs severely disrupted the normal gut microbiota,
which always led to the recurrence of CDI and IBD. Instead, FMT allowed the rapid reconstitution
of a normal composition of microbial communities. The wonderful effect and desperate need in
the patients would drive the development of FMT in the next few years (Hamilton et al., 2012). (ii)
Diarrhea: Antibiotic-associated colitis caused by *Clostridium difficile* was the most common cause of hospitalization for diarrhea (Cohen et al., 2015). It was caused by disrupting the normal gut flora and led to dysbiosis that enables *Clostridium difficile* colonization of the patients’ gut. Satisfactorily, FMT, a promising therapy for *Clostridium difficile*-associated diarrhea, has the high cure rate of diarrhea (Kelly et al., 2014b; Gough et al., 2011). However, some problems should be further solved and perfected, such as whether FMT should be used as a first-line therapy for the patients with *Clostridium difficile*-associated diarrhea. (iii) Case series: There are many different treatments for CDI and IBD, but none of the treatments proved to be very useful. In order to find the solution that worked best, it was necessary to analyze representative cases. Rubin et al. (Rubin et al., 2013) found the effectiveness of FMT in the therapy of CDI and IBD from a case series of 75 FMT course. This gave the future researchers a clue that case series would be an appropriate way.

There are some limitations to the current study. Non-English publications were excluded and as landmark articles published in other languages were not considered. The study only focused on the publications in WoSCC database, and the inclusion of other databases, such as PubMed and Scopus which might produce slightly different results. Nevertheless, WoSCC is a comprehensive and popular Web database in the field of scientometrics (Miao et al., 2017b).

**CONCLUSIONS**

In conclusion, based on the detailed analysis of the distribution and changes in countries, citations, references, journals, authorship, institutions and keywords, the results of this research and analysis...
indicate that FMT is an area of very active research. This analysis using bibliometric methods provides a solid overview of current FMT research and may help in providing guidance for further studies.

**FIGURE LEGENDS**

Figure 1 Overview of article selection process.

Figure 2 The number of annual publications on FMT from 2004 to 2017(A), growth trends of countries on FMT from 2004 to 2017(B), the cooperation of countries/regions contributed to publications on FMT from 2004 to 2017(C), growth trend of keywords on FMT from 2004 to 2017(D).

Figure 3 Correlations between the number of citations and number of countries (A); the number of institutions (B); the number of the years since publication(C); the number of authors (D).

Figure 4 Reference co-citation map of publications (A); Network map of authors contributed to publications (B); Network map of co-cited authors contributed to publications (C); Network map of institutions contributed to publications (D) on FMT from 2004 to 2017.

**ABBREVIATIONS**

FMT fecal microbiota transplantation

CDI *Clostridium difficile* infection
IBD inflammatory bowel disease

SCI-E the Science Citation Index Expanded

WoSCC the Web of Science Core Collection

T100 the top 100

JCR the Journal Citation Reports

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ADDITIONAL INFORMATION AND DECLARATIONS

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Competing interests

The authors declare that they have no competing interests.

Author contributions

• Yan Li conceived and designed the experiments, performed the experiments, drafted the work or revised it critically for important content, approved the final draft of the manuscript submitted for review and publication.
• Ziyuan Zou conceived and designed the experiments, contributed reagents/materials/analysis tools.

• Yushan Huang performed the experiments, analyzed the data, contributed reagents/materials/analysis tools.

• Xiaohui Bian contributed reagents/materials/analysis tools, prepared the figures and/or tables.

• Yanru Wang drafted the work or revised it critically for important content.

• Chen Yang contributed reagents/materials/analysis tools, drafted the work or revised it critically for important content.

• Jian Zhao analyzed the data, contributed reagents/materials/analysis tools.

• Lang Xie conceived and designed the experiments, drafted the work or revised it critically for important content.

Data Availability

The following information was supplied regarding data availability:

The raw data can be directly obtained from the Web of Science Core Collection (WoSCC) of Thomson Reuters.

Supplemental Information

Figure S1. Correlations between citation index (WoSCC) and time cited (WoSCC) (A); citation index (Scopus) and time cited (Scopus) (B); citation index (Scopus) and citation index (WoSCC) (C).
Table S1. The top 100 most-cited articles ranked by the number of times cited

Table S2. Major clusters of co-cited references.

Table S3. Journals with the top 100 articles ranked by the number of citation.

REFERENCES


Figure 1

Overview of article selection process.

Keywords and free words search in Web of Science Core Collection (WoSCC) (n=2062)

Titles and abstract screened (n=824)

Titles and abstracts of articles excluded (n=1238)
Titles and abstracts unrelated to the study (n=809)
The main content unrelated to the study (n=125)
The abstract inaccessible (n=302)
Duplicates (n=2)

Language of articles assessed for eligibility (n=796)

Language containing non-English (n=28)

Articles included in quantitative synthesis (bibliometric-analysis) (n=796)
Figure 2

The number of annual publications (A), and growth trends of countries (B), the cooperation of countries/regions (C), growth trend of keywords (D) on FMT from 2004 to 2017.

The number of annual publications on FMT from 2004 to 2017 (A), growth trends of countries on FMT from 2004 to 2017 (B), the cooperation of countries/regions contributed to publications on FMT from 2004 to 2017 (C), growth trend of keywords on FMT from 2004 to 2017 (D).
Figure 3

Correlations between the number of citations and countries (A), institutions (B), the years since publication (C), and authors (D).

Correlations between the number of citations and number of countries (A); the number of institutions (B); the number of the years since publication (C); the number of authors (D).
Figure 4

Reference co-citation map (A), Network map of authors (B), Network map of co-cited authors (C) and Network map of institutions (D) contributed to publications on FMT from 2004 to 2017.

Reference co-citation map of publications (A); Network map of authors contributed to publications (B); Network map of co-cited authors contributed to publications (C); Network map of institutions contributed to publications (D) on FMT from 2004 to 2017.
Table 1 (on next page)

Bibliometric information associated with the top 5 of the top 100 cited articles in FMT from 2004 to 2017

Bibliometric information associated with the top 5 of the top 100 cited articles in FMT from 2004 to 2017
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<th>Years</th>
<th>Times cited</th>
<th>Citation index (WoSCC)</th>
<th>Time cited</th>
<th>Citation index (Scopus)</th>
</tr>
</thead>
</table>

Table 2 (on next page)

The top 5 journals of the top 100 articles ranked by the number of citation contributed to publications on FMT from 2004 to 2017.

The top 5 journals of the top 100 articles ranked by the number of citation contributed to publications on FMT from 2004 to 2017.
Table 2. The top 5 journals of the top 100 articles ranked by the number of citation contributed to publications on FMT from 2004 to 2017.

<table>
<thead>
<tr>
<th>Rank</th>
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<th>Country</th>
<th>No. of articles</th>
<th>IF 2017</th>
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<td>AMERICAN JOURNAL OF GASTROENTEROLOGY</td>
<td>the US</td>
<td>10</td>
<td>10.231</td>
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<td>2</td>
<td>GASTROENTEROLOGY</td>
<td>the US</td>
<td>8</td>
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<tr>
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<td>JOURNAL OF CLINICAL GASTROENTEROLOGY</td>
<td>the US</td>
<td>8</td>
<td>2.975</td>
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<tr>
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<td>CLINICAL INFECTIOUS DISEASES</td>
<td>the US</td>
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<tr>
<td>5</td>
<td>CELL</td>
<td>the US</td>
<td>3</td>
<td>31.398</td>
</tr>
</tbody>
</table>
Table 3 (on next page)

The top 5 authors ranked by the number of articles

The top 5 authors ranked by the number of articles
Table 3. The top 5 authors ranked by the number of articles

<table>
<thead>
<tr>
<th>Rank</th>
<th>Authors</th>
<th>No. of articles</th>
<th>Total citations</th>
<th>First Citations of first</th>
<th>Correspond</th>
<th>Citations of correspond</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kassam, Z</td>
<td>38</td>
<td>325</td>
<td>4</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Khoruts, A</td>
<td>33</td>
<td>755</td>
<td>6</td>
<td>9</td>
<td>202</td>
</tr>
<tr>
<td>3</td>
<td>Kelly, CR</td>
<td>24</td>
<td>375</td>
<td>5</td>
<td>8</td>
<td>297</td>
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<td>4</td>
<td>Sadowsky, MJ</td>
<td>23</td>
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<td>6</td>
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<td>Allegretti, JR</td>
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<td>5</td>
<td>4</td>
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Table 4 (on next page)

The top 5 authors ranked by the number of citations

The top 5 authors ranked by the number of citations
Table 4. The top 5 authors ranked by the number of citations

<table>
<thead>
<tr>
<th>Rank</th>
<th>Authors</th>
<th>No. of articles</th>
<th>Total citations</th>
<th>First Citations of first Correspond</th>
<th>Citations of correspond</th>
</tr>
</thead>
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<td>1</td>
<td>Khoruts, A</td>
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<td>755</td>
<td>6</td>
<td>153</td>
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<tr>
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<td>342</td>
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<td>3</td>
<td>de Vos, WM</td>
<td>8</td>
<td>557</td>
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<td>171</td>
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<tr>
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<td>Zoetendal, EG</td>
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</tr>
</tbody>
</table>
Table 5 (on next page)

The top 5 institutions ranked by the number of articles contributed to publications on FMT from 2004 to 2017.

The top 5 institutions ranked by the number of articles contributed to publications on FMT from 2004 to 2017.
Table 5. The top 5 institutions ranked by the number of articles contributed to publications on FMT from 2004 to 2017.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Institution</th>
<th>No. of articles</th>
<th>No. of citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>University of Minnesota, Gemini, Minnesota, the US</td>
<td>99</td>
<td>1999</td>
</tr>
<tr>
<td>2</td>
<td>University of Washington, Seattle, Washington, the US</td>
<td>58</td>
<td>1136</td>
</tr>
<tr>
<td>3</td>
<td>McMaster University, Hamilton, Ontario, Canada</td>
<td>34</td>
<td>1099</td>
</tr>
<tr>
<td>4</td>
<td>Emory University, Atlanta, GA, the US</td>
<td>32</td>
<td>119</td>
</tr>
<tr>
<td>5</td>
<td>University of Alabama Birmingham, Birmingham, Alabama, the US</td>
<td>30</td>
<td>58</td>
</tr>
</tbody>
</table>
Table 6 (on next page)

Core Keywords related to FMT from 2004 to 2017.

Core Keywords related to FMT from 2004 to 2017.
### Table 6. Core Keywords related to FMT from 2004 to 2017.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Topic</th>
<th>Percentage Within Core Keywords, %</th>
<th>Frequency of Keyword Occurrence (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disease domain</strong></td>
<td>Infection</td>
<td>16.79</td>
<td>Clostridium difficile infection (171), infection (5), bacterial infections (4), refractory clostridium difficile infection (4), fulminant clostridium difficile infection (3)</td>
</tr>
<tr>
<td></td>
<td>Inflammatory</td>
<td>13.73</td>
<td>Inflammatory bowel disease (66), ulcerative colitis (38), crohn's disease (23), colitis (11), inflammation (8), pseudomembranous colitis (7)</td>
</tr>
<tr>
<td></td>
<td>Diarrhea</td>
<td>5.48</td>
<td>Antibiotic-associated diarrhea (26), diarrhea (16), recurrent clostridium difficile infection (16), infectious diarrhea (3)</td>
</tr>
<tr>
<td></td>
<td>Metabolism</td>
<td>2.6</td>
<td>Obesity (12), metabolic syndrome (9), diabetes (4), metabolism (4)</td>
</tr>
<tr>
<td></td>
<td>Functional disease</td>
<td>1.26</td>
<td>Irritable bowel syndrome (11), functional bowel disease (3)</td>
</tr>
<tr>
<td></td>
<td>Emotion</td>
<td>0.63</td>
<td>Depression (4), anxiety (3)</td>
</tr>
<tr>
<td>Domain</td>
<td>Subject</td>
<td>Method</td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Nosogenesis domain</strong></td>
<td>Microbiota 11.13 Gut microbiota (49), microbiota (40), intestinal microbiota (27), bifidobacterium (5), lactobacillus (3)</td>
<td>16s rRNA analysis (8), metagenomics (4), clinical trial (3)</td>
<td></td>
</tr>
<tr>
<td>(total, 14.63%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment 2.69 Dysbiosis (17), gut (4), rain-gut axis (3), gastrointestinal (3), gut permeability (3)</td>
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<tr>
<td>Immunity 0.81 Immunomodulation (9)</td>
<td></td>
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<tr>
<td><strong>Trial domain</strong></td>
<td>Subject 2.42 Children (13), germ-free (5), germ-free animals (3), mathematical modeling (3), mouse models (3)</td>
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<tr>
<td>(total, 3.77%)</td>
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</tr>
<tr>
<td>Method 1.35 16s rRNA analysis (8), metagenomics (4), clinical trial (3)</td>
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<tr>
<td><strong>Therapy domain</strong></td>
<td>Transplantation 33.3 Fecal microbiota transplantation (301), microbiome (41), stool transplantation (9), bacterial consortium transplantation (7), bacteriotherapy (6), gut microbiome transplantation (4), transplantation (3)</td>
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</tr>
<tr>
<td>(total, 41.44%)</td>
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<tr>
<td>(total, 41.44%)</td>
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<tr>
<td>Food 4.13 Probiotics (33), prebiotic (8), diet (5)</td>
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<tr>
<td>Antibiotics 2.87 Antibiotic therapy (13), fidaxomicin (6), vancomycin (6), metronidazole</td>
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</tr>
<tr>
<td>Procedure</td>
<td>Value</td>
<td>Procedure</td>
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</tr>
<tr>
<td>-----------------</td>
<td>--------</td>
<td>--------------------</td>
<td></td>
</tr>
<tr>
<td>Fibroptic</td>
<td>0.81</td>
<td>Colonoscopy</td>
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<tr>
<td>endoscopy</td>
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<td>(9)</td>
<td></td>
</tr>
<tr>
<td>(4), infection control (3)</td>
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<td></td>
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</tbody>
</table>
Table 7 (on next page)

The top 7 Keywords with the Strongest Citation Bursts on FMT from 2004 to 2017

The top 7 Keywords with the Strongest Citation Bursts on FMT from 2004 to 2017
Table 7. The top 7 Keywords with the Strongest Citation Bursts on FMT from 2004 to 2017

<table>
<thead>
<tr>
<th>Keywords</th>
<th>Year</th>
<th>Strength</th>
<th>Begin</th>
<th>End</th>
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<td>2011</td>
<td>2014</td>
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<tr>
<td>bacteriotherapy</td>
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<td>7.6856</td>
<td>2009</td>
<td>2013</td>
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<tr>
<td>diarrhea</td>
<td>2004</td>
<td>7.0221</td>
<td>2011</td>
<td>2013</td>
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</tr>
<tr>
<td>antibiotic associated</td>
<td>2004</td>
<td>5.4075</td>
<td>2010</td>
<td>2013</td>
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</tr>
<tr>
<td>coliti</td>
<td>2004</td>
<td>5.0701</td>
<td>2010</td>
<td>2013</td>
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<tr>
<td>enterocolitis</td>
<td>2004</td>
<td>4.3316</td>
<td><strong>2010</strong></td>
<td>2013</td>
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