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特　集

研究論文業績と世界大学ランキング：機関（北海道大学）と構成部局（歯学）の計量書誌学的指標を中心に

Scientific Publications and World University Rankings : Focus on Bibliometric Indicators at Institution (Hokkaido University) and Department (Dental Medicine) Levels

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ABSTRACT : This paper gives a brief overview of the scientific publications related to Hokkaido University (HU) in general and its Graduate School/Faculty/School of Dental Medicine (HU-DENT) in particular. It focuses on the bibliometric analysis of the peer-reviewed scientific publications (articles and reviews in journals with journal impact factor, almost exclusively in English) covering a 10-yrs period (2006-2015). The bibliographic data and citation impact indicators were extracted respectively from the Web of Science (WoS) core collections and InCites managed formerly by Thomson Reuters but now by Clarivate Analytics. Several research performance indicators (number of papers, percent share relative to the world, average citation per paper, category normalized citation impact (CNCI), percent papers belonging to top 10% by citation, and international co-authorship) using various disciplinary schemes (ESI22, WoS 251, KAKEN-L3) both at the university and department (HU-DENT) levels are used to assess the research output and impact and to identify major international collaborators, the effect of collaboration on citation impact, and so on. The use of science mapping to visualize the words, authors, subject areas, journals etc. relationships is illustrated by some concrete examples related to HU-DENT. In view of the close connections between bibliometric and university ranking indicators, a brief description of the aspects of world university rankings is also given with emphasis on the differences in the QS and THE World University Rankings. The latest rankings data are used to benchmark the Japanese Research Universities RU11 aiming at positioning Hokkaido University among them.

Key Words : bibliometry, citation, dental medicine, research performance, science map, rankings

1. Introduction

There is a general consensus today that most comprehensive universities have 3 important missions : education, research and community engagement (i.e., commercialization-related collaborations with the business sector, regional societal contributions, etc.). Hokkaido University (HU, hereafter), one of the top national seven universities in Japan, is a comprehensive university dedicated to all these missions. Since its foundation in 1876 as the Sapporo Agricultural College, whose first principal was Dr William S Clark, President of the Massachusetts Agricultural College in the US, the spirit of field-research and internationalization are embedded in its faculty and students. Some factual data related to HU as of May 1, 2015 are as follows : 11,727 undergraduate students, 5,941 graduate students, 200 research students and auditors, 3,897 staff (ca. 60% of them being engaged in teaching and research), 2 campuses in Sapporo and Hakodate, the latter being specialized in the fisheries sciences (Source : Hokkaido University Guidebook 2015-2016). HU is a research-intensive university that currently produces ca. 3,200 articles and reviews each year, indexed in the Web of Science (WoS) (http://apps.webofknowledge.

Creative Research Institution, Hokkaido University, Kita 21 Nishi 10, Kita-ku, Sapporo, Hokkaido, 001-0021, Japan

com/) core collections, covering a wide range of academic fields in natural sciences, engineering, medicine, social sciences, arts and humanities (Fig. 1). In fact, the post-1990 accelerated growth in the number of scientific publications, most probably owing to prioritization of the postgraduate education and various other reforms leading to the enhancement in research performance, seems to have reached saturation by 2004 that coincides with the year the national universities acquired the status of a corporation. Similar trend is largely valid also for several major national universities. In the author's observation, one of the peculiarities of HU is the active engagement of its researchers and graduate students in field-based research (e.g., biodiversity, geoscience, environment, etc. in remote tropical forests, mountain regions, polar regions and so on) throughout the globe, and therefore, the formation of a vast international network for research collaborations and mutual exchange.

Analysis of the research performance of universities is becoming increasingly important in recent years. As stated by Moed (2016) and references therein, this can be attributed to various reasons, such as (i) demand from the governments or related agencies for indicators that enable to measure the effectiveness and efficiency of the research supported through grants, use them to systematically evaluate for optimizing their research allocations, re-orient their research support, rationalize research organizations, restructure research in particular fields, or augment research productivity ; (ii) necessity of having data on research output in order to set goals in terms of often numerical key performance indicators in relation with effective strategic planning as well as

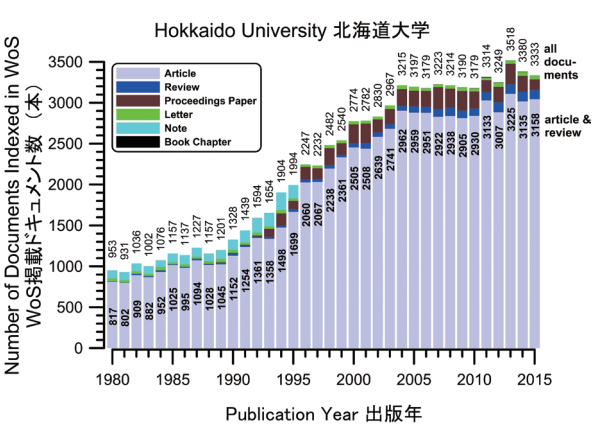

Fig. 1　Annual variation of the scientific publications, from Hokkaido University, indexed in the Web of Science database. Data source : InCites managed by Clarivate Analytics, accessed 2016. 11. 30.

execution of large-scale projects ; and (iii) the increasing influence on the higher education landscape of the university rankings leading to the need of thorough analysis of the research output, research and education environment, and research outcome that influence the position of one's institution in the university rankings, performed at global, regional and even national levels.

This paper comprises 3 sections : 1) A short bibliometric analysis of the core journal publications of HU during the recent 10-yrs period (2006-2015) ; 2) Analysis of scientific publications (2006-2015) of the Graduate School/Faculty/School of Dental Medicine (HU-DENT, hereafter), and ; 3) Benchmarking of the Japanese research universities forming the RU11 consortium in terms of the weighted scores of indicators used by Times Higher Education (THE) and Quacquarelli Symonds (QS) world university rankings in order to show the relative position of Hokkaido University.

Before moving to the individual sections, mentioned above, a brief description of the bibliometric indicators used in this paper will be given. This study deals primarily with the articles and reviews indexed in WoS core collections, in terms of the publication volume, citations - as the measures of the influence or impact (as a proxy of quality) of published research as judged by the peer researchers, in the respective fields, by citing them in their own research papers, and collaboration (based on the authorship in papers). The scientific publications for the period 2006-2015 were subjected to analysis for the following bibliometric indicators using 3 different disciplinary schemes (ESI 22 field, WoS251 Subject Categories, and KAKEN-L3 66 Categories) available in WoS and/or InCites (http://ip-science.thomsonreuters.jp/products/incites/).

(i) Number of documents in each discipline, Ndoc. It is the indicator of the production of scientific publications by discipline (field or category) during the period concerned. In general, the whole counting method, by which each entity (country, institution) participating in the production of a document gets full credit (i.e., 1), has been used. In the case of KAKEN-L3 scheme related to HU-DENT, fractional counting (each category forming a part of n categories assigned to an article gets a credit of 1/n) is also used. As the publishing practices vary with discipline/category (e.g., researchers in chemistry publish far more papers in average than those in mathematics), this number may not be used for

direct comparison of performance across disciplines.

(ii) Percent disciplinary share, % share = $100*N_{doc}/n$ (%). It indicates the relative share of each discipline out of the total scientific publications (n). if n is the global total of publications in a particular field, the calculated value is the so-called world share.

(iii) Number of papers, in each discipline, with citation percentile equal or below 10, N_{Top10}. It is derived using the value of citation percentile (0-100) for each document in InCites.

(iv) Percentage of top 10% papers, PPTop10 $=100*N_{Top10}/N_{doc}$ (%). Also denoted by Q, it is assumed as the proxy of quality (influence, to be more accurate) of the set of publications considered. By definition, a value of 10% means performance equal to the world average.

(v) Discipline level category normalized citation impact (CNCI) averaged over Ndoc documents. CNCI of each document was extracted from InCites, where it is calculated by dividing the actual count of citing items by the expected citation rate for documents with the same document type, year of publication and subject area. CNCI is considered as a valuable and unbiased indicator of impact irrespective of age, subject focus of document type, and in strict sense, a value of close to 1 (the exact value depends on the many different ways of counting in the case of disciplinary schemes involving multiple category assignments of papers, and the normalization procedure) represents performance at par with world average. For discipline with a small n, however, the CNCI values may be inflated by a single highly cited document.

(vi) International co-authorship is calculated as the ratio of the number of documents with at least one more affiliating country besides Japan to the total number of documents and expressed in percentage after multiplying it by 100.

2. Scientific Publications of Hokkaido University : A Brief Bibliometric Analysis

The annual volume of different types of publications from Hokkaido University for 1980-2015 presented in Fig. 1 was retrieved from InCites through search for "Hokkaido University" as an institution. For detailed bibliometric analysis for 2006-2015, however, a different approach was adapted : (i) Retrieving publications from WoS Core Collection (SCIE, SSCI, A&HCI modules) by searching for "OG= Hokkaido University" as Organization-enhanced in "advanced search", as well as "Hokkaido Univ" in address in "basic search" modes ; (ii) Combining them and restricting to "article", "article, proceeding paper" and "review" ; (iii) Downloading the combined dataset comprising the bibliographic records of all articles as WoS text files into Excel spreadsheet, and confirming the affinity to HU through "author address" or "reprint address" or "e-mail address" of each article, and deleting those not related to HU. This procedure yielded a total of 29,565 documents (articles : 97.1%, reviews : 3.5% ; the partial overlap is due to dual assignment of a number of documents) for bibliometric analysis discussed below. Documents with authors restricted to Japan in these three addresses are "domestic" as opposed to those with at least one country other than Japan recognized as "international". The 29,565 documents were subjected to disciplinary analysis using several classifications such as Essential Science Indicators (ESI) 22 fields, WoS 251 subject categories, and partially also the Japanese Grants-in-Aid KAKEN-L3 66 categories. The ESI22 fields scheme (journal-based assignment of document to single field) may be good for a general overview, but a more realistic picture about the research activity in smaller subject areas emerges while using the WoS 251 scheme (single document assigned often to multiple subject categories, such that the cross-disciplinarity is better captured). Although citation data were retrieved from the WoS itself, the impact indicators derived from these data have been taken from InCites that facilitates the extraction of data from many different perspectives : organization, subject area scheme, raw or normalized citations, or impact parameter, and so on.

2. 1 Disciplinary Contribution and the Citation Impact

Data on publications volume and impact analysed using ESI22 classification is presented in Fig. 2. From the left diagram, it is obvious that research at HU encompasses all 22 disciplines, though it is dominated by natural sciences, technology and medical fields, as the share of the social sciences and humanities fields ("Social Sciences, general", "Economics & Business", and partially "Psychiatry/Psychology" and "Multidisciplinary") is about 1%. One may identify largely 4 groups with fields with differing share ranges : (i) 10% or more documents : Chemistry, Clinical Medicine, Physics, Plant & Animal Science ; (ii) 5-10% documents : Biology & Biochemistry, Geosciences, Materials Science ; (iii) 2.5-5% documents :

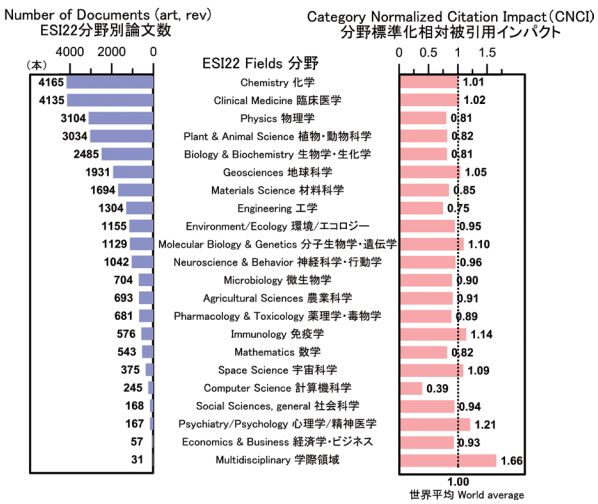

Fig. 2　Volume and impact of scientific publications (2006-2015) from Hokkaido University. Left : Number of documents in each ESI 22 field, arranged in descending order. Right : the relative citation impact, showing that Hokkaido University's research impact is above the world's average in 8 of the 22 fields.

Engineering, Environment/Ecology, Molecular Biology & Genetics; and, (iv) <2.5% documents: Microbiology, Agricultural Sciences, Pharmacology & Toxicology, Immunology and others. It should be emphasized here that these fields are not confined to specific departments and therefore may not provide any definite clues about the volume of research produced by them. For example, department-level analysis for 2006-2015 for the Graduate School/Research Faculty/School of Agriculture (HU-AGR) by the author reveals that 86.5% of its 2,254 documents are assigned to six ESI22 fields (Plant & Animal Science (34.0%), Agricultural Sciences (16.4%), Biology & Biochemistry (17.7%), Environment/Ecology (8.9%), Molecular Biology & Genetics (5.2%), Microbiology (4.3%)) such that the "Agricultural Sciences" field captures only one-sixth of all HU-AGR documents.

The research impact (CNCI) shows how the performance of HU in different fields compares with the world average. Following Saari & Moilanen (2012, p. 183), the following CNCI ranges may be more realistically used to judge the performance relative to the world : <0.5 : significantly far below ; 0.5-0.8 : below ; 0.8-1.2 : about ; 1.2-2.0 : above, and >2.0 : far above. Hence, HU's comparative performance may be said to be above the world in Psychiatry/Psychology and Multidisciplinary fields, about the world average in 18 fields, below the world average in Engineering, and far below that in Computer Science. A department level study of total publications for 2005-2014 recorded in WoS and Scopus from the Graduate School of Engineering and Graduate School of Science and Technology of HU by the author revealed that the share of conference papers in them is 24% and 53%, respectively. As these two departments are largely the contributors to the ESI22 fields of Engineering and Computer Science, the inferences on low impact derived from this study, which doesn't consider into account the proceeding papers and limits the analysis to WoS alone, need to be taken with caution.

A more realistic fine-scale picture is likely to emerge using the WoS 251 subject categories. To be brief, five subject categories to each of which >5% of total documents are assigned were found to be the followings : Biochemistry & Molecular Biology ; Materials Science, Multidisciplinary ; Chemistry, Physical ; and Physics, Applied. Two subject categories ("Engineering, Environmental" and "Engineering, Chemical") show performance above the world average (i.e., CNCI > 1.2).

2. 2 Research Collaboration (University Level)

The annual variation in the number of total, domestic only and internationally co-authored documents for the whole university is presented in Fig. 3. The number of papers fluctuated annually, with an average of 2843.6 and 3069.4 during the first (2006-2010) and second (2011-2015) 5-yrs periods, respectively, showing an 8% increase. The absolute count of the internationally collaborative papers as well as the international co-authorship show a linear

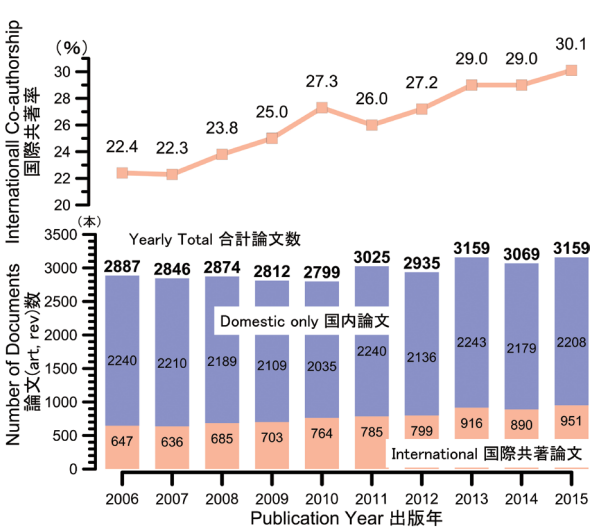

Fig. 3　Research collaboration trends (2006-2015). *Bottom* : Bar diagram showing annual variation of total, domestic only and internationally collaborative papers from Hokkaido University. *Top* : Annual change and the generally increasing trend of international authorship.

increase, the values for the latter being 22% in 2006 to 30% in 2015. This trend is in line with the university's strategy to systematically promote internationally collaborative research, which is known to be effective in wider dissemination of the research achievements and also in enhancing the citation impact of publications.

The top 25 universities from abroad most intensely collaborating with HU are identified in Fig. 4 along with the number of collaborative documents and the average research impact for each of them. Collaboration with just 1 institution has slightly below the world average performance (CNCI=0.79) and it may be due to the short history of collaboration. It is significant that other collaborative documents show performance far above the world average (18 universities), while those with the remaining others (6 universities) indicate performance above the world average.

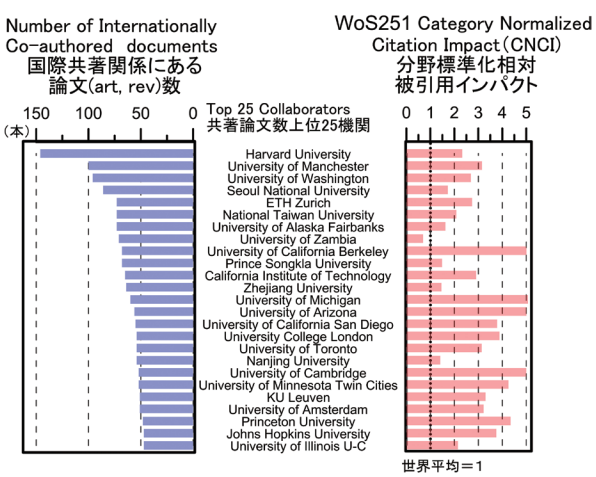

Fig. 4 Volume of internationally collaborative documents co-authored with Hokkaido University and the research impact of joint documents with 25 topmost collaborators from abroad.

Domestic collaborations also are known to yield higher impact compared to the collaborations confined within HU alone. To demonstrate this, Fig. 5 identifies top 25 domestic collaborators. Here too, with the exception of two institutions, the research impact judging from CNCI is higher than the world average, reinforcing the idea that domestic collaborations also result in relatively high impact.

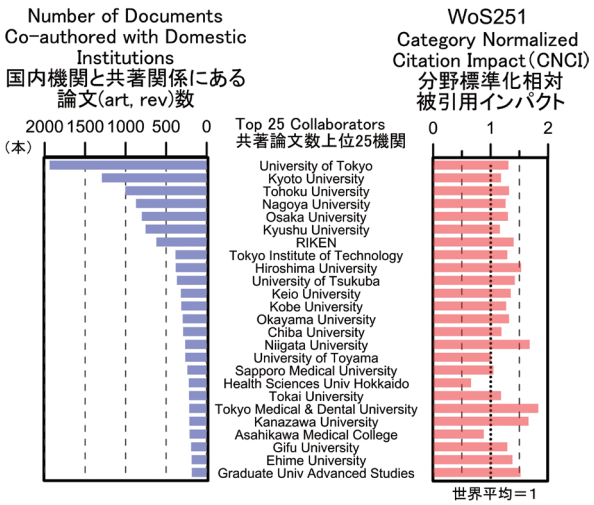

Fig. 5 Volume of collaborative documents with domestic institutions and the research impact of joint documents with 25 topmost collaborators within Japan.

3. Scientific Publications (2006-2015) of Graduate School/Faculty/School of Dental Medicine (HU-DENT)

This section briefly describes the scientific publications with at least one author affiliation at HU-DENT. The partial dataset for HU=DENT is a part of 29,565 articles and reviews parsed to 62 different organizations. It has 726 documents, 97.1% being articles and 2.9% reviews. The basic approach and procedure of analysis are described in Gautam (2016). Two studies did bibliometric analysis at the level of HU's Creative Research Institution (Gautam & Yanagiya 2012) and large-scale externally-funded research projects (Hokkaido University Research & Business Park Project and the Future Drug Discovery Project) (Gautam, Kodama & Enomoto 2014).

3.1 Disciplinary Structure and the Citation Impact

Fig. 6 shows the breakdown of the HU-DENT documents into the ESI22 fields. Due to the lack of ESI field that contains terms with root 'dent', this classification is not suited to see the details. Of the 726 documents, 711 only have been assigned to ESI22 fields and 40.6% to the Clinical Medicine. Other two prominent fields are : Materials Science (13.1%) and Biology & Biochemistry (10.8%). Three other important fields, each of which contains about 5% documents, are : Chemistry, Molecular Biology & Genetics, and Neuroscience & Behavior. Altogether, these 6 fields comprise 90% of the total documents. In terms of CNCI, only Materials Science (1.15) and Biology & Biochemistry (0.81) show

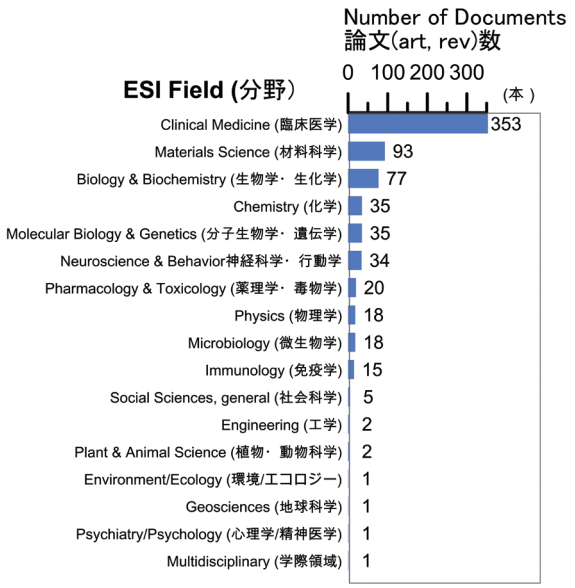

Fig. 6　Scientific publications from HU-DENT assigned to ESI 22 fields. Each document corresponds to one field mainly based on the journal (with impact factor) used for publishing it.

citation impact of about the world average.

The disciplinary profile of HU-DENT in terms of the KAKEN-L3 66 categories scheme, restricted to the categories with 4 or more documents by whole counting, is presented in Fig. 7. This classification is supposed to best reflect the research conducted primarily under the Grants-in-Aid or KAKENHI Projects. Use of whole

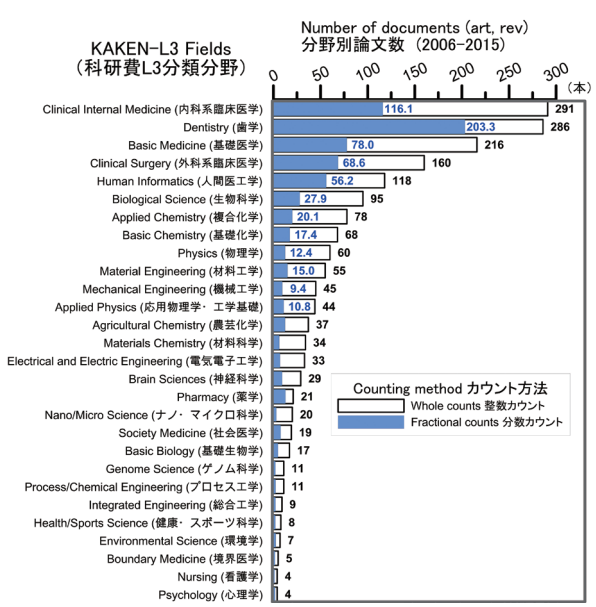

Fig. 7　Distribution of core journal publications of HU-DENT into the Grants-in-Aid classification scheme (KAKEN-L3) categories. Categories with 4 or more documents by whole counting are shown. Dentistry is the most prolific category by fractional counting.

counting for this scheme that assigns a single document to a large number of fields, however, largely exaggerates the size of each field. Clinical Internal Medicine category is related to most documents (291) followed by Dentistry (286) by whole counting. By fractional counting, however, Dentistry with 203.3 documents is the most prolific, while Clinical Internal Medicine counts to just 116.1 or about 60% of Dentistry counts. Basic Medicine, Clinical Surgery, Human Informatics and Biological Science are the next categories that are well represented. The large differences arising from counting methods point to the large documentary overlaps among these categories. For example, 190 (88%) of the 216 documents assigned to Basic Medicine are common with Clinical Internal Medicine. Similarly, 115 (97.4%) documents assigned to Human Informatics belong to Dentistry (286 documents), and 128 (80%) documents in Clinical Surgery belong to Clinical Internal Medicine (291 documents).

In order to judge the publication volume and citation impact of HU-DENT, the WoS 251 scheme is more appropriate as it helps to recognize the diversity of research conducted in cross-disciplinary manner and the impact in diverse categories. Though not free from multiple assignments, and hence some disciplinary overlaps, its long history of usage and refinements make it robust and popular. Fig. 8 presents several indicators calculated for 27 prolific subject categories with a minimum of 10 documents assigned. Three subject categories with the highest number of documents and at the same time also the largest world share related to HU-DENT are : (i) Dentistry, Oral Surgery & Medicine ; (ii) Materials Science, Biomaterials ; and (iii) Engineering, Biomedical. As shown in the middle part of Fig. 8, three subject categories (Engineering, Biomedical ; Chemistry, Multidisciplinary ; Microscopy) exhibit impact above the world average, while the performance is about the same as the world average in 6 subject categories such as Materials Science, Biomaterials, Pathology, and Biotechnology & Applied Microbiology. It is significant to note that PPTOP10% exhibits values equal to the average or significantly above that, with 4 categories (Microscopy ; Chemistry, Multidisciplinary ; Pathology ; and Engineering, Biomedical) being noteworthy. The extreme right side in Fig. 8 shows the international co-authorship that shows positive correlation with the two impact indicators : CNCI and PPTOP10%.

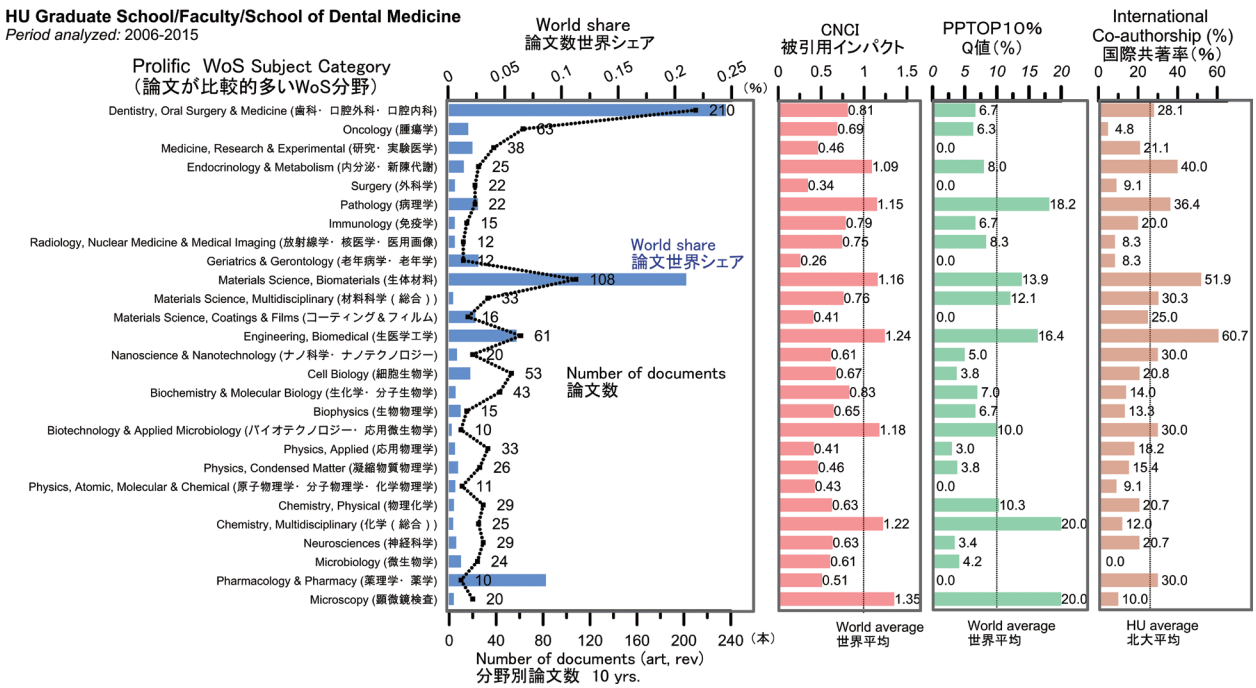

Fig. 8 Breakdown of core journal publications into the WOS subject categories and major bibliometric indicators. Of the 92 categories to which the documents belong, only those with 10 or more documents are listed and the broadly similar subject categories are placed together. Note that an individual article may be assigned to one or more fields (1.58 in average, in this case). Data source: Web of Science and InCites by Clarivate Analytics.

3. 2 Research Collaboration (at the Level of HU-DENT)

Data on the annual changes in the number of total, domestic only and internationally co-authored documents related to HU-DENT are presented in Fig. 9. Judging from the mean values of 72.6±9.5 for total documents, 25.1 ±4.4% for the international co-authorship as well as the smooth undulations of the numerical values, the number of papers and nature of collaboration remained almost at the same level. The positive trend in the international co-authorship is expected to accelerate further as HU has set a definite goal for internationalization in line with the mid-term strategy and increased international collaborations at each departmental level are expected.

In order to see how collaboration enhances the citation impact of scientific publications, a CNCI versus institutions with the number of joint papers with HU-DENT (with or without engagement of others) plot is shown in Fig. 10. For the 721 documents (with CNCI) of HU-DENT, the average CNCI is 0.8. For documents co-authored with 21 foreign institutions shown, the average citation impact is 1.0, i.e. the world average in a strict sense. For one-third of collaborative works with these foreign institutions, CNCI exceeds 1.20 implying that the performance with them is far above the world average. In contrast, the average CNCI for collaborative documents with 27 domestic institutions is 0.73, i.e. below the world average. Collaboration with about 40% of them results in citation impact above the world average,

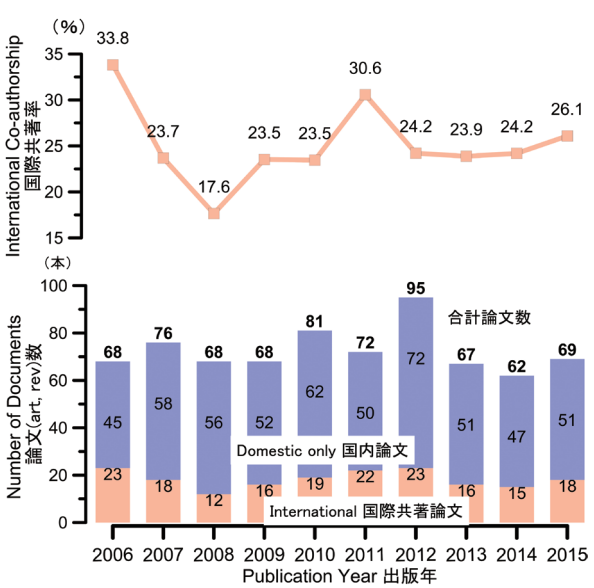

Fig. 9 Research collaboration trends (2006-2015). Bar diagram, at the lower part, shows annual variation of total, domestic only and internationally collaborative papers from the Graduate School/Faculty/School of Dental Medicine. The upper part shows the yearly change in the international co-authorship.

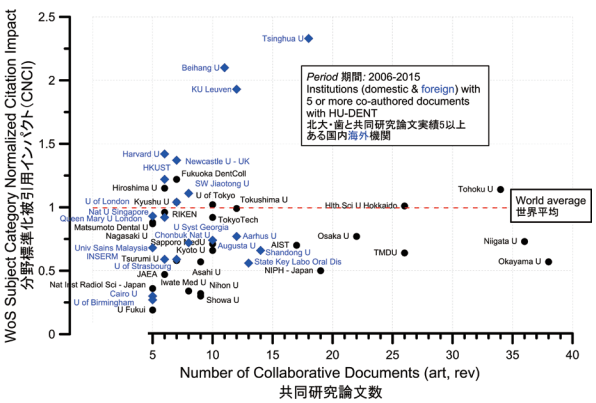

Fig. 10　Bi-plot showing the impact of collaborative research papers co-authored by at least one author each from the Graduate School/Faculty/School of Dental Medicine (HU-DENT) and domestic (black) or foreign (blue) institution. The data may be interpreted to support the notion that international collaboration leads to enhanced research impact. For clarity, the names of institutions are abbreviated.

while with only one domestic institution it is far above the world average. Fig. 10 facilitates rapid identification the most collaborative institutions (plotting in the right half), and the most impactful collaborators (plotting in the upper left). Caution is needed while comparing the impact of research with institutions having largely varying number of documents, as aggregation of a large number of documents results in masking the high impact of individual documents while the opposite or exaggeration of the average impact due to the effect of a few very highly cited documents is true for smaller dataset.

3. 3 Publication Practice, Journal Impact Factor and the Impact of HU-DENT Publications

A histogram depicting the frequency of the publications from HU-DENT against the logarithmically (with a base of 2) transformed journal impact factor (IF) intervals is shown in Fig. 11. The distribution follows a lognormal rule, with the most frequent IF interval of 2-4. The curve is asymmetric and skewed towards left (i.e., more publications in journals with lower IF). The part below the histogram lists typical journals, both domestic and international, used by HU-DENT researchers as a medium of publishing their works.

In order to see the relationship between the impact of publications of HU-DENT and the impact factor of journals carrying them, three types of graphs are combined together (Fig. 12). The lowermost graph is a horizontal arrangement of journals in the descending

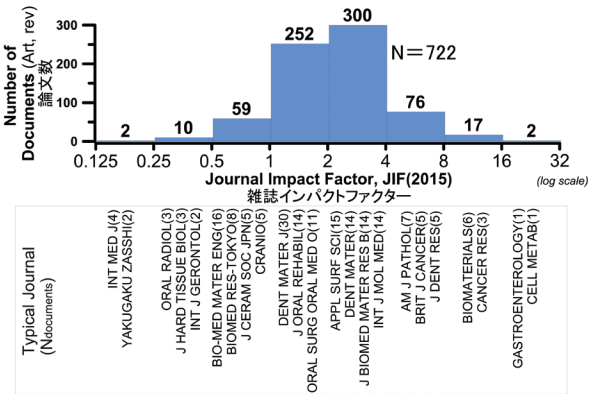

Fig. 11　Histogram showing the frequency of documents as a function of the journal impact factor intervals, which successively increase by a factor of 2 (i.e., 0.125-0.25, 0.25-0.5, etc.). The resulting distribution is approximately lognormal. Typical journals with varying IF ranges are shown.

order of the number of documents shown by the length of the vertical bars. There are 74 journals carrying 3 or more documents each, amounting to 466 documents (i.e., 64% of all). This graph gives an idea which journals are preferred most at HU-DENT. The graph at the middle, sharing the same horizontal axis as the lower one, shows the impact factor of each journal by the vertical bars. The individual bar in the upper graph represents the average of the citations per year acquired by documents appearing in the related journal. In general, visual inspection alone reveals the presence of good to excellent agreement between the journals with IF of about 3 or more and average citations per year of about 2 or more times. These HU-DENT documents published in IF journals have succeeded in being relatively well cited. In other words, submitting papers to high impact journals is a good strategy to enhance the overall citation impact. A good publication strategy would be to increase submitting manuscripts to those journals that plot to the right side of the histogram (Fig. 11) and proportionally reduce the submissions to those plotting in the left side (i.e., IF < 2). For journals indexed only in Scopus, data from which are used by 2 major university rankings mentioned later, one can use the value of CiteScore introduced by Elsevier (http://jp.elsevier.com/online-tools/scopus/citescore).

3. 4 Research Strengths and Bibliographic Community Detection by Science Mapping

According to the Essential Science Indicators database module, 3 papers (Li XM et al., Biomaterials 33(19) : 4818-4827 Jun 2012 ; Li XM et al., J Biomed Mater Res

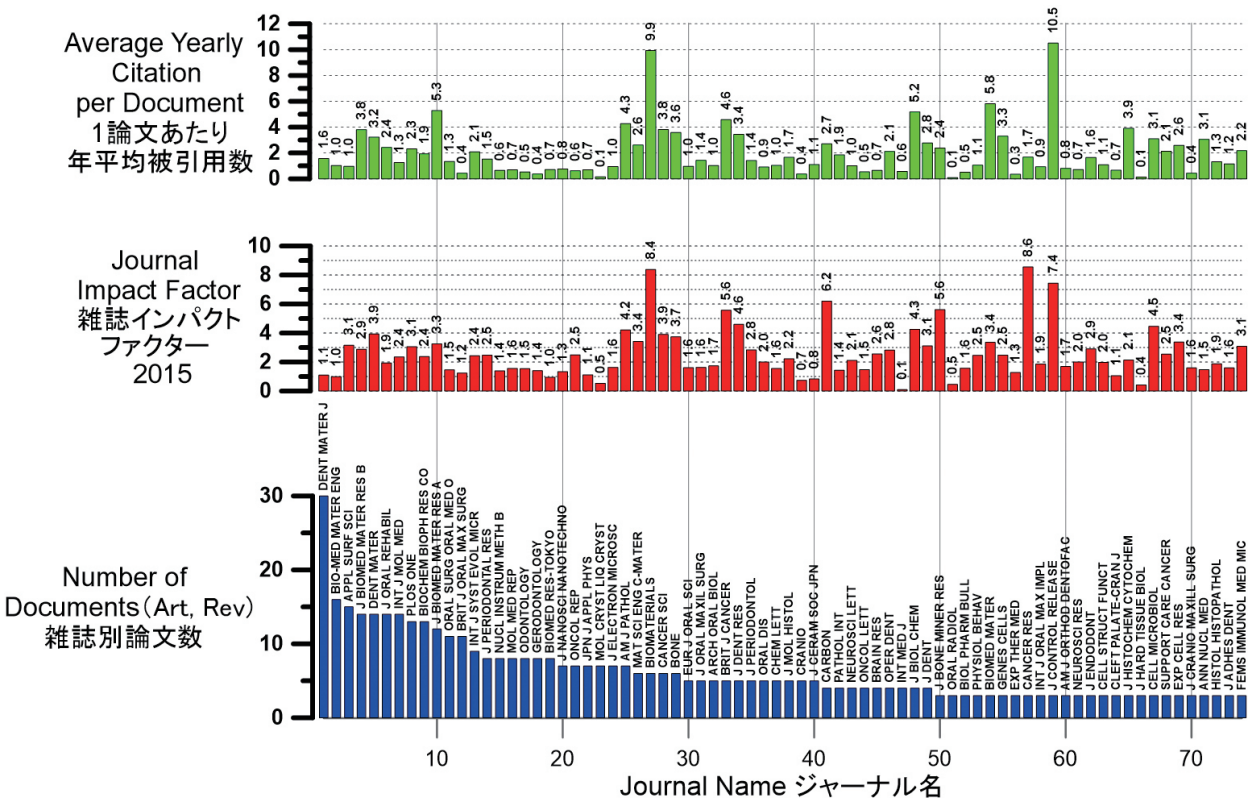

Fig. 12 Diagrams showing the relationship between the journal impact factor (IF) and average annual citation of documents appearing in 74 journals that carry 3 or more documents authored by Graduate School/Faculty/School of Dental Medicine. Articles appearing in high IF seem can be said to be well cited.

Part A 101(8) : 2424-2435 AUG 2013 ; and Hassan M et al., Biomed Res Int 2014) related to biomaterials exhibit very high impact (highly cited and hot papers). The first two constitute the research front labelled "ectopic bone formation ; bone tissue engineering ; human adipose-derived mscs ; carbon nanotubes ; nanostructured scaffolds". Interestingly, these 3 papers are internationally collaborative papers.

According to Elsevier's SciVal (an analytical tool for data recorded in Scopus database ; https://www.elsevier.com/solutions/scival (accessed 2014)) research on biomaterials (Authors : F Watari, T Akasaka, A Yokoyama, S Abe and others ; main keywords : graphene ; nanoparticles ; tissue engineering ; alloys ; scaffolds) shows sustained leadership of Hokkaido University for >10 years, with 2011-2013 period characterized by "distinctive competency". Other themes showing "emerging competencies" and appearing for more than twice (in different years) are : (i) dentin-bonding agents ; methacrylates ; adhesives (H Sano, S Inoue, N Kudo, T Ikeda and others), (ii) neck ; carcinoma ; squamous cell ; fluorodeoxyglucose F18, pet, lymph nodes (KI Notani, Y Yamazaki, Y Kitagawa, H Furukawa), and bruxism ; sleep ; tooth (A Tomonaga, H Izumi, T Arima, W Yachida). Research on "mastication ; tooth ; tooth loss" by N Inoue, A Morita and K Tei is another promising emerging competency.

The conceptual structure of the overall research, the research impact, the nature of international and domestic collaborations, the knowledge base of the research conducted, and the research fronts, etc., related to HU-DENT can be explored in detail through bibliographic data (e.g., meta-data from WoS output), and analytical tools that enable citation analysis and science mapping (e.g., co-word, co-citation, and bibliographic coupling analyses using various pieces of information such as terms, (co-)authors, cited items, citing items, institutions, countries. A word map constructed from the nouns or noun phrases occurring >10 times in the titles and abstracts of all publications in binary counting mode (occurrences counted only once) using VOSviewer visualization software (Van Eck & Waltman 2010) is presented in Fig. 13. Five clusters, each provided with a list of 10 significant words, represent the research themes pursued at HU-DENT.

In order to get further insights on the past research

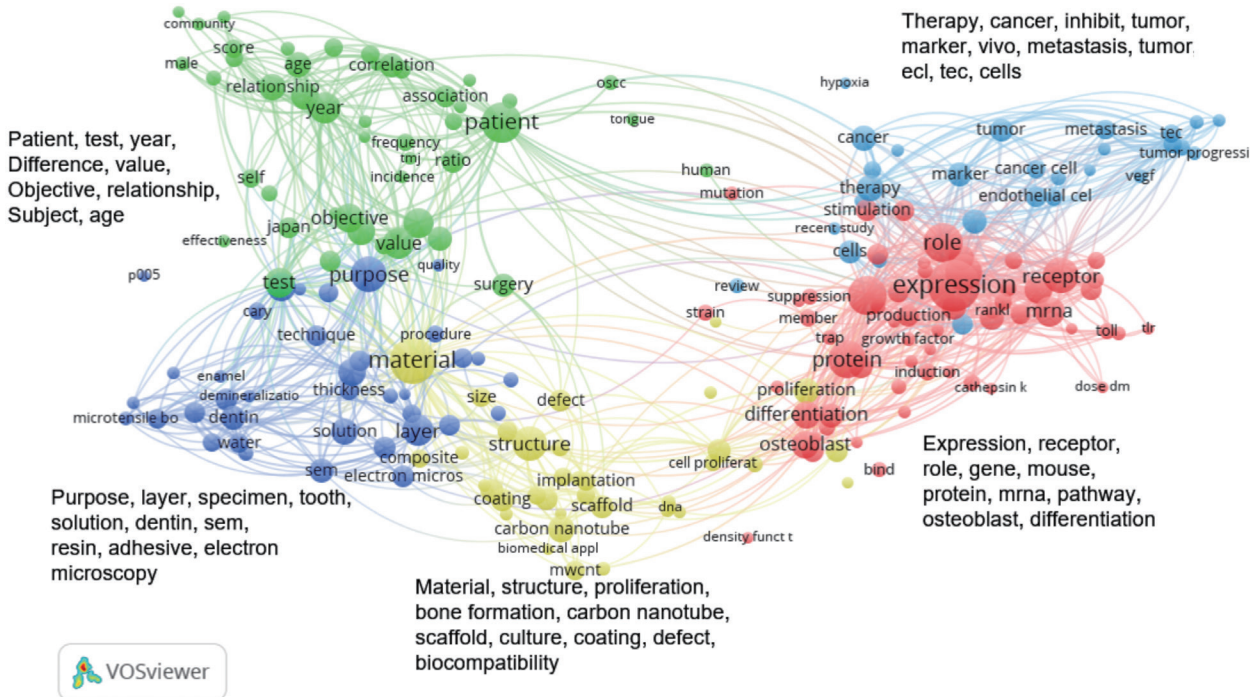

Fig. 13　Map of words (nouns or noun phrases) occurring in the titles and abstracts of the HU-DENT scientific publications (2006-2016). Size of the node (term) is proportional to the frequency of occurrence, while the edge (link) indicates their co-occurrence. For the 5-clusters, obtained by setting the term frequency to a minimum of 10, significant terms (up to 10) related to the research theme are listed.

Table 1　Bibliographic coupling communities detected from 711 HU-DENT publications

BC Community No.	Most frequent keyword	Most frequent author	Number of papers	Research theme (tentative)
1	IN-VITRO	Watari, F	96	Carbon nanotubes as tissue scaffolds
2	EXPRESSION	Amizuka, N	96	Bone cells expressions
3	ENAMEL	Sano, H	53	Enamel/dentin: effect of adhesives on bonding
4	IN-VITRO	Kuboki, Y	50	Periodontal ligament cells of bone
5	ABNORMALITIES	Hida, K	49	Cancer (endothelial cells) and abnormalities
6	INNATE IMMUNITY	Shibata, K	35	Toll-like receptors and immune responses
7	POPULATION	Inoue, N	32	Gerodontology
8	TEMPOEOMANDIBULAR DISORDERS	Svensson P	28	Temporomandibular (Jaw-muscle) joints disorders
9	CANCER	Shindo, M	27	Cancer and cells expressions
10	3'PROCESSINGENDORIBONUCLEASE	Tamura, M	24	Gene expressions of Bone Cells
11	IN-VIVO	Watari, F	18	Structural (physico-chemical) characterization of nanomaterials
12	HEAD	Kitagawa, Y	15	Oral cancer and squamous cells
13	IN-VITRO	Komatsu, H	15	Human enamel, fluorine uptake and nuclear analyses
14	MAXIMUM-LIKELYHOOD	Yumoto, I	13	Microbiological studies
15	CHILDREN	Iida, J	13	Cranio-facial surgery
16	NF-KAPPA-B	Wataha, J C	11	Dental cells
17	FUNCTIONAL ESSAY	Moriuchi, T	11	Oral carcinoma and cell expression

at finer scale, and also to reveal a more comprehensive picture on the research communities in terms of diverse items other than the disciplines and citations, this study attempts to explore the bibliographic coupling (BC) method to extract the BC communities (Grauwin & Jensen 2011). There are three reasons for application of this method : (i) It makes the use of all documents irrespective of cited or not after publication ; (ii) The result is the form of a set of community cards grouping diverse items (author & publisher keywords, subject categories (WoS 251 SCs), publication sources, institutions of affiliation of authors, publication sources in references, and countries of locations of institutions) characterizing a large number of research themes/topics ; and (iii) Free availability of BiblioTools software (http://www.sebastian-grauwin.com) for rapid analysis.

Processing the bibliographic data parsed into individual items by Louvain algorithm limiting to 10 documents at minimum yielded 17 ID cards, each representing a BC community. A short summary of these ID cards is given in Table 1. Two largest communities, each with 96 documents, are related respectively to carbon nanotubes

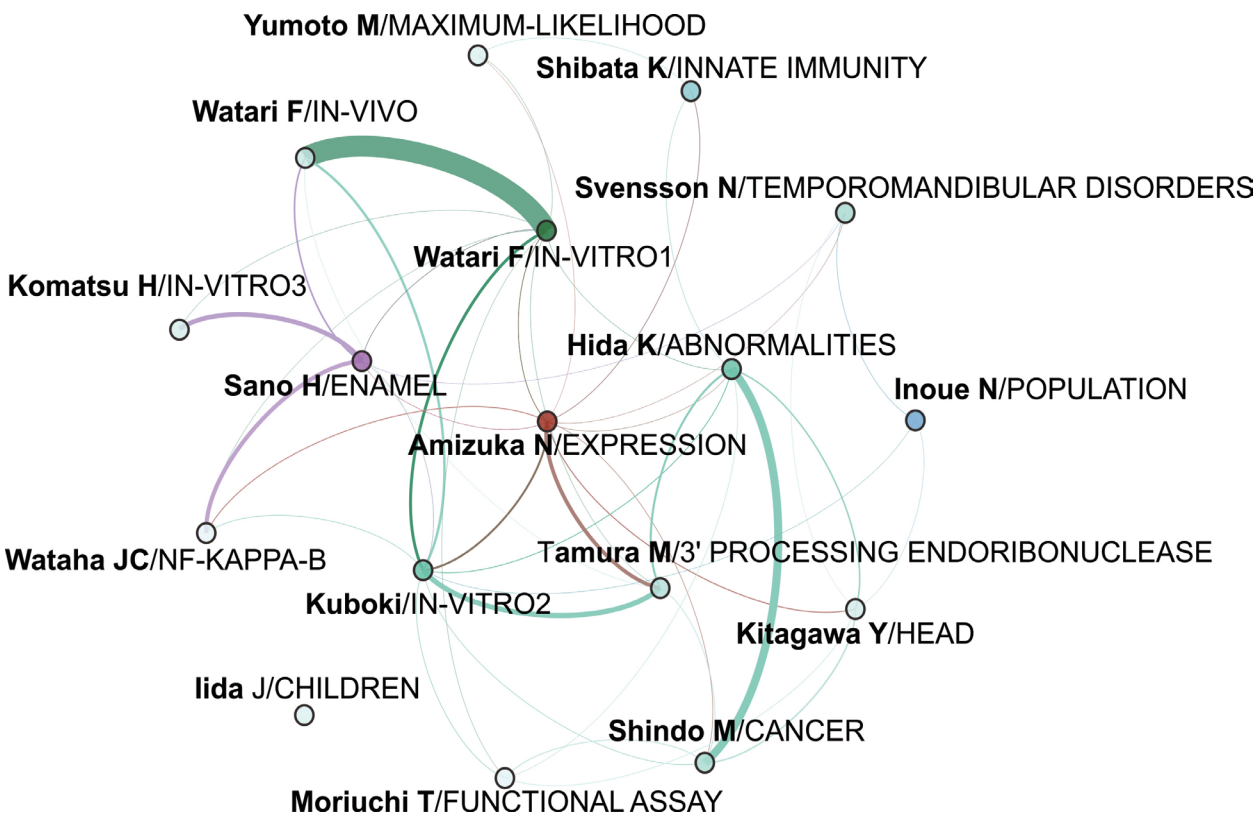

Fig. 14 Network of 17 bibliographic coupling communities (each identified by node with most frequently occurring author/keyword) detected from the HU-DENT 2006-2015 publications using the Biblio Tools software. The thickness of arcs connecting the nodes is proportional to the strength of the link between them. For a list of these BC communities, with minimum of 10 documents, refer to Table 1. Drawn by Gephi 0.9.1 open source software.

as tissue scaffolds and bone cells expressions. The third largest community with 53 documents is related to the theme dealing with enamel and dentin. Fig. 14 is a network map showing the relationship among these different communities. Two communities (BC1 and BC11), with the same lead author and nanoscale/nanomaterials theme, have the strongest link as shown by the thick edge connecting them, whereas BC15 related to children and cranio-facial surgery seems to be rather isolated. A pdf file comprising the 17 ID cards is available for download from the following link : https://www.den.hokudai.ac.jp/fd/

4. World University Rankings and The University Research Capacity

Many world university ranking (WUR) systems and models used to compare the universities are largely based on scientific output (bibliometric) measures and indicators (Moed & Halevi 2015). The "Academic Ranking of World Universities" (ARWU) is produced by the Centre of World Class Universities at Shanghai Jiao Tong University. It provides a list of world top 500 universities ranked by 'combining bibliometric data from Thomson Reuters with data on prizes and awards of current and former academic staff or students' (Moed 2016) without relying on questionnaire surveys or university-supplied data that have some subjectivity. On the other hand, the "Times Higher Education (THE) WUR" and "Quacquarelli Symonds (QS) WUR" try to use a multilevel approach combining the quality and prestige of higher education institutions as perceived by opinion polls of academics alone or also employers, institutional data indicative of research and teaching environments including international outlook, bibliometric data as indicators of research output and impact, and to some extent also the social and economic impact data to assess the universities for performance and to rank them. THE WUR (2016-2017) lists 980 institutions from 79 countries and ranks 801 universities from 70 countries, whereas the latest QS WUR 2018 places almost 1,000 universities in the ranking system and consider many more for inclusion.

According to the latest WUR data, HU is ranked 122 in QS WUR, 151-200 in Shanghai ARWU, and 401-500

in THE WUR. The large discrepancies in the overall ranking position of HU and also other universities from Japan are due to the differences in the ranking indicators, the ways they are calculated (using different databases and survey questionnaires), normalized (country, regional or disciplinary adjustments ; use of cut-offs or thresholds; normalizing by maximum, or using percentile ranks with or without adding an exponential component), and weighted while combining into an integrated score used to form the respective league tables (Moed, 2016).

In general, universities in non-English speaking countries (e.g., Japan, South Korea, Taiwan, China) seem to be evaluated higher in terms of the research-related citation impact scores by QS than THE and therefore ranked better by the former. There is an increasing consensus these days that the use of a single aggregated score combining the seemingly unrelated indicators through arbitrarily assigned weights to construct the league table and rank universities with differing missions is questionable. However, there seems to be general agreement that individual indicators, especially the raw values (which are unfortunately not easily available), can be used to place one's university relative to the other universities of similar scale, environment, disciplinary orientations and missions globally. Moed (2016) performed an overlap analysis of 5 ranking systems (ARWU, THE, QS, Leiden I and Leiden II) and concluded that there is no such set as 'the' top 100 universities in terms of excellence, as he found only 35 institutions to appear in the top 100 lists of all 5 systems. Accordingly, he opined that governments aiming to put their universities in the 'top' of the ranking of world universities should specify the ranking system to be used as a standard and give the reasons for the selection. As HU has been executing the Top Global University Project "Hokkaido Universal Campus Initiative – Collaborate with the World" since FY2014 (JSPS, 2017) and it aims at drastically improving own ranking status through integrated efforts for enhanced reputation, research impact, and internationalization by the time it approaches its 150th anniversary in 2026, an integrated approach and effort to address all these aspects is required.

In order to give an idea about the position of HU among the top research-intensive and prestigious universities in Japan, two diagrams comparing the scores of latest indicators in THE and QS rankings are presented in Figs. 15 & 16, respectively.

In the case of QS WUR, reputation alone is given 50% total weight: 40% for (i) Academic Reputation based on expert opinions of academics in the higher education regarding teaching and research 'quality' at the world's universities, and 10% for (ii) Employer Reputation based on the opinions of employers (both international and domestic contribution 50% each) regarding the institutions from which they source the most competent, innovative, effective graduates. The remaining 50% weight is allocated to teaching quality (20%), measured indirectly by the (iii) Faculty/Student Ratio, research output (20%) measured by (iv) Citations per Faculty, calculated using the average number of Scopus-based field-normalized citations (excluding self-citations) obtained by papers (published during 5 years) during 6 years (publication period plus one additional year) time span per faculty, the ability to attract international faculty (5%) measured by (v) International Faculty Ratio, and ability to attract international students (5%) measured by (vi) International Students Ratio. Regarding the Citations per Faculty indicator, QS seems to apply also the faculty area normalization to ensure that universities specialized in areas with high production and citation practices are not unduly advantaged (QS 2017). The six indicators are claimed by QS to be 'simple' metrics meant to effectively

Benchmarking Research Universities (RU11) -1

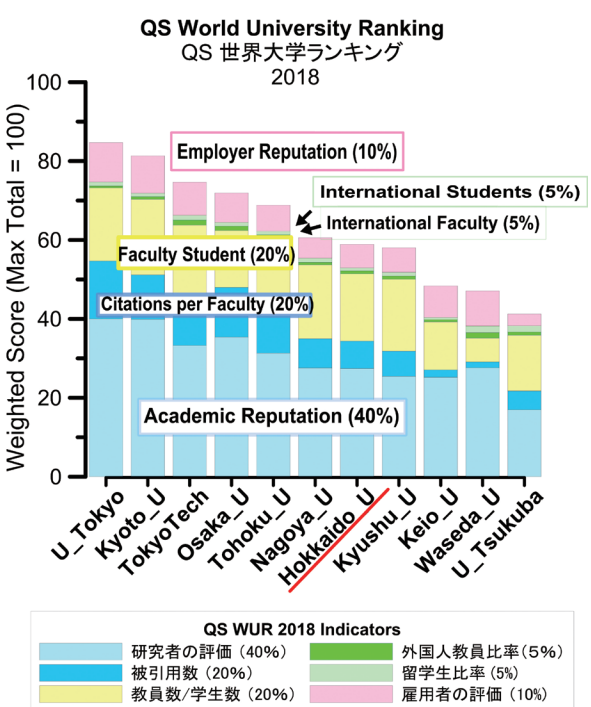

Fig. 15　Positioning of Hokkaido University among the Japanese Research Universities (RU11) by QS World University Ranking (WUR) Indicators

capture university performance. In Fig. 15, HU is in 7th position lying between Nagoya University and Kyushu University ; the former has slightly higher Citation per Faculty score than HU, whereas HU has slightly better Academic Reputation score than the latter such that the differences between at least these three institutions are rather small.

In the case of THE WUR, there are 13 different or 'simple' metrics (THE 2016), of which the Citation per Paper indicator related to the research impact (30% weight), similar to some extent to QS's Citation per Faculty indicator (though of just 20% weight), is the single most influential. The Industrial Income (2.5% weight) indicator seeking to capture the ability of university to attract funding from industry as a proxy of the degree of innovation-related knowledge transfer to industry and scaled against the academic staff is another simple metric. Research (30% weight) is a complex and so-called pillar metric that combines 3 different indicators (reputation determined through survey of academics, research income, and research productivity) variously weighted and mathematically transformed from raw values to scores. Likewise, Teaching (30% weight) is a pillar made up of 5 indicators (research reputation based on opinion polls of academics, staff-to student ratio, doctorate-to-bachelor's ratio, doctorates-awarded-to-academic-staff ratio, and institutional income) as indirect indicators of the teaching environment. The International Outlook (7.5% weight), another pillar metric for university's internationalization, is similar to QS's two international indicators but it includes one more aspect related to the degree of international co-authorship in scientific publications. The problem with these pillar metrics data (scores easily available) is that the aggregated score of each pillar provides very little information to the performance captured by individual indicators (data sold in package). According to the THE WUR scores in Fig. 16, HU is in 8th position among RU11, and here it lies in between Kyushu University (with slightly better citation impact) and University of Tsukuba, all of which have small differences in the overall scores.

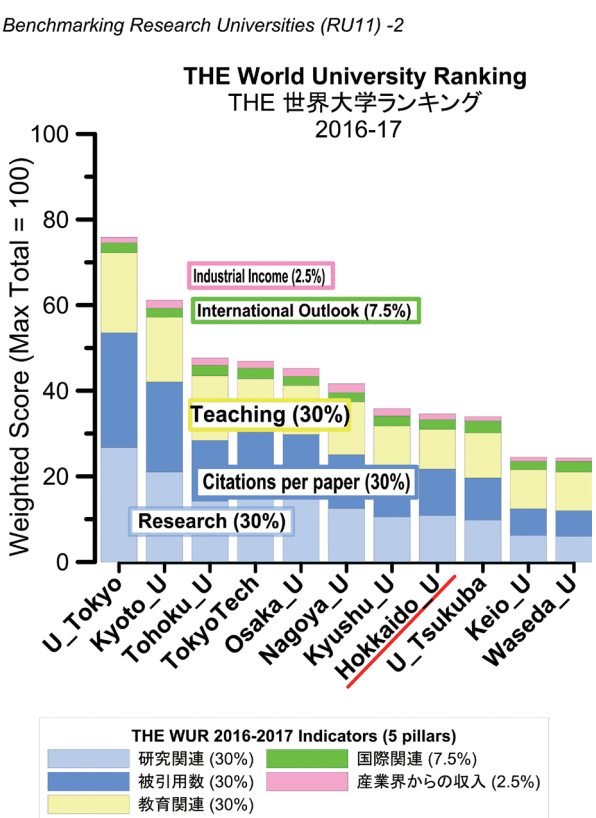

Fig. 16 Positioning of Hokkaido University among the Japanese Research Universities (RU11) by Times Higher Education (THE) World University Ranking (WUR) Indicators

5. Concluding Remarks

This paper briefly described a bibliometric analysis of 10-yrs long research output represented by 29,565 documents indexed as the journal articles & reviews in WoS Core Collection at the level of whole university (HU) and a subset of 726 documents attributed to one of its constituent department (HU-DENT). The purpose of this study was to understand the actual status of research output through analysis of meta-data contained in the bibliographic records as well as show the citation-based analysis combined with science mapping techniques, the latter being briefly demonstrated at the departmental level. Such analysis is believed to be more and more important in future in connection with the increasing tendency to use objective data for internal and external assessments, benchmarking with peers and many other purposes. As bibliometric data are extensively used in university rankings (world, regional, and national) in the form of various indicators, such analysis helps in understanding the university's performance in various rankings and using the indicators for better strategic planning.

The discussion on rankings showed that world university rankings use a number of indicators to capture the diverse missions (education, research, links with the business sector), employability of graduates, internationalization, prestige and so on to assess their

'performance'. The data collected by WUR systems for such purpose, however, are those collected with ease from the universities and employers worldwide directly or through surveys and also from the databases currently available, expressed in numbers, and combined in various ways in the form of metrics and scores to create tables so as to enable users to benchmark themselves. Universities themselves should carefully and critically examine the ranking scores, weights assigned to each simple indicators, and related raw data as far as possible and wisely use them for benchmarking and other purposes directed at improvements of their own academic setting and performance.

It was shown that a number of ranking indicators use the results of the university's total research output or related aspects, such as the number of scientific publications, citation impact, and international co-authorship. Each university researcher (faculty, post-doctoral fellow, graduate student) can directly contribute to improvements (e.g., engagements in internationally collaborative research leading to publishing in high impact journals) in different aspects and thus contribute to better performance in university rankings. As a participant of the Top Global Project and promoter of the Hokkaido Universal Campus Initiative, HU has been executing many programs to enhance the overall research capacity, internationalization, ranking performance and so on. It is the author's belief that awareness towards the current trends in research and education and targeted actions by each university researcher will result in the enhancement of the performance at all scales (i.e., researcher, department and university levels).

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