Eur J Oral Sci 2006; 114: 102–108
Printed in Singapore. All rights reserved

European Journal of
Oral Sciences

World dental research production: an ISI database approach (1999–2003)

Jose Antonio Gil-Montoya[1], Jose Navarrete-Cortes[2], Rosa Pulgar[1], Samaly Santa[2], Felix Moya-Anegón[2]

[1]Faculty of Dentistry; [2]Faculty of Biblioteconomy and Documentation, Granada University, Granada, Spain

Gil-Montoya JA, Navarrete-Cortes J, Pulgar R, Santa S, Moya-Anegón F. World dental research production: an ISI database approach (1999–2003). Eur J Oral Sci 2006; 114: 102–108. © 2006 The Authors. Journal compilation © 2006 Eur J Oral Sci

The objective of this study was to obtain a geographic world map of scientific production in dentistry by analysing published papers. Articles and reviews in the Dentistry, Oral Surgery & Medicine category published from 1999 to 2003 were accessed through the ISI database. The data were analyzed quantitatively (number of documents, number of researchers, productivity, interannual variation rate and relative specialization index), qualitatively (weighted impact factor, relative impact factor, citation rate per document and top 5 publications) and socioeconomically (number of documents per inhabitant and per dentist and in relation to the country's GDP). The USA, UK, Japan and Scandinavian countries were found to be the most productive countries (number of publications). Publications from Scandinavian countries were also of high quality as measured by Impact Factor and Citation Rate, while the UK had one of the highest productivity rates (number of documents per researcher).

Dr José Antonio Gil-Montoya, Facultad de Odontologìa, Paseo de Cartuja s/n, 18071 Granada, Spain

Telefax: +34–95–8243796
E-mail: jagil@ugr.es

Key words: biomedical research; dentistry; impact factor; bibliometric.

Accepted for publication July 2005

The analysis of scientific research in biomedical fields is a complex process and no methodology has been developed that fully satisfies the needs of researchers, institutions and administrators. The analysis of publications is one of the most widespread approaches but has also drawn the most criticism (1–3). The qualitative evaluation of scientific publications as the direct output of research is usually performed in one of two ways: by the number of citations (4) or by the Impact Factor (IF) published by the Institute for Scientific Information, ISI (Philadelphia, PA, USA). Despite the many critics of IF (5, 6), there is no other assessment system so widely accepted by the scientific community and by academic administrators. Criticisms of the use of the IF in dentistry have focused on the 2-year period required for its evaluation in a field with a slow turnover and the difficulty of its application in a field containing multiple disciplines. Questions have also been raised about the relative importance of the number of citations in determining the IF (3).

Despite the above drawbacks, there has been considerable interest in the analysis of publications in general biomedical research and in the ranking of countries according to their production, which has shown some countries in the EU and Asia and some states in the USA as frontrunners (7–11). However, no objective data have been published to determine whether research in the field of dentistry follows the same order. Analysis of research outcomes may help inform the development of scientific and technological policies in dentistry, of especial relevance in emerging countries (e.g. China, Thailand, South Korea, Brazil) and in the EU, currently undergoing major reorganization.

The present study was designed to depict the international geographic dimension of dental research by recording and analysing scientific production in this field across different countries.

Material and methods

The database selected for the analysis of dental research productivity was the ISI Web of Science (WoS), using the Science Citation Index Expanded (SCI-E). Further information was also gathered on journals covered by the ISI from 1999 to 2003 and contained in the Journal Citation Report (JCR) database. JCR presents quantifiable statistical data that provide a systematic objective way to evaluate the world's leading journals and their impact and influence in the global research community.

Using the above sources of information, all bibliographic references were gathered from papers published in the 52 journals included in the 'Dentistry, Oral Surgery & Medicine' category throughout the 5-year period 1999–2003. Only documents classified as '*Article*' or '*Review*' in the '*document type*' field were selected. References from countries that published fewer than 20 papers in the 5-year study period were excluded from the study.

The data gathered were entered into an *ad hoc* database that integrated and interrelated the information in a manner that allowed simple, flexible and rapid analysis using different bibliometric indicators (12, 13). Table 1 lists the indicators selected for application in the present study. Software based on Microsoft Access was specifically developed for loading, modelling and managing information from the ISI database.

A multiple count approach was taken to documents written by authors from more than one country; the document and Correspondence(s) were assigned to all

Table 1
Analyzed indicators

Indicator	Explanation	Formula
Quantitative dimension		
Ndoc (N° Documents): N° of publications of *Article* and *Review* assigned to each country.	The origin of documents is assessed using the *addresses* field. A document signed by authors from different countries is assigned to each country with equal value.	$\text{Ndoc} = doc_1 + doc_2 + doc_n$
Nres (No. of Researchers): Total number of signing authors assigned to a country.	All signing authors are assigned to their country, regardless of the country of origin of the document.	$\text{Nres} = Nres_1 + Nres_2 + Nres_n$
Prod (Productivity): Number of publications per researcher assigned to a country.	Productivity is calculated by dividing the number of documents assigned to a given country by the number of researchers assigned to that country, allowing comparison between countries with different human resource levels.	$\text{Prod} = \frac{Ndoc}{Nres}$
MIVR (Mean Interannual Variation Rate): Percentual average increase during study of the productivity and the number authors of a country.	The Interannual Variation Rate shows the percentage variation in the productivity or number of authors of a country with respect to the previous year. This indicator was calculated for each studied year. The MIVR is the mean value for the 5-year study period for both the number of documents (*MIVR*/Ndoc) and the number of researchers (*MIVR*/*Nres*).	$MIVR/Ndoc_n = \frac{ndoc_n - ndoc_{n-1}}{ndoc_n} * 100$ $MIVR/Nres_n = \frac{nres_n - nres_{n-1}}{nres_n} * 100$
RSI (Relative Specialization Index): Specific weighting of the dental scientific production of a country in relation to its general scientific production.	The Dentistry Specialization Index (SI) of a country is the ratio of dentistry documents to the total scientific production of a country. The RSI was calculated by dividing the SI of a country by the mean SI of our sample. It therefore reflects the relative activity of a country in a field. i.e. its specialization level, and shows the relative effort put into the discipline.	$RSI_{cat1} = \frac{Ndoc_{cat(Country)} / \sum Ndoc_{(Country)}}{Ndoc_{cat(Series)} / \sum Ndoc_{(Series)}}$
Qualitative dimension		
WIF and RIF (Weighted and Relative Impact Factor).	The Total Impact (TI) of a country is the sum of the impact factors of each document affiliated to a given country. The WIF is the ratio of the TI to the total number of documents of that country. The RIF is the ratio of WIF of the country divided by the WIF of our sample, showing the distance of each country from the mean World Impact.	$RIF = \frac{WIF_{Country}}{WIF_{World}}$ $WIF = \frac{TI_{Country}}{Ndoc_{Country}} \quad TI = \sum(Ndoc * IF)$ (TI = Total Impact)
Ncit/doc: Mean Citation Rate for each document.	This expresses the sum of the citations received by all documents from a given country from 1999 to April 2004. Dividing this figure by the total number of documents gives the mean citation rate of documents from country.	$Ncit/doc = \frac{\sum Ncit_{Country}}{\sum Ndoc_{Country}}$
NTop5: Number of documents from a country in the five JCR journals with highest impact factor.	This indicator gives rise to the '%NTop5', the percentage of documents published in the 'top 5′ with respect to the total number of documents of a country, and the ''%NTop5-sample'', the percentage of documents from the 'top 5′ with respect to the total number of documents in our sample.	$\text{NTop} = doc\ 1_{rank\ 1-rank\ 5} + doc\ 2_{rank\ 1-\text{rank}\ 5} + docn_{rank\ 1-rank\ 5}r$

countries appearing in the 'address' field. Since the workload of each researcher was not known, it was considered the most unbiased way to consider the efforts of each country (13). Moreover, this method also measures a country's capacity to attract foreign researchers and thereby increase its human resources for scientific research.

We also performed an analysis of citations in journals that could be considered of scientific excellence, using as criterion its position at some point in the 5-year period within the first decile of the 'Dentistry, Oral Surgery & Medicine' category (1). The following publications were included in this category: *Caries Research*, *Clinical Oral Implants Research*, *Critical Reviews in Oral Biology and*

Medicine, *European Journal of Oral Sciences*, *Journal of Clinical Periodontology*, *Journal of Dental Research*, *Journal of Orofacial Pain*, *Journal of Periodontology Dental Materials*, *Oral Oncology*, *Periodontology 2000*. The leading top five journals in any year of the study were noted and designated '*top5*'.

Production data were analysed in relation to the number of inhabitants of the country and continent, the number of dentists and the Gross Domestic Product (GDP). These data were obtained from the World Bank Group (*http://www.worldbank.org*) and the FDI World Dental Federation (*http://www.fdi.org*) for 2000–02.

Results

Quantitative analysis of scientific production

Inclusion criteria were met by 20,121 documents; 217 of these were excluded because the country produced fewer than 20 documents (e.g. Yugoslavia, Portugal and Iceland), or because no country appeared in the 'addresses' field. Therefore, 19,904 documents were included in the final study, 19,248 original articles and 656 review articles. Forty-one countries (our sample) published more than 20 articles during the 5-year period.

Table 2

Results of each indicator

	Quantitative dimension						Qualitative dimension			
Country	Ndoc	Nres	Prod	MIVR/ *N*doc	MIVR/ *N*res	RSI	WIF	RIF	*N*cit/ *N*doc	*N*Top5
Total of the sample*	19904	38721	0.514	− 0.82	3.07	1.00	1.06	1.0	2.36‡	1264
Distribution by country†										
1. USA	6779	12032	0.563	− 4.96	− 0.55	1.071	1.078	1.013	2.75	466
2. United Kingdom	2667	4387	0.608	− 3.48	− 0.79	0.838	0.998	0.938	2.37	117
3. Japan	2442	4296	0.568	2.8	3.83	1.07	1.138	1.070	2.39	184
4. Germany	1218	2351	0.518	4.71	8.39	0.54	1.109	1.042	2.71	80
5. Sweden	925	1612	0.574	− 7.41	− 3.66	1.875	1.136	1.068	3.15	75$
6. Brazil	826	1860	0.444	24.67	24.79	2.107	1.056	0.993	1.87	36
7. Italy	720	1459	0.493	− 0.28	− 0.74	0.657	1.181	1.110	2.42	74
8.Turkey	596	1161	0.513	29.56	24.27	2.571	0.9	0.846	1.27	15
9. The Netherlands	568	1104	0.514	− 1.7	0	0.852	1.302	1.224	3.08	71
10. Canada	553	1193	0.464	− 9.83	− 6.8	0.435	1.164	1.094	3.17	45
11. Australia	520	959	0.542	9.93	6.87	0.675	0.919	0.864	2.59	23
12. Israel	471	776	0.607	0.72	0.8	1.248	1.031	0.969	2.26	27
13. China	390	808	0.482	35.35	32.92	0.383	1.037	0.978	2.08	20
14. Switzerland	383	768	0.499	1.89	6.93	0.822	1.246	1.171	3.61	40
15. Finland	367	800	0.459	1.95	4.36	1.537	1.175	1.104	2.75	31
16. France	354	928	0.381	− 7.72	0.31	0.225	1.154	1.085	2.82	31
17. Norway	341	603	0.566	0.66	6.97	2.087	1.106	1.040	2.81	21
18. Denmark	335	572	0.586	− 1.16	− 3.32	1.245	1.187	1.116	3.14	31
19. Spain	283	858	0.330	1.41	3.82	0.369	1.09	1.024	2.18	24
20. Hong Kong§ (Ch)	282	409	0.689	11.49	18.41	1.490	1.06	1.0	2.75	14
21. Taiwan	279	497	0.561	7.91	15.82	0.87	1.112	1.045	2.39	23
22. Korea	266	615	0.433	35.47	32.74	0.548	0.962	0.904	1.76	13
23. Belgium	230	517	0.445	− 1.61	1.36	0.656	1.163	1.093	4.20	22
24. Austria	212	360	0.589	8.51	8.97	0.838	0.977	0.919	2.55	15
25. Greece	201	468	0.429	16.25	30.27	1.136	0.919	0.864	2.02	2
26. India	132	366	0.361	16.31	11.01	0.241	1.025	0.964	2.05	9
27. Thailand	132	353	0.374	29.1	46.52	2.862	1.093	1.028	1.90	8
28. Singapore	115	229	0.502	23.22	24.87	0.918	1.064	1.000	1.99	3
29. South Africa	113	235	0.481	0.36	− 2.77	0.869	0.999	0.939	1.63	5
30. New Zealand	95	163	0.583	17.98	4.3	0.633	1.104	1.038	2.22	5
31. Saudi Arabia	83	164	0.506	25.12	35.95	1.849	0.931	0.875	1.43	1
32. Jordan	77	133	0.579	34.25	28.66	4.219	0.972	0.913	1.21	1
33. Iran	57	99	0.576	38.51	51.42	1.039	0.764	0.718	0.95	0
34. Hungary	54	140	0.386	− 7.12	− 4.7	0.404	1.155	1.086	3.48	2
35. Argentina	52	142	0.366	− 4.1	− 1.69	0.351	1.058	0.994	1.65	3
36. Poland	47	136	0.346	7.77	15.41	0.145	1.041	0.978	2.70	1
37. Croatia	43	117	0.368	24.79	24.01	1.056	0.9	0.846	1.19	0
38. Mexico	41	143	0.287	1.08	4.19	0.181	1.252	1.177	2.12	6
39. Chile	38	113	0.336	− 13.07	− 14.77	0.546	1.079	1.014	3.08	3
40. Nigeria	34	58	0.586	19.17	11.25	1.499	0.901	0.847	1.71	1
41. Slovenia	31	53	0.585	− 12.99	− 15.1	0.659	1.177	1.106	2.23	4

*Value of indicator for global sample.
†Value of indicator for each country after multiple count (using the multiple count method, total values of the indicator for each column do not correspond to total value for the overall sample).
‡Mean citation rate per document for countries in our sample.
§In accordance with ISI affiliation criteria and because of their large scientific production, Hong Kong is not included in the total production of China.

Table 2 shows the results for each indicator in the overall sample and in selected countries, applying the multiple count system described in Material and Methods. Countries are ordered according to the number of publications in the ISI (*N*doc). The USA, UK and Japan had the highest number of publications and together accounted for more than 60% of the production of the overall sample.

Table 3 shows the 20 top-ranking countries in terms of number of documents per million people (led by Sweden and Norway), number of documents per dentist (led by Hong Kong and Singapore), productivity (led by Hong Kong and the UK) and number of documents in relation to GDP (led by Jordan, Israel and Sweden). Table 4 shows the distribution across continents, with Europe contributing 40% of the total production of our sample, followed closely by North America.

The Mean Interannual Variation Rate (MIVR) of our sample in relation to the number of documents produced was almost zero, with a small (3%) increase in signing authors over the 5-year period (Table 1) (Fig. 1). The MIVR score for the number of publications (MIVR/*N*doc) ranged from an increase of 38.51% in Iran to a decrease of 13.07% in Chile, while the MIVR for researchers (MIVR/*N*res) ranged from an increase of 51.42% in Iran to a decrease of 15.1% in Slovenia. Among the five highest producing countries, only Germany and Japan increased their number of publications and signing authors.

Calculation of the Relative Specialization Index (RSI) showed that Jordan had the highest dental research production in relation to its general scientific production. Among countries with major dental research production, the highest RSI values were shown by Scandinavian countries (Norway, Sweden, Finland and Denmark), Turkey, Brazil and Hong Kong (Table 2).

Qualitative analysis of scientific production

Figure 2 depicts the results for Weighted Impact Factor (WIF) and citation rate per document (*N*cit/*N*doc) by country. The Netherlands (1.302), Mexico (1.252), Switzerland (1.246), Denmark (1.187), and Italy (1.181) were the top-ranking countries, while Greece (0.919), Nigeria (0.901), Turkey (0.9), Croatia (0.9), and Iran (0.764) were at the bottom. The mean WIF score in our sample was 1.064. The Relative Impact Factor (RIF) (Table 2), which allows the WIF of a country to be placed in relation to the whole sample, showed the same order, with the Netherlands (1.224), Mexico (1.177), Switzerland (1.171), Denmark (1.116), and Italy (1.110) as the top-ranking countries.

The mean number of citations per document was 2.36 in the sample (Table 2 and Fig. 2). The country with the highest citation rate was Belgium (4.20 citations per document), followed by Hungary (3.48), Switzerland (3.61), Canada (3.17), and Sweden (3.15). Iran (0.95), Croatia (1.19), Jordan (1.21), Turkey (1.27) and Saudi Arabia (1.43) had the lowest mean citation rates.

Table 5 lists the top-ranking countries in terms of the number of publications in journals of scientific excellence (*N*top5). The highest percentage of documents published in the top five journals with respect to total production (%*N*top5) during the 5-year period came from Mexico,

Table 3

Twenty top-ranking countries in terms of number of documents per million population, number of documents per dentist, and the number of documents per million dollars (US) of GDP

Country	Ndoc/Mill population	Country	Ndoc/ dentist*	Country	Prod†	Country	Ndoc/ GDP‡
5. Sweden	103.35	20. Hong Kong, Ch	0.164	20. Hong Kong, Ch	0.689	32. Jordan	0.0078
17. Norway	74.78	28. Singapore	0.126	2. UK	0.608	12. Israel	0.0045
12. Israel	70.51	14. Switzerland	0.106	12. Israel	0.607	5. Sweden	0.0031
15. Finland	70.44	2. UK	0.095	24. Austria	0.589	8.Turkey	0.0025
18. Denmark	62.27	32. Jordan	0.078	18. Denmark	0.586	15. Finland	0.0023
14. Switzerland	52.18	15. Finland	0.076	40. Nigeria	0.586	20. Hong Kong, Ch	0.0018
2. UK	44.99	9. The Netherlands	0.073	41. Slovenia	0.585	6. Brazil	0.0017
20. Hong Kong, Ch	41.19	18. Denmark	0.072	30. New Zealand	0.583	18. Denmark	0.0016
9. The Netherlands	35.04	5. Sweden	0.068	32. Jordan	0.579	17. Norway	0.0015
28. Singapore	27.06	30. New Zealand	0.066	33. Iran	0.576	37. Croatia	0.0015
24. Austria	26.34	17. Norway	0.065	5. Sweden	0.574	2. UK	0.0015
11. Australia	26.14	12. Israel	0.062	3. Japan	0.568	28. Singapore	0.0013
30. New Zealand	23.75	11. Australia	0.061	17. Norway	0.566	30. New Zealand	0.0012
1. USA	23.29	24. Austria	0.055	1. USA	0.563	14. Switzerland	0.0012
23. Belgium	22.24	1. USA	0.039	21. Taiwan	0.561	41. Slovenia	0.0012
3. Japan	19.20	8. Turkey	0.038	11. Australia	0.542	25. Greece	0.0012
25. Greece	18.82	23. Belgium	0.033	4. Germany	0.518	9. The Netherlands	0.0011
10. Canada	17.48	10. Canada	0.030	9. The Netherlands	0.514	11. Australia	0.0010
41. Slovenia	15.82	3. Japan	0.029	8. Turkey	0.513	27. Thailand	0.0009
4. Germany	14.75	41. Slovenia	0.027	31. Saudi Arabia	0.506	24. Austria	0.0008

The number preceding each country indicates its position in the Ndoc column in Table 2.
*Number of dentists in Taiwan is not known.
†'Prod': Productivity: number of documents per signing authors.
‡Value of Gross Domestic Product in millions of US dollars.

Table 4

Distribution of number of publications across continents during 1999–2003

Continent	Total no. of documents (%)	No. of documents per million inhabitants
Europe	8,717 (39 7)	12.02
North America	7,245 (33.0)	24.72
Asia	4,351 (19.8)	1.25
South America and Caribbean region	915 (4.2)	1.89
Australia and Oceania	607 (2.8)	21.67
Africa	147 (0.7)	0.20

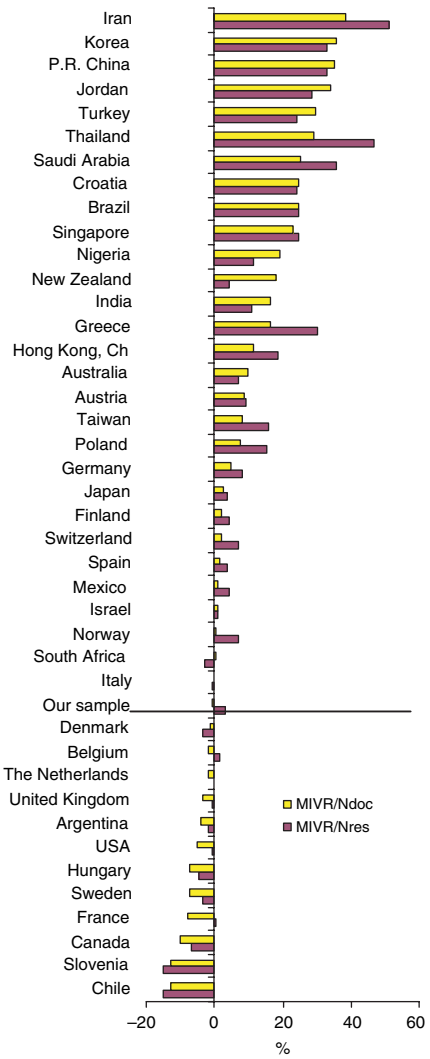

Fig. 1. Comparison among Mean Interannual Variation Rates of production and number of authors in different countries

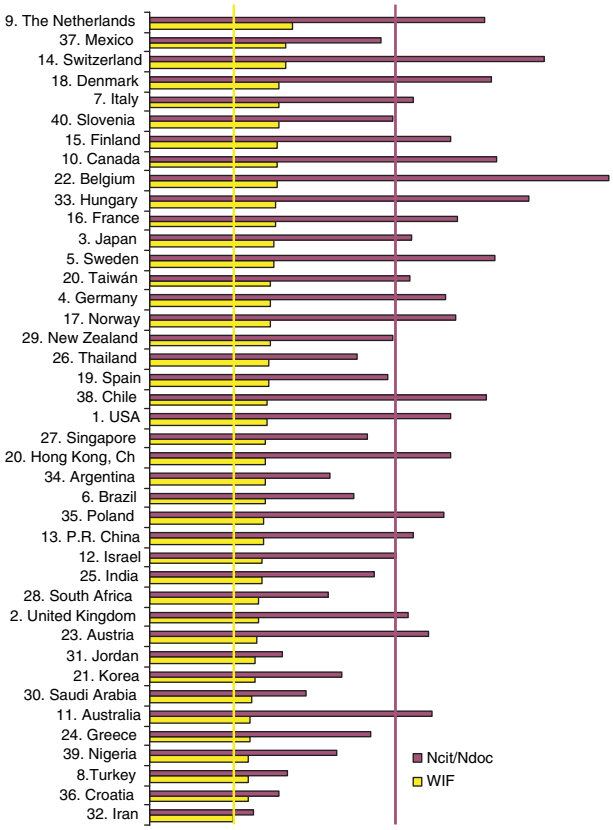

Fig. 2. Graphic representation of the Weighted Impact Factor and the Mean Citation Rate per article and per country (the light vertical line shows the WIF of the sample, 1.06, and the dark line shows the Mean Citation Rate per document of the sample, 2.36). The number preceding each country indicates its position in the Ndoc column in Table 2.

Table 5

Ten top-ranking countries in terms of percentage of documents published in top five JCR journals with respect to their total production and to total world production

Countries	%NTop5	Countries	%NTop5–Sample
38. Mexico	14.63	1. USA	2.34
41. Slovenia	12.90	3. Japan	0.92
9. the Netherlands	12.50	2. United Kingdom	0.59
14. Switzerland	10.44	4. Germany	0.40
7. Italy	10.28	5. Sweden	0.38
23. Belgium	9.57	7. Italy	0.37
18. Denmark	9.25	9. the Netherlands	0.36
16. France	8.76	10. Canada	0.23
19. Spain	8.48	14. Switzerland	0.20
15. Finland	8.45	6. Brazil	0.18

The number preceding each country indicates its position in the Ndoc column in Table 2.

Slovenia and the Netherlands. USA, Japan and UK contributed the largest percentage of documents to the top five journals in relation to the total production of the present sample (%*N*top5 – *sample*) (Table 5).

Therefore, the countries with the largest production (USA, UK, Japan, Germany and Sweden) were not the top-ranking countries in terms of the quality of their publications (although Sweden is the fifth country in number of citations and in number of documents published in *N*top5).

Finally, Fig. 3 combines both dimensions: qualitative analysis, with the RIF and number of citations measuring the expected and observed quality, respectively; and quantitative analysis, by means of the 'Relative Specialization Index'. It shows countries where dental research has an important weighting in relation to remaining research fields (RSI), and depicts the quality of the publications (RIF). If a country can be considered to be at the vanguard of dental research when it has a high RSI, a high RIF value and an above-average number of citations, then Norway, Sweden, Finland, Denmark and Japan are clearly among the leading countries in this field.

Discussion

Despite the limitations implied by using the Impact Factor to analyze scientific production (14), this study may be of assistance to identify the main geographic areas of dental scientific production in the world, i.e. the USA, UK, Japan and Scandinavia, although world rankings vary considerably according to the measurement under consideration. A growth in dental research production was observed in emerging countries, such as Brazil, Turkey, China, South Korea, Thailand, Jordan and Iran. The qualitative analysis showed that not all countries with a large absolute production had a correspondingly high relative impact factor, weighted impact factor or number of citations.

Publication analysis, as with any method chosen to assess scientific production, does not cover the entirety of scientific production. However, the ISI database allowed identification of 100% of the documents and indexed journals that met the inclusion criteria, unlike Medline, which has been used in other partial analyses of dental research production (15–17). Moreover, the well-documented quality of the ISI database is guaranteed by peer review (18). One limitation for the present study was that the country of origin of the author did not always appear clearly in the 'addresses' field, so that the production of certain countries may have been underestimated. A further possible weakness of the study was its limitation to a 5-year period. In fact, the interannual variation rates of countries varied considerably, with a large rise in the production of some emerging countries and a constant or even decreasing production in some developed countries with long histories of major scientific activity. This finding for dental research is not consistent with those for research on general biomedical production by Benzer *et al.* (9) and Rahman and Fukui (7), who observed very little change over time in world rankings, whether based on absolute figures or on production per million inhabitants. There are no published data on dental research production to confirm or refute this difference. The present study was also limited to journals included in the 'Dentistry, Oral Surgery & Medicine' category of the ISI database, and some dental research papers included in other categories of the ISI database may have been missed. On the other hand, the ISI database assigns journals to a given category when most of its citations derive from journals of the same category, ensuring the widest and most appropriate selection.

Hefler *et al.* (8) and Thompson (11) found that scientific production in biomedicine depended on population size, but that smaller countries took the lead in per capita production. Our data confirm this observation (Table 3). The countries producing the most documents per 100,000 inhabitants were Sweden, Norway, Israel, Finland, Denmark and Switzerland, all with populations at or below 9 million. The order also differed from that for overall production volume, when the production was expressed in terms of the number of dentists or the GDP (Table 3). Some authors have attributed the low number of publications per capita in large countries such as France, Germany, or Italy to their considerable production of studies in their own languages and within national journals, and so with no international visibility. This hypothesis is not supported by the present results, because none of the five nations with highest productivity or number of international publications per capita are English-speaking countries. GDP per capita and

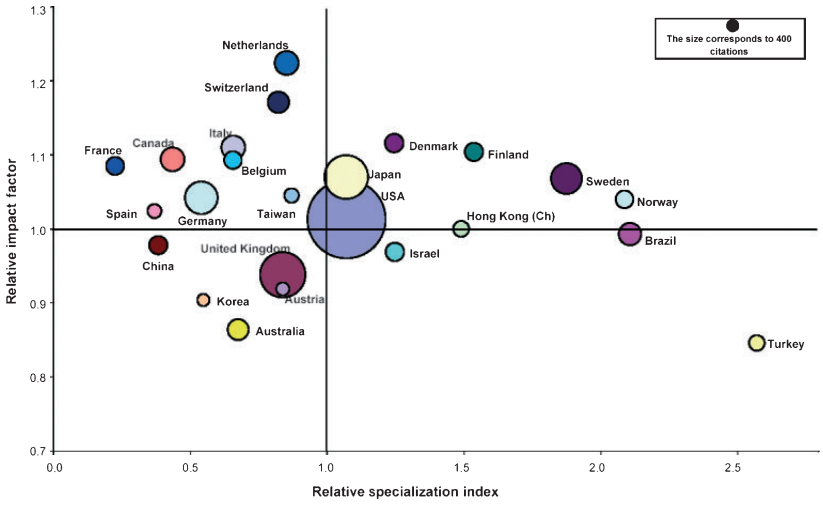

Fig. 3. Comparison of the Relative Specialization Index, Relative Impact Factor and Total Citation Rate in some countries of the sample. (The mean RIF and the RSI of the sample is 1.0).

R & D expenditure have also been described as related to biomedical scientific production (19) but were not fully investigated in the present study. The analysis of these and other indicators, as well as the influence of institutional funding on the quality of the publications, will be the aim of future studies by our group.

Perhaps the most striking finding was the presence of emerging countries such as Brazil or Turkey in the 10 countries with most published articles (Table 2). Other emerging countries also showed an increasing volume of dental research during the 5-year period, including China, South Korea, Hong Kong (also the most productive country in the sample), Thailand, Jordan and Iran. The growth in the number of publications in these countries and their generally high specialization index reflect the efforts being undertaken and their increasing presence in the international setting.

In contrast, the production of developed countries with the highest publication levels has tended to stagnate, as found in the present sample and reported by other authors for biomedical publications in general (7–11). The distribution by continents shows the clear influence of economic and development levels (Table 4). As found by RAHMEN *et al*. for biomedicine (10), dental research production is clearly greater in Europe, North America and Australia-Oceania than in Asia, Africa and South America.

The qualitative results of this study were not consistent with the quantitative findings, and the countries that produced most publications were not always those that produced work of the highest quality. Thus, although the WIF was generally higher in countries that also had an above-average citation rate (2.36 citations per document), Mexico (2.12) and Slovenia (2.23) showed a high WIF but a low citation rate (2.12 and 2.23, respectively) and absolute production (Fig. 2). This may be explained by a greater interest by the latter countries in obtaining visibility by publishing in journals of higher impact, reinforced by the reliance of administrators and employers on impact factors to judge researchers' performance. On the other hand, the unexpectedly high number of citations per document achieved by other countries may be a result of their high level of collaboration with high-ranking countries, as in the case of Hungary with USA, UK and Belgium.

Unsurprisingly, the countries with the highest production of articles also had the most publications in the best journals (Table 2). A better indication of the quality of the production of a country may be represented by the percentage of its production that appears in these journals (Table 5). By this yardstick, Mexico is the top-ranking country followed by Slovenia and the Netherlands.

On the other hand, from a statistical viewpoint, countries with the highest production levels, such as the USA, Japan or the UK, could be expected to show RSI and RIF values very close to the means for the sample (1.05 and 1.00, respectively). Nevertheless, the USA had RIF and RSI values above the mean values found (1.013 and 1.071, respectively). Moreover, the UK was found to be the second most productive country as well as having a large absolute production.

Combined analysis of qualitative indicators such as RSI, RIF and *N*cit allows countries to be compared (Fig. 3). We highlight the position of Scandinavian countries, which showed a production of moderate volume but high quality. HEFLER *et al*. (8), in their Medline study on the biomedical productivity of European Union countries during 1990 and 1998, concluded that Sweden, Finland and Denmark, together with the Netherlands and Spain, were the most productive countries in relation to population size and GDP. The present study also placed Scandinavian countries within the 10 most productive countries in relation to these parameters.

In conclusion, the USA, UK, Japan and Scandinavia were found to be the most productive countries in terms of number of publications. Publications from Scandinavian countries were also of high quality as measured by Impact Factor and Citation Rate, while the UK had one of the highest productivity rates (number of documents per researcher).

References

1. UGOLINI D, PARODI S, SANTI L. Analysis of publication quality in a cancer research institute. *Scientometrics* 1997; **38**: 263–274.
2. CLEATON-JONES P, MYERS G. A method for comparison of biomedical publication quality across ISI discipline categories. *J Dent Educ* 2002; **66**: 690–696.
3. LINDE A. On the pitfalls of journal ranking by impact factor. *Eur J Oral Sci* 1998; **106**: 525–526.
4. WHITEHOUSE GH. Citation rates and impact factors: should they matter? *Br J Radiol* 2001; **74**: 1–3.
5. GARFIELD E. Fortnightly review: how can impact factors be improved? *BMJ* 1996; **313**: 411–413.
6. Not-so-deep impact [Editorial]. *Nature* 2005; **435**: 1003–1004.
7. RAHMAN M, FUKUI T. Biomedical publication-global profile and trend. *Public Health* 2003; **117**: 274–280.
8. HEFLER L, TEMPFER C, KAINZ C. Geography of biomedical publications in the European Union, 1990–98. *Lancet* 1999; **353**: 9167.
9. BENZER A, POMAROLI A, HAUFE H, SCHMUTZHARD E. Geography analysis of medical publications in 1990. *Lancet* 1993; **341**: 8839.
10. RAHMAN M, FUKUI T. Biomedical research productivity in Asian countries. *J Epidemiol* 2000; **10**: 290–291.
11. THOMPSON DF. Geography of U. S. biomedical publications, 1990–97. *N Engl J Med* 1999; **340**: 817–818.
12. MOED HF, BRUIN RE, VAN LEEUWEN TN. New bibliometric tools for the assessment of national research performance: Database description, overview of indicators and first application. *Scientometrics* 1995; **33**: 381–422.
13. VAN RAAN AFJ. Advanced bibliometric methods for the evaluation of Universities. *Scientometrics* 1999; **45**: 417–423.
14. GARFIELD E. The impact factor. *Curr Contents* 1994; **25**: 3–7.
15. MAVROPOULOS A, KILIARIDIS S. Orthodontic literature: an overview of the last 2 decades. *Am J Orthod Dentofacial Orthop* 2003; **124**: 30–40.
16. YANG S, NEEDLEMAN H, NIEDERMAN R. A bibliometric analysis of the pediatric dental literature in MEDLINE. *Pediatr Dent* 2001; **23**: 415–418.
17. ELIADES T, ATHANASIOU AE. Impact factor. A review with specific relevance to orthodontic journals. *J Orofac Orthop* 2001; **62**: 74–83.
18. KAWAMURA M, THOMAS CDL, KAWAGUCHI Y, SASAHARA H. Lotka's law and the pattern of scientific productivity in the dental literature. *Med Inform* 1999; **24**: 309–315.
19. RAHMAN M, FUKUI T. Biomedical research productivity. Factors across the countries. *Int J Technol Assess* 2003; **19**: 249–260.