Review

Publication performance and trends in temporomandibular disorders research: A bibliometric analysis

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ABSTRACT

Background: Temporomandibular disorders (TMD) are common, can be both painful and non-painful, and encompass various conditions affecting the temporomandibular joint, the masticatory muscles or both TMD. Therefore, the purpose of this bibliometric analysis was to synthetically analyze citation performance in TMD, to address a more innovative method including details of article title, author keyword, KeyWords Plus, and abstracts.

Material and methods: Data used in this study were retrieved from the Clarivate Analytics Web of Science Core Collection, the online version of the Science Citation Index Expanded (SCI-EXPANDED) between 1992 and 2021. The distribution of key words in the article title and author-selected keywords were used to evaluate research trends.

Results: Of the 7,228 documents in SCI-EXPANDED, 6,138 documents met all inclusion criteria and were included in the final analysis, of which 4,945 were articles. The present bibliometric analysis of the articles published in the research field of TMD revealed that orofacial pain, bruxism, chronic pain, and myofascial pain are the most commonly used keywords by the authors. Further, over the last 30 years 4,945 articles are published in the field of TMD, and the far most frequently cited study was published 8 years ago and handles the diagnostic criteria of TMD.

The USA and Brazil were top two ranking productive countries of publication on TMD. The most productive journal was Journal of Oral Rehabilitation, followed by Cranio-The Journal of Craniomandibular & Sleep Practice and Journal of Oral & Facial Pain and Headache. The most productive authors were P. Svensson, R. Ohrbach, and F. Lobbezoo. The most productive institutes were Sao Paulo University (Brazil), Malmo University (Sweden), and Washington university (USA).

Conclusion: Based on the outcome of this bibliometric study, the authors hope that both clinicians and researchers will have information to shape their future research focus, finding prominent institutions in their nearby area, or even to be stimulated to initiate new international or even multinational collaborations.

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1. Introduction

The umbrella term temporomandibular disorders (TMD) encompass various conditions affecting the temporomandibular joint, the masticatory muscles or both [1,2]. TMD can be both painful and non-painful. Based on a recent systematic review the overall prevalence of TMD is approximately 31% for adults/elderly and 11% for children/adolescents, and the most prevalent TMD is the non-painful condition disk displacement with reduction [3]. The second most common TMD, affecting 10–15% of the general population, and up to 70% of all painful TMD-cases is pain from the masticatory muscles, i.e., myalgia [4–8]. Further, there is evidence that women are more susceptible to TMD than men [9]. Besides the sensory unpleasantness, painful TMDs are also emotionally disadvantageous, causing feelings such as anxiousness, stress, guilt, misery, isolation, even sleeping difficulties, which could lead to development of depression [10–12].

In order to quantify the quality of published papers for organizations, authors, and even countries as well as to identify the impact of publications and research groups in their field of research, bibliometrics are used [13,14]. This, since bibliometrics makes it simple to study and decode the developments on a subject, to pursue the dynamics and evolution of scientific knowledge. Bibliometrics is a powerful tool to comprehensively review research trends, investigate publication performances and providing future perspectives. Furthermore, the possibility to identify future research directions, based on a bibliometric analysis on the characteristics of available literature in a
specific field, reduces the error margin and improves the decision-making [15,16]. Currently, research on TMD is published in peer-reviewed journals on a daily basis. The dilemma with the presence of such a huge amount of evidence is the ability to navigate in the jungle of publications finding the most important or influential publications.

Traditionally, the purpose of this bibliometric analysis is not just to synthetically analyze citation performance in TMD, but it will also address the more innovative method including details of including of article title, author keyword, KeyWords Plus [17], and abstracts should be included in the bibliometric analyses [18].

2. Methodology

Data used in this study were retrieved from the Clarivate Analytics Web of Science Core Collection, the online version of the Science Citation Index Expanded (SCI-EXPANDED) (data updated on 22 May 2022). Quotation marks (" " ) and Boolean operator or "were used which ensured the appearance of at least one search keyword in the terms of TOPIC (title, abstract, author keywords, and KeyWords Plus) from 1992 to 2021. The search keywords used were: "temporomandibular disorders", "temporomandibular disorder", "temporomandibular joint (TMJ) disorders", "temporomandibular joint disorder", "temporomandibular joint diseases", "temporomandibular joint disease", "temporomandibular joint diseases", "temporomandibular joint dysfunction", "temporomandibular dysfunction", "temporomandibular diseases", and "temporomandibular dysfunctions". In addition, some misspelling keywords were also considered: "temporomandular disorders", "temporomandular disorder", "temporomandular pain
disease", "temporomandular dysfunction", "arthrogenous TMD", "arthrogenous TMDs", "temporomandibular joint dysfunction", "temporomandibular dysfunction", "temporomandibular diseases", and "temporomandibular dysfunctions". It resulted 7228 documents in SCI-EXPANDED. KeyWords Plus supplies additional search terms extracted from the titles of articles cited by authors in their bibliographies and footnotes in the Institute of Science Information (ISI) (now Clarivate Analytics) database, and substantially augments title-word and author-keyword indexing [19]. It was pointed out that documents only searched out by KeyWords Plus are irrelevant to the search topic [20]. Ho's group firstly proposed the 'front page' as a filter including the article title, abstract, and author keywords [13,21]. It has been reported that a big difference was found by using the 'front page' as a filter in bibliometric research topics published in medical related journals in SCI-EXPANDED, for example, Chinese Medical Journal [22], World Neurosurgery [23], Annals of Translational Medicine [24], and BioMed Research International [25]. This filter can avoid introducing unrelated publications for bibliometric analysis.

The full record in SCI-EXPANDED and the number of citations in each year for each document were checked and downloaded into Excel Microsoft 365, and additional coding was manually performed [26,27]. The functions in the Excel Microsoft 365, for example, Counta, Concatenate, Filter, Match, Vlookup, Proper, Rank, Replace, Freeze Panes, Sort, Sum, and Len were applied. Finally, 6138 documents (85% of 7228 documents) including search keywords in their 'front page' were defined as temporomandibular disorders research publications. The journal impact factors (IF2020) were taken from the Journal Citation Reports (JCR) published in 2020.

In the SCI-EXPANDED database, the corresponding author is labelled as reprint author, but in this study, we used the term corresponding author [13]. Single author in articles with unspecified authorship were both the first as well as corresponding author [28]. Similarly, in a single institutional article, the institution is classified as the first as well as the corresponding-author institution [28]. In multi-corresponding author articles, all the corresponding authors, institutes, and countries were considered. Articles with corresponding authors in SCI-EXPANDED, that had only address but not affiliation names were checked out and the addresses were changed to be affiliation names.

Affiliations in England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK) [29]. Affiliations in Hong Kong before the year of 1997 were reclassified as in China [30].

Published were assessed using following citation indicators: $C_{year}$: the number of citations from Web of Science Core Collection in a particular year (e.g. $C_{2021}$, describes citation count in 2021) [13].

$T_{year}$: the total citations from Web of Science Core Collection received since publication year till the end of the most recent year (2021 in this study, $T_{2021}$) [31].

Six publication indicators were applied to evaluate publication performance of countries and institutions [33].

- $TP$: total number of articles
- $IP$: number of single-country or single-institution articles
- $CP$: number of internationally or inter-institutionally collaborative articles
- $FP$: number of first-author articles
- $RP$: number of corresponding-author articles
- $SP$: number of single-author articles

Six citation indicators related to the six publication indicators ($C_{year}$) were also applied to evaluate the publication impact on countries and institutes [34].

Y-index ($j$, $h$) was used to evaluate publication performance of authors, and defined as [13,35]:

$$h = \pi/2, \quad \text{indicates an author that has only published corresponding-author articles, } j = \text{the number of corresponding-author articles; }$$

$\pi/2 > h > 0.7854$ indicates that an author has more corresponding-author articles than first-author articles ($FP > 0$);

$h = 0.7854$ indicates that an author has the same number of first- and corresponding-author articles ($FP > 0$ and $RP > 0$);

$0.7854 < h < 0$ indicates an author with more first-author articles than corresponding-author articles ($RP > 0$);

$h = 0$, indicates that an author has only published first-author articles, $j$ is the number of first-author articles.

3. Results and discussion

3.1. Characteristics of document-types

Ho and his group have identified the characteristics of document-type based on the citations per publication ($C_{year}/TP$) and the number of authors per publication ($AAP = AU/TP$) as basic information of document-type in a research topic [36]. Using $T_{2021}$ and $C_{2021}$ is advantageous owing to invariability and ensured repeatability when compared to just number of citations from the Web of Science Core Collection [37].

A total of 6138 TMD documents published in SCI-EXPANDED were found among 15 document-types which are presented in Table 1. This publication count includes 4945 articles (81% of 6138 documents) with an $AAP$ (number of authors per publication) of 4.8. The percentage of articles regarding TMDs (81%) was higher than other medical-related topics, for example 77% in Q fever [38], 70% in Ebola [39], 69% in breast reconstruction [40], 68% in cisplatin-based chemotherapy for small-cell lung-cancer [32], 66% in acupuncture [41], 66% in insomnia [42], and 66% in keloid [24]. However, a higher percentage of articles (89%) was found in fracture nonunion [43].
A review entitled “Central sensitization: Implications for the diagnosis and treatment of pain” [44] was the most frequently cited document in the research field of TMD with a TC_{2021} of 2175. This review was also the only classic document with TC_{2021} of 1000 or more [45].

The document-type proceedings papers, including 127 documents, had the greatest CPP_{2021} value of 39. The CPP_{2021} of the document-type review articles was found to be 1.7 times of articles. Also this variable was higher than of other medical-related topics, for example, insomnia (1.4 times) [42], fracture nonunion (1.3 times) [43], and breast reconstruction (0.86 times) [40].

Since documents can be categorized in two different document-types in Web of Science Core Collection [46], the cumulative percentages in Table 1 exceed 100%. Examples of documents that were categorized in two different document-types were the 127 proceedings papers, two book chapters, and one data paper.

The content of different document-types differs, and therefore only articles were used for the further analysis. This since articles generally contain introduction, methods, results, discussion, and conclusion. A total of 4945 TMD-related articles in 12 different languages were analyzed and are presented below. The most used language was English with 96% of the articles (4842 out of 4945 articles) followed distantly by German (37 articles), French (23), Spanish (13), and Turkish (13). Less the ten articles used other languages as follows: Portuguese (7), Hungarian (2), Korean (2), Serbian (2), and for each of Czech, Italian, and Polish respectively. Finally, one article was bilingual (English and Estonian) and published in Annals of Plastic Surgery. A notable finding was that non-English articles had fewer citations, with a CPP_{2021} of 4.6, while English articles had a CPP_{2021} of 22. The same accounted for APP where non-English articles had an APP of 3.5, while English articles had an APP of 4.8.

3.2. Characteristics of publication outputs

Ho proposed in 2013 a correlation between annual number of articles (TP) and their citations (CPP_{year} = TC_{year}/TP) by year to understand the development trends and impacts of publications in a research topic [32]. In the last decade, it has been applied in several medical-related topics including dengue fever [37], Ebola [39], breast reconstruction [40], insomnia [42], fracture nonunion [43], keloid [24], and Q fever [25]. Between the years 1992 and 2021, 4945 articles associated to TMDs were published in SCI-EXPANDED. The mean value of TC_{2021} was 22 with 1980 as the maximal value for an article. Fig. 1 demonstrates the distribution of the annual number of articles and their CPP_{2021} by year, which was expressed as TC_{2021}/TP [32], where TP is number of articles published in that year. Fig. 1 is showing that the number of publications in the field of TMD is increasing rapidly and the number of citations declining drastically, and that it takes approximately ten years to reach a plateau of accumulated citations. This study together with previous studies evaluating the impact of articles in the fields of dengue fever [37], Ebola [39], breast reconstruction [40], insomnia [42], and Q fever [25] indicate that a decade has to pass before one can assess and evaluate the impact of articles.

3.3. Web of science category and journal

In 2020, Journal Citation Reports (JCR) indexed 9531 journals with citation references across 178 Web of Science categories in SCI-EXPANDED. In 2021, identify the characteristics of the Web of Science category based on their citations per publication (CPP_{year} = TC_{year}/TP) and the number of authors per publication (APP = AU/TP) as basic information of the Web of Science category in a research topic were presented [34,43]. Total 628 journals published articles related to temporomandibular disorders in 93 Web of Science categories in SCI-EXPANDED. Table 2 shows the top ten productive categories, mainly in the category of dentistry, oral surgery and medicine (contains 92 journals in the category) with 3136 articles (64% of 4945 articles). When

<table>
<thead>
<tr>
<th>Web of Science category</th>
<th>No. Journals</th>
<th>TP(%)</th>
<th>APP</th>
<th>CPP_{2021}</th>
</tr>
</thead>
<tbody>
<tr>
<td>dentistry, oral surgery and medicine</td>
<td>92</td>
<td>3171 (64)</td>
<td>4.5</td>
<td>21</td>
</tr>
<tr>
<td>clinical neurology</td>
<td>208</td>
<td>410 (8.3)</td>
<td>5.6</td>
<td>42</td>
</tr>
<tr>
<td>neurosciences</td>
<td>273</td>
<td>398 (7.8)</td>
<td>5.8</td>
<td>45</td>
</tr>
<tr>
<td>surgery</td>
<td>212</td>
<td>373 (7.5)</td>
<td>4.9</td>
<td>16</td>
</tr>
<tr>
<td>anesthesiology</td>
<td>33</td>
<td>206 (4.2)</td>
<td>5.4</td>
<td>60</td>
</tr>
<tr>
<td>general and internal medicine</td>
<td>169</td>
<td>201 (4.1)</td>
<td>5.3</td>
<td>13</td>
</tr>
<tr>
<td>radiology, nuclear medicine and medical imaging</td>
<td>134</td>
<td>141 (2.9)</td>
<td>5.1</td>
<td>20</td>
</tr>
<tr>
<td>rehabilitation</td>
<td>68</td>
<td>140 (2.8)</td>
<td>4.6</td>
<td>15</td>
</tr>
<tr>
<td>research and experimental medicine</td>
<td>140</td>
<td>132 (2.7)</td>
<td>5.4</td>
<td>11</td>
</tr>
<tr>
<td>biomedical engineering</td>
<td>90</td>
<td>95 (1.9)</td>
<td>5.5</td>
<td>14</td>
</tr>
</tbody>
</table>

TP: total number of articles; %: percentage of articles in all temporomandibular disorder articles; APP: number of authors per paper; CPP_{2021}: citations per paper (TC_{2021}/TP).
comparing the top ten categories, articles published in the category of anesthesiology displayed the greatest CPP$_{2021}$ reaching up to 60. Articles published in the category of neurosciences displayed the highest APP reaching up to 5.8. Since journals can be classified in more than one category in SCI-EXPANDED, the cumulative percentage of categories exceeds 100% in Table 2. For instance Pain was classified in categories of anesthesiology, clinical neurology, and neurosciences [35].

Recently, Ho (2021) proposed to display the characteristics of the journals based on their citations per publication (CPP$_{year} = TC_{year}/IP$) and the number of authors per publication (APP = AU/TP) as basic information of the journals in a research topic [34]. Table 3 shows the top 12 most productive journals with journal impact factors, CPP$_{2021}$, and APP. The Journal of Orofacial Pain with 228 articles and Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontology with 84 articles were not listed in SCI-EXPANDED after 2013 and 2011 respectively. In 2014, the official journal of the American Academy of Orofacial Pain, the European Academy of Orofacial Pain and Dysfunction, the Asian Academy of Craniomandibular Disorders, and the Australian and New Zealand Academy of Orofacial Pain, namely the Journal of Orofacial pain changed name to Journal of Oral & Facial Pain and Headache. Therefore, articles published in Journal of Orofacial Pain from 1998 to 2013 and Journal of Oral & Facial Pain and Headache from 2014 to 2021 were in this study merged to on group and called Journal of Oral & Facial Pain and Headache. Top productive journal was found to be the Journal of Oral Rehabilitation (IF$_{2020} = 3.837$) that published 487 articles representing 9.8% of the 4945 articles, followed by the Cranio-The Journal of Cranio- mandibular & Sleep Practice (IF$_{2020} = 2.020$) with 394 articles (8.0%) and the Journal of Oral & Facial Pain and Headache (IF$_{2020} = 1.871$) with 358 articles (7.2%). When comparing the top 12 productive journals, TMD articles published in Pain (IF$_{2020} = 6.961$) showed the highest CPP$_{2021}$ reaching to 55 while articles in the Cranio-The Journal of Cranio- mandibular & Sleep Practice (IF$_{2020} = 2.020$) only reached a CPP$_{2021}$ of 13. The APP ranged from 6.1 in Pain to 3.4 in the Journal of Prosthetic Dentistry. When it comes to impact factors, the journal with the highest IF$_{2020}$ of 21.405 was the Pain (2020 = 21.405) only reached a CPP$_{2021}$ of 13. The APP ranged from 6.1 in Pain to 3.4 in the Journal of Prosthetic Dentistry. When it came to the six related citation indicators CPP$_{2021}$ among the top 16 productive countries, Denmark with 147 articles had the highest CPP$_{2021}$ of 42 for their TP, 47 for their IP, 43 for their IF, 41 for their RP. Australia and Sweden had, on the other hand, the highest CPP$_{2021}$ of 53 for their CP, and 54 for their SP. When it comes to development trends in number of published articles, the top five productive countries in 2021 are presented in Fig. 2. When countries such as USA (rank 1st), Brazil (rank 2nd) have been the most productive counties the last 15 years, countries like China, Italy, and Turkey are approaching. This study could show that they have published 44 articles (rank 7th), 38 (rank 5th), and 34 articles (rank 8th) in the year of 2021 (Fig 2, Table 6).

Concerning institutions, 1886 articles in the field of TMD (38% of 4945 articles) originated from single institutions with a CPP$_{2021}$ of 22, while 3018 articles (62%) were institutional collaborations with a CPP$_{2021}$ of 21. The top 15 productive institutions and their characteristics are presented in Table 5. The University of Sao Paulo in Brazil ranked top in five of the six publication indicators with a TP of 275 articles (5.2% of 4945 articles), an IP of 81 articles (4.3% of 1886 single-institution articles), a CP of 174 articles (5.8% of 3018 inter-institutionally collaborative articles), an RP of 177 articles (3.6% of 4945 first-author articles), and an RP of 130 articles (2.7% of 4802 corresponding-author articles). The University of Washington and the

### Table 3

<table>
<thead>
<tr>
<th>Journal</th>
<th>TP (%)</th>
<th>IF$_{2020}$</th>
<th>APP</th>
<th>CPP$_{2021}$</th>
<th>Web of Science category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journal of Oral Rehabilitation</td>
<td>487 (9.8)</td>
<td>3.837</td>
<td>4.7</td>
<td>20</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>Cranio-The Journal of Cranio- mandibular &amp; Sleep Practice</td>
<td>394 (8.0)</td>
<td>2.02</td>
<td>4.1</td>
<td>13</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>Journal of Orofacial Pain</td>
<td>228 (4.6)</td>
<td>N/A</td>
<td>4.3</td>
<td>42</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>Journal of Oral &amp; Facial Pain and Headache</td>
<td>130 (2.6)</td>
<td>1.871</td>
<td>5.5</td>
<td>19</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>Acta Odontologica Scandinavica</td>
<td>123 (2.5)</td>
<td>2.331</td>
<td>3.9</td>
<td>23</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>Journal of Oral and Maxillofacial Surgery</td>
<td>118 (2.4)</td>
<td>1.895</td>
<td>4.3</td>
<td>23</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>International Journal of Oral and Maxillofacial Surgery</td>
<td>111 (2.2)</td>
<td>2.789</td>
<td>4.9</td>
<td>19</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>Pain</td>
<td>100 (2.0)</td>
<td>6.961</td>
<td>6.1</td>
<td>95</td>
<td>anesthesiology</td>
</tr>
<tr>
<td>Journal of Prosthetic Dentistry</td>
<td>97 (2.0)</td>
<td>3.426</td>
<td>3.4</td>
<td>30</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>Dentomaxillofacial Radiology</td>
<td>84 (1.7)</td>
<td>2.419</td>
<td>4.9</td>
<td>20</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
<tr>
<td>Journal of Dental Research</td>
<td>84 (1.7)</td>
<td>N/A</td>
<td>4.5</td>
<td>31</td>
<td>dentistry, oral surgery and medicine</td>
</tr>
</tbody>
</table>

IP: total number of articles; TC: percentage of articles in all temporomandibular disorder articles; IF$_{2020}$: Journal impact factor in 2021; APP: number of authors per article; CPP$_{2021}$: citations per paper (TC$_{2021}$/IP).
first-author articles (ranked 4th), 22 corresponding-author articles (ranked 3rd), and three single-author articles (ranked 6th). D. Manfredini with 69 articles, the fourth most productive author, was the author with the most first-author articles (35 articles), and the most corresponding-author articles (49 articles). Although not among the top 20 productive authors, W.E. Shankland was the most productive single author (only publishing single author articles) with five published articles (ranked 1st). Finally, among the top 20 productive authors, W. Maixner was found to have the greatest CPP\(_{2021}\), of 191 for first-author articles, and corresponding-author articles respectively. On the other hand, S.F. Dworkin had the greatest CPP\(_{2021}\), for total articles with 178.

Only nine of the top 20 productive authors were also found to be top 20 publication potential authors as evaluated by the Y-index. These were D. Manfredini, P. Svensson, K. Sipila, R. Ohrbach, E. Wino-cur, G.D. Slade, A. Micheliotti, C.M. Visscher, and M.T. John.

A total of 4819 articles in the field of TMD (97% of 4945 articles) had both first and corresponding author information in SCI-EXPANDED. Based on the Y-index, 4819 TMD related articles were contributed by 12,514 authors in which 8576 authors (69% of 12,514 authors) had no first- and/or no corresponding-author articles with Y-index (0, 0); 753 (6.0%) authors published only corresponding-author articles with \( h = \pi/2 \); 225 (1.8%) authors published more corresponding-author articles with \( \pi/2 > h > 0.7854 \) \((FP > 0)\); 1634 (13%) authors published the same number of first- and corresponding-author articles with \( h = 0.7854 \) \((FP > 0) \text{ and } RP > 0\); 132 (1.1%) authors published more first-author articles with 0.7854 > h > 0 \((RP > 0)\); and 1194 (9.5%) authors published only first-author articles with \( h = 0\).

In the polar coordinates (Fig. 3), the distribution of the Y-index (j, h) of the leading 29 potential authors in the research field of TMJ with \( j \geq 18 \) was demonstrated. Every point has a coordinate Y-index (j, h) that could symbolize a single author or multiple authors, for example, J.C. Turp, D.R. Reissmann, K. Kaneyama, and T. Badel with the same Y-index (20, 0.7854). D. Manfredini with Y-index (84, 0.9505) and R. Emshoff with Y-index (54, 0.8593) showed to have a much higher publication potential than the other top 29 authors in research field of TMD. D. However, Manfredini had lower CPP\(_{2021}\) (Table 6). W. Maixner had higher CPP\(_{2021}\) but lower publication potential.

One can only speculate why D. Manfredini was found to have the greatest publication performance, but by analyzing his publications at one of the search engines PubMed (https://pubmed.ncbi.nlm.nih.gov).
gov/?term=Manfredini%2C+Daniele%5BAuthor%5D) there are some indicators. He has several publications on bruxism, one of the most common causes of TMD [48], as well as several studies on diagnostics and treatment approaches of TMD, which are indicated that he has published several systematic reviews on risk-factors, diagnostics, and treatment approaches of TMD, which are also studies resulting in several citations.

C.M. De Felicio (25, 1.131), E. Winocur (25, 1.058), K.G. Raphael (25, 0.8254), and A.G. Gratos (25, 0.8254) all had the same j of 25. All these authors are located on the same curve (j = 25) in Fig. 3, indicating that they had the same publication potential in the research field of TMD with a j of 25 but different publication characteristics [37].

De Felicio published more corresponding-author articles than first-author articles with an h of 1.131, followed by Winocur with an h of 1.058. Both of Raphael and Gratos published the same number of first-author articles and corresponding-author articles with an h of 0.8254, respectively. Similarly, A. Wanman (18, 1.204), H. Kurita (18, 0.7854), and C.S. Greene (18, 0.6747) are also located on the same curve with j of 18. Wanman had more corresponding-author articles with an h of 1.204. Kurita had the same number of first- and corresponding-author articles with an h of 0.7854. However, Greene had more first-author articles with an h of 0.6747 that indicated Yano still active to perform temporomandibular disorder research. Similar situations for authors located on j of 19, 20, 21, and 22 were found. G.D. Slade (22, 0.7854), R.J.M. Gray (22, 0.7854), J.C. Turp (20, 0.7854), D.R. Reissmann (20, 0.7854), K. Kaneyama (20, 0.7854), T. Badel (20, 0.7854), R.B. Fillingim (20, 0.6747), M.T. John (20, 0.6747), C.M. Visscher (20, 0.6747), L. Guarda-Nardini (20, 0.6747), and J.D. Greenspan (20, 0.6747) are also located on the same curve.
of citations from the Web of Science Core Collection since publication year to the end of the most recent year of 2021 (TC_{2021}) was applied to avoid bias using data from the database directly [50]. A total of 2308 articles (47% of 4945 articles), 4135 articles (85% of 4876 articles with abstract in SCI-EXPANDED), and 2375 articles (65% of 3659 articles with author keywords in SCI-EXPANDED) were found to contain search keywords in their title, abstract, and author keywords respectively. Although it is recommended having search keywords in article title or author keywords rendering more hits in a search as well as in bibliometric studies [34], six of the top ten cited articles only contained search keywords in their abstracts. Table 7 shows the top 10 most frequently cited articles with search keywords in their title or author keywords.

Citations of a highly cited article are not always high [35]. Therefore, it is necessary to understand the citation history of a highly cited article. The citation histories of the TMD articles contain search keywords in their title or author keywords as shown in Fig. 3. (In the text Fig. 3 should be changed to Fig. 4.)

0.7854), and H. Kurita (18, 0.7854) are located on the diagonal line (h = 0.7854) indicating that they had the same publication characteristics but different publication potential. Slade and Gray had the greatest publication potential with a j of 22 followed by Turp, Kaneyama, and Badel with a j of 20, and Kurita with a j of 18. The location on the graph along with one of the curves or along a line from the origin represents different families of author publication potential or publication characteristics, respectively. A potential for bias in the analysis of authorship might attributes to different authors having the same name, or the same author using different names over time [49].

### 3.6. Citation histories of the ten most frequently cited articles

Total citations are updated from time to time on the Web of Science Core Collection. To improve bibliometric study, the total number of citations from the Web of Science Core Collection since publication year to the end of the most recent year of 2021 (TC_{2021}) was applied to avoid bias using data from the database directly [50]. A total of 2308 articles (47% of 4945 articles), 4135 articles (85% of 4876 articles with abstract in SCI-EXPANDED), and 2375 articles (65% of 3659 articles with author keywords in SCI-EXPANDED) were found to contain search keywords in their title, abstract, and author keywords respectively. Although it is recommended having search keywords in article title or author keywords rendering more hits in a search as well as in bibliometric studies [34], six of the top ten cited articles only contained search keywords in their abstracts. Table 7 shows the top 10 most frequently cited articles with search keywords in their title or author keywords.

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![Fig. 3. Top 29 authors with Y-index (j ≥ 18) Citations of a highly cited article are not always high [35]. Therefore, it is necessary to understand the citation history of a highly cited article. The citation histories of the TMD articles contain search keywords in their title or author keywords as shown in Fig. 4. (In the text Fig. 3 should be changed to Fig. 4.).](image)

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Citations of a highly cited article are not always high [35]. Therefore, it is necessary to understand the citation history of a highly cited article. The citation histories of the TMD articles contain search keywords in their title or author keywords as shown in Fig. 3. Green Giants were found in the Web of Science category of environmental sciences and in pain research [51]. The Green Giant in the research field of TMD was the article entitled “Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for Clinical and Research Applications: Recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group” (Schiffman et al., 2014) by 34 authors from USA, Canada, Sweden, Denmark, Netherlands, Italy, Switzerland, Germany, Belgium, Australia, France, and the UK.

It is not surprising that this article is the Green Giant in the research field of TMD since it is about and describes the internationally accepted and validated clinical examination (Axis I) and biopsychosocial evaluation (Axis II), including the diagnostic criteria for TMD. Based on this, all clinical and experimental trials, epidemiological, and aetiological studies involving human participants are referring to this study. Therefore, it will continuously increase its citations since all new studies will refer to this, until these diagnostic criteria will be revised. This becomes even more obvious when looking at Table 7, since the third most cited article is one about image analysis in the previous article about diagnostic criteria [52].

### 3.7. Research foci

The article title, abstract, author keywords, and KeyWords Plus convey the most important information about the research. Therefore, word distribution analysis is very useful for evaluating research focuses and their development trends in a specific research topic [53]. In the last decade, Ho and his group proposed distributions of words in article titles and abstracts, author keywords, and KeyWords Plus to determine research focuses and their trends [18,53]. These analyses can minimize various limitations: the incomplete meaning of individual words in article titles and abstracts, the small sample size of author keywords, and the indirect relationship between KeyWords Plus and research topics [54]. Therefore, the article title, article abstract, author keywords, and words in KeyWords Plus were analyzed during the research period to show rough trends [53]. The 20 most frequently used author keywords in TMD related research, and their distribution in three sub-periods (1992–2001, 2002–2011, and 2012–2021) are listed in Table 8.

The most frequently used author keywords, except for the search words, were not surprising: 1) orofacial pain; 2) bruxism; 3) chronic pain, and 4) myofascial pain. This since painful TMDs are not just physical, but also affect the patients emotionally, triggering feelings of anxiousness, stress, guilt, misery, isolation, even sleeping difficulties, which in turn often results in depression [10–12]. Bruxism is, as mentioned before, one of the most important factors of
painful TMDs[48] and as many as 10−15% of the general population, and up to 70% of all painful TMD-cases is chronic pain from the masticatory muscles, i.e., myofascial pain or myalgia [4−8].

4. Conclusion

The present bibliometric analysis of the articles published in the research filed of TMD revealed that orofacial pain, bruxism, chronic pain, and myofascial pain are the most commonly used keywords by the authors. Further, over the last 30 years 4945 articles are published in the field of TMD, and the far most frequently cited study was published 8 years ago and handles the diagnostic criteria of TMD. Further, the most productive authors as well as those with the highest performance share some common features. They have several national and international collaborations, they have a wide range of article types spanning from causes to treatments, from risk-factors to how TMD conditions affect sensory, emotional, and mechanical function, to systematic reviews. Based on the outcome of this bibliometric study, the authors hope that both clinicians and researchers will have information to shape their future research focus, finding prominent institutions in their nearby area, or even to be stimulated to initiate new international or even multinational collaboration.

References
