Measuring the social impact of dental research: An insight into the most influential articles on the Web

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Objectives: To identify the most discussed dental articles on the Web and to assess the association between the intensity of online attention, publication characteristics, and citations.

Materials and methods: An Altmetric Explorer search was conducted for articles published in the 91 dental journals included in 2015 InCites™ Journal Citation Report® and mentioned online at all times. The 100 articles with the highest online attention, as measured by the "Altmetric Attention Score" (AAS), were screened for journal title, quartile of impact factor distribution (Q1–Q4), publication date, origin and affiliation of first author, article topic, type, and access. Citation counts were harvested from Scopus.

Results: The top 100 articles presented a median AAS of 119 and were mostly discussed on news outlets, Twitter, and Mendeley. Forty-one articles were published in Q1 journals, 24 in Q2 journals, 32 in Q3 journals, and three in Q4 journals. AAS was significantly higher in articles of Q2 journals (median AAS = 398, range = 70–513) than in articles of Q1. A weak reverse correlation existed between AAS and time since publication (r = −.25, p < .05). No correlation was detected between AAS and other publication characteristics or number of citations.

Conclusions: Increased social impact of dental articles is not significantly associated with high citation rates.

KEYWORDS
altmetrics, citations, dental journals, impact factor, social media, Web

1 | INTRODUCTION

The electronic transformation of the scholarly publishing industry during the last decades allowed rapid dissemination and monitoring of research data through the Web. Innovative developments such as open access platforms, social network tools, and other online usage, and comment-based statistics, created new perspectives on evaluating academic output (Melero, 2015). At the same time, traditional bibliometrics, such as citation rates and Journal Impact Factor (IF), are striving to keep pace with the changing times and have been criticized as vulnerable to gaming, slow to accrue, and incapable of assessing the social impact of published research (Priem, Groth, & Taraborelli, 2012; Priem, Taraborelli, Groth, & Neylon, 2010).

The call for new metrics motivated scholars to introduce altmetrics (Priem et al., 2012), that is, Web-based metrics measuring the impact of scholarly material with an emphasis on social media outlets as source of data (Shema, Bar-Ilan, & Thelwall, 2014). The newly developed metrics, also referred to as alternative metrics, aspire to measure the early influence of published work on academic and lay audiences. High online visibility of an article has the potential to draw attention to the publishing journal, to the authors, as well as to the study itself (Chavda & Patel, 2016). Aside from individual researchers, altmetrics...
are getting increasingly accepted by other stakeholders in academic research, viz. institutions, publishers, and funders, for promoting careers, establishing editorial policies, and processing grant applications.

Several altmetrics-tracking Web sites offer nowadays free and paid services as well as tools that automatically filter the literature and identify items that are getting noticed in a multitude of online sources. Altmetric Explorer (www.altmetric.com) is one of the most popular, commercially available analytical tools for altmetrics. It rates both the origin and intensity of the digital attention a research output receives by compiling data from three main sources: social media, mainstream and science-specific media, and online reference managers. Altmetric database covers most comprehensively social media data related to research articles and has been proven to outperform rival systems (Haustein, Costas, & Larivière, 2015). Major publishing groups like BMJ, Elsevier, Oxford University Press, SAGE, Springer, Taylor & Francis Group, and Wiley have already integrated Altmetric features into the online version of their journals to inform readers about the performance of the articles.

To the best of our knowledge, studies investigating the application of altmetrics in articles published in journals dedicated to dentistry, oral surgery, and oral medicine have been so far scarce (Kolahi & Khazaei, 2016). Therefore, the objectives of this study were to identify the dental articles that provoked the most intense online activity and discussion as well as to assess the association between Altmetric scores, publication characteristics, and citation counts.

2 | MATERIAL AND METHODS

2.1 | Search engine

Altmetric Explorer (Altmetric LLP, London, UK) was selected to run the literature search for the purposes of the study. It is a Web-based application that monitors engagement of research data in the following sources (Altmetric®):

- Public policy documents
- Mainstream media (over 2,000 outlets around the world)
- Online reference managers like Mendeley and CiteULike
- Postpublication peer-review platforms, including Pubpeer and Publons
- Wikipedia (English language version)
- Open Syllabus Project, which monitors the course syllabi of over 4,000 institutions worldwide
- Over 9,000 academic and non-academic blogs
- Research highlights from F1000
- A wide selection of Social Media Networks (Facebook public pages, Twitter, Google+, LinkedIn, Sina Weibo, and Pinterest)
- Multimedia and other online platforms (YouTube, Reddit, Q&A)

Altmetric algorithm generates a weighted score, the Altmetric Attention Score (AAS), which is illustrated by the Altmetric donut, a multicolored circle that reflects the relative contribution of each source (Figure 1). In other words, each color represents a certain source, and the thickness of the stripes indicates the frequency of mentions in each source. AAS weightings are ranging between 0.25 and 8 with the highest values assigned to mentions on news agencies and blogs (Table S1).

2.2 | Search strategy

An Altmetric Explorer search was conducted on Thursday, February 23, 2017, for articles published in the 91 journals included in 2015 InCites™ Journal Citation Report® (JCR) grouped under the subject category "Dentistry, Oral Surgery & Medicine." No restrictions were applied regarding language, date of publication, AAS, keywords, title of output, type of output, or scholarly identifiers.

Two researchers (K.D. and C.L.) read the full text of the 100 articles with the highest AAS (Feijoo, Limeres, Fernández-Varela, Ramos, & Diz, 2014) and extracted by consensus information regarding (i) journal title and quartile of IF distribution (Q1-Q4); (ii) article origin, that is, North America, Europe, or rest of the world; (iii) affiliation of the first author, that is, university, public health service, private practice/company, or other; (iv) article topic, that is, behavioral/psychology/quality of life, diagnosis, treatment, facial esthetics, practice management, socio-demographics, new techniques/technologies, oral hygiene/caries, side effects, or other; (v) study type, that is, original research, review, or case report; and vi) article access, that is, open access and pay for access. Citation counts were harvested from Scopus (https://www.scopus.com/) in order to be correlated to AAS.

2.3 | Statistical analysis

Analysis was carried out with IBM SPSS Statistics 20 (SPSS, Chicago, IL, USA). The Kruskal–Wallis H test was used to compare differences in AAS between the different groups of articles. Spearman correlation coefficient was used to analyze the relationship between AAS and time since publication or citation counts. Correlations ($r$) $<$0.3 were interpreted as a poor association, 0.3–0.5 as low, 0.5–0.7 as moderate, 0.7–0.9 as high, and $>$0.9 as very high (Hinkle, Wiersma, & Jurs, 2003). P values <0.05 were considered statistically significant.
TABLE 1 Descriptive statistics of online mentions per source for the articles analyzed in the study

<table>
<thead>
<tr>
<th>Source</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>News stories</td>
<td>13.5</td>
<td>0</td>
<td>110</td>
<td>31.5</td>
</tr>
<tr>
<td>Blog posts</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Policy documents</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Tweets</td>
<td>11</td>
<td>2</td>
<td>202</td>
<td>41</td>
</tr>
<tr>
<td>Weibo posts</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>Facebook posts</td>
<td>1</td>
<td>0</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Wikipedia pages</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Google+ posts</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>LinkedIn posts</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Reddit posts</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Research highlight platforms</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Q and A threads</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Videos</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Mendeley readers</td>
<td>17</td>
<td>1</td>
<td>673</td>
<td>32</td>
</tr>
</tbody>
</table>

3 | RESULTS

Altmetric Explorer originally identified 27,229 articles as having online mentions. The AAS, title of journal, and publication date of the first 100 articles are summarized in Table S2. The median AAS assigned to the top 100 articles was 119 (range 69–1,307, Interquartile range [IQR] = 289). The articles were mostly discussed on news outlets (median = 13.5, range = 0–110), Twitter (median = 11, range = 2–202), and Mendeley (median = 17, range = 1–673), as shown in Table 1. Journal of Dental Research and British Dental Journal were the prevailing journals with 20 articles each, followed by Journal of the American Dental Association and Journal of Clinical Periodontology with nine and seven outputs, respectively (Figure 2). AAS differed significantly between the journals, with Journal of Oral Implantology achieving the highest score (median AAS = 489, range = 91–498, IQR = 139; Figure 3).

Regarding demographics, 43 articles originated from North America, 47 articles from Europe, and 10 articles from the rest of the world. In 76 articles, the first author was affiliated with a university, in 14 articles with a public health service and in 10 articles with a private practice or company. Approximately one-fourth of the most popular articles online dealt with topics of common interest, such as oral hygiene and caries prevention (n = 24). Articles referring to treatment received the highest AAS (median = 388, range = 73–524, IQR = 409, Table 2). No significant differences were observed in AAS between geographical areas, first author’s affiliations, or article topics. Studies running their second year after publication were the most popular ones (AAS median = 377, range = 70–377, IQR = 349; Figure 4), but we could only detect a weak reverse correlation between AAS and days since publication of articles (r = −.25, p < .05). No correlation was detected between AAS and number of citations. A subanalysis, after excluding articles that had been recently published and, thus, possibly not given the chance to be cited yet (time since publication ≤ 2 years), showed no significant correlation between AAS and number of citations (r = .27, p > .05).

FIGURE 2 Journals with the highest number of articles with online mentions as tracked after the Altmetric Explorer search for articles published in the 91 journals included in 2015 InCites™ JCR grouped under the subject category ‘Dentistry, Oral Surgery & Medicine’
Sixty-two of the outputs were original articles, 32 were reviews, and 6 were case reports. Full text was freely available in 74 articles, while for 26 articles subscription/payment was required, and AAS did not differ significantly between article types and between free/paid article accesses.

In relation to IF ranking, 41 articles were published in Q1 journals, 24 articles in Q2 journals, 32 articles in Q3 journals, and three articles in Q4 journals. The AAS was significantly higher in articles published in Q2 journals (median AAS = 398, range = 70–513, IQR = 403; Figure 5). Additionally, no significant difference was observed in AAS in articles published in either Q1, Q3, or Q4 journals. The most popular article at the time the search was performed (AAS = 1307, Table S2) had been published in a Q3 journal and specifically in the Journal of Esthetic and Restorative Dentistry. Three Q2 journals, namely Journal of Oral Implantology, Journal of American Dental Association, and Journal of Oral and Maxillofacial Surgery, dominated the top 10 ranking with 7 in total articles. The other top 10 articles were hosted in Q1 journals, viz., Journal of Periodontology and Oral Oncology (articles No 2 and No 10, respectively).

4 | DISCUSSION

To the authors’ knowledge, this is the first study to report on online attention regarding scientific papers published in the dental field without applying any search limits. Previously, Kolahi and Khazaei (Kolahi & Khazaei, 2016) described the Altmetric details of the top 50 dental articles published in 2014. However, these authors did not further investigate possible links between article characteristics and AAS or number of citations. Like in the aforementioned study, British Dental Journal and Journal of Dental Research contributed the most articles in the top 100 ranking, too.

The most interesting finding was that articles of Q2 journals received higher online attention than articles of Q1 journals, as depicted by the higher AAS, although articles of Q1 journals outnumbered the articles of Q2 journals in the list of the top 100 articles. Combined with the lack of differences in AAS between the other IF quartile journals, it suggests that articles published in the highest (Q1) IF journals are not expected to trigger more discussions on social media platforms than the ones published in lower profile journals. The true

### TABLE 2 Descriptive statistics of Altmetric Attention Score (AAS) and distribution of articles per subject

<table>
<thead>
<tr>
<th>Subject</th>
<th>n</th>
<th>AAS</th>
<th>Median</th>
<th>Range</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavioral/psychology/quality of life</td>
<td>9</td>
<td>90</td>
<td>69–501</td>
<td>432</td>
<td></td>
</tr>
<tr>
<td>Diagnosis</td>
<td>3</td>
<td>109</td>
<td>80–191</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>19</td>
<td>388</td>
<td>73–524</td>
<td>409</td>
<td></td>
</tr>
<tr>
<td>Facial esthetics</td>
<td>3</td>
<td>106</td>
<td>72–457</td>
<td>.</td>
<td></td>
</tr>
<tr>
<td>Practice management</td>
<td>5</td>
<td>161</td>
<td>70–513</td>
<td>256</td>
<td></td>
</tr>
<tr>
<td>Socio-demographics</td>
<td>17</td>
<td>114</td>
<td>70–458</td>
<td>245</td>
<td></td>
</tr>
<tr>
<td>New techniques/technologies</td>
<td>7</td>
<td>189</td>
<td>72–500</td>
<td>111</td>
<td></td>
</tr>
<tr>
<td>Oral hygiene/caries</td>
<td>24</td>
<td>119</td>
<td>70–443</td>
<td>182.75</td>
<td></td>
</tr>
<tr>
<td>Side effects</td>
<td>9</td>
<td>116</td>
<td>9–1,307</td>
<td>403</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>72</td>
<td>71–212</td>
<td>106</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 4** Distribution of Altmetric Attention Score (AAS) related to time since publication. Horizontal lines indicate median AAS. Asterisk (*) indicates $P < 0.05$

**FIGURE 5** Distribution of Altmetric Attention Score (AAS) in Q1, Q2, Q3 and Q4 journals. Horizontal lines indicate median AAS
reasoning behind this discrepancy can be currently only speculated. Hypothetically, Q2 journals may publish research studies more relevant to the needs of social media users or readers of these journals may be more skilled in sharing online and commenting on articles of interest. Another possible explanation can be that the mentions of the users of the online platforms may be directed to articles of lesser scientific interest for reasons that have still to be determined. Similar trends were seen in previous research on the 100 most cited articles in dentistry according to traditional bibliometric AAS (Feijoo et al., 2014). Although three principal dental journals attracted more than half of the articles included in that list, a substantial number of articles were published in less prestigious journals, with a lower IF (Feijoo et al., 2014).

AAS was not significantly associated with citation counts, even after removing the less likely to have been cited recent studies (time since publication ≤2 years). This is in line with the findings of an extended analysis on research data published in the last five and half decades (Peters, Kraker, Lex, Gumpenberger, & Gorraiz, 2016). Barbic, Tubman, Lam, and Barbic (2016) demonstrated a weak positive correlation between altmetrics and citations for the 50 most frequently cited articles in emergency medicine. Others found some weak evidence of association for six of the eleven source categories screened by altmetric.com (tweets, Facebook wall posts, research highlights, blog mentions, mainstream media mentions, and forum posts) in biomedical sciences and for articles with at least one mention (Thelwall, Haustein, Larivière, & Sugimoto, 2013). Nevertheless, Thelwall et al. (2013) could not further elucidate the effect size of this correlation and warned against the low coverage of all the altmetrics except for Twitter. Overall, when interpreting these conclusions, parameters such as the analyzed sample size, the type of source, and the discipline of the journal need to be considered. Most importantly, it should be stressed that one needs to realize that the new metrics are not meant to replace but complement traditional citation-based metrics (Melero, 2015). The newly introduced metrics are designed to inform about the online presence rather than the scientific quality or significance of research publications. Nonetheless, by combining both types of metrics together, the interest and debate an article generates can be quantified from the moment it is published (Warren, Raison, & Dasgupta, 2017).

The best scoring article, a narrative review published in 2006, which discussed a topic of general interest, that is, the potential carcinogenicity of hydrogen peroxide-based tooth whitening products, was hosted on a Q3 journal. Breakdown of the score showed that this review was heavily mentioned on Facebook pages (55,994 times), bookmarked by nine Mendeley users, tweeted twice, and was cited only five times when considering the time elapsed since publication. Narrative (unsystematic) reviews were predominant in studies that investigated citation-based metrics in dental and endodontic journals (Fardi, Kodonas, Gogos, & Economides, 2011; Feijoo et al., 2014). Putting it all together, it can be assumed that in the eyes of the public, the generalizability of research implications or the potential applicability in everyday life outweighs the low scientific evidence of the study itself.

Although the large body of literature claims the citation advantage of open access articles, researchers are still arguing about the causes and effect of this advantage (Davis, 2011; Davis, Lewenstein, Simon, Booth, & Connolly, 2008; Eysenbach, 2006; Gargouri et al., 2010; Hua, Sun, Walsh, Worthington, & Gleny, 2016). Our analysis showed that there was no significant association of free article access with AAS. This is in agreement with bibliometric studies in dentistry and oral and maxillofacial surgery, in which no significant differences in citations were found between open access and pay-for-access articles (Gaule & Maystre, 2011; Tahim, Bansai, Goodson, Payne, & Sabharwal, 2016). Apparently, other factors than accessibility of research work motivate readers to disseminate or recommend scholarly material online.

Our results demonstrated a tendency for mentions on media, blogs, and reference managers to reach their peak in the first 2 years following publication. On the other hand, articles begin to receive citations 1 or 2 years after publication, and may take up to >10 years, in total, to achieve maximum citation rates (Marx, Schier, & Wanitschek, 2001). An even longer time window, ranging between 10 and 20 years, is usually necessary for a journal article to be recognized as "classic" in a field (Albert, 1988; Garfield, 1987; Hall, 1998). The faster accumulation of citations on electronic media indicates the immediacy of altmetrics in identifying popular new research. Readership interested in the most discussed online research and before standard citation data become available should not expand Altmetric search beyond the second year after publication.

4.1 | Strengths and limitations

Besides the novelties of the present study in terms of objectives and breadth of search, the choice to use Altmetric Explorer can be considered advantageous. Altmetric.com cleans up and normalizes collected data before making it available for analysis. In contrast to other social media monitoring services, Altmetric disambiguates links to outputs. For example, even though some tweets might link to a PubMed abstract, newspapers to the publisher’s site, and blog posts to a dx.doi.org link, Altmetric will take into account they are all related to the same article. Moreover, by counting only one mention from each person per source, intentional or accidental score manipulation can be controlled (Altmetric®). Last but not least, the user-friendly, illustrative, and self-explaining Altmetric interface facilitates navigation and interaction by lay persons.

AAS helps the user to identify at real time the level of online activity arising from a particular research output, without, however, differentiating between positive and negative publicity or quantifying the quality of the topic presented. The fact that allocation of weights in score generation was arbitrarily decided according to assumptions of the developers about their expected reach should not be ignored, either. Additionally, the effect of time on altmetrics as well as the dynamic nature of social media needs also to be acknowledged while comparing traditional and alternative metrics. Associations between different metrics can be easily removed or reversed at different times, even within the same year (Thelwall et al., 2013). Running repeated metrical examinations at short intervals may prove useful in studying how the correlation between scientific and social impact...
indicators develops over time. More research is needed to disclose the identity and motives of social media users publishing citations to academic articles. Differences in users’ groups and attitudes between social media platforms and between disciplines may vary, and therefore should be borne in mind when applying altmetrics in research evaluation (Brigham, 2014; Thelwall et al., 2013). After all, the new metrics aim to capture the online visibility of research work and as such indicators should be viewed. By combining citation metrics and altmetrics, a more holistic assessment of research impact can be substantiated.

5 | CONCLUSIONS

- Article citations are not significantly associated with mentions on Web platforms.
- Analysis of the 100 most popular articles on the Web showed that research articles published in Q1 dental journals outnumbered the articles published in Q2 journals, although the latter attracted significantly higher online attention.
- The electronic profile of Q1 journals needs to be revised in order to reach broader audiences.
- There is a tendency for the articles to reach their peak in online attention in the second postpublication year.
- Combining new and traditional metrics provides a more comprehensive picture of research impact.
- Further comparative studies on the traditional and new metrics will enable our understanding on the scientific and social impact of research output, and its relevance to the larger society.

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AUTHOR CONTRIBUTION

K. Delli: designed the study, developed the methodology, performed the analysis, and wrote the manuscript. C. Livas: designed the study, developed the methodology, performed the analysis, and wrote the manuscript. F.K.L. Spijkervet: wrote the manuscript and approved the final draft. A. Vissink: wrote the manuscript and approved the final draft.

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SUPPORTING INFORMATION
Additional Supporting Information may be found online in the supporting information tab for this article.

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