

# Top-Cited Articles in Implant Dentistry

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**Purpose:** Citation analysis is the field of bibliometrics that uses citation data to evaluate the scientific recognition and the influential performance of a research article in the scientific community. The aim of this study was to conduct a bibliometric analysis of the top-cited articles pertaining to implant dentistry, to analyze the main characteristics, and to display the most interesting topics and evolutionary trends. **Materials and Methods:** The 100 top-cited articles published in "Dentistry, Oral Surgery, and Medicine" journals were identified using the Science Citation Index Database. The articles were further reviewed, and basic information was collected, including the number of citations, journals, authors, publication year, study design, level of evidence, and field of study. **Results:** The highly cited articles in implant dentistry were cited between 199 and 2,229 times. The majority of them were published in four major journals: Clinical Oral Implants Research, International Journal of Oral & Maxillofacial Implants, Journal of Clinical Periodontology, and Journal of Periodontology. The publication year ranged from 1981 to 2009, with 45% published in a nine-year period (2001 to 2009). Publications from the United States (29%) were the most heavily cited, followed by those from Sweden (23%) and Switzerland (17%). The University of Göteborg from Sweden produced the highest number of publications (n = 19), followed by the University of Bern in Switzerland (n = 13). There was a predominance of clinical papers (n = 42), followed by reviews (n = 25), basic science research (n = 21), and proceedings papers (n = 12). Peri-implant tissue healing and health (24%), implant success/failures (19.2%), and biomechanical topics (16.8%) were the most common fields of study. **Conclusion:** Citation analysis in the field of implant dentistry reveals interesting information about the topics and trends negotiated by researchers and elucidates which characteristics are required for a paper to attain a "classic" status. Clinical science articles published in high-impact specialized journals are most likely to be cited in the field of implant dentistry. INT J ORAL MAXILLOFAC IMPLANTS 2017;32:555–564. doi: 10.11607/jomi.5331

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Beginning with Swedish orthopedic surgeon Brånemark's first reports of osseointegration and titanium dental implants, the practice of replacing missing teeth changed the dental practice.<sup>1</sup> Since then, research in implant dentistry has evolved at a rapid pace, and a substantial body of literature has

presented significant developments. Much of the scientific contribution of Brånemark's investigations and that of other important historical advances to dental implant research is reflected in the number of received citations.

Bibliometrics is a field of quantitative science that applies mathematical and statistical methods, such as citation analysis, to evaluate the scientific recognition and the influential performance of a research article in the scientific community. Although the number of citations is not indicative of the quality or the importance of a research paper, it determines the reputation of the authors as well as the journals' impact factor.<sup>2</sup> Web of Science belongs to the Thomson Reuters Corporation and provides electronic access to the world's citation databases. Science Citation Index Expanded, which was developed by the Institute for Scientific Information (ISI), may be accessed via Web of Science Core Collection.<sup>3</sup> Web of Science also publishes the annual Journal Citation Reports, which offers systematic means to critically evaluate the world's leading journals based on citation data.<sup>4</sup>

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المنارة للاستشارات

Evaluation of the academic impact of the published literature is gaining substantial interest. There have been numerous publications that have attempted to generate "citation classics," "top," or "highly" cited papers in different specialties of medical science, including cardiology,<sup>5</sup> radiology,<sup>6,7</sup> orthopedics,<sup>8</sup> emergency medicine,<sup>9</sup> neurosurgery,<sup>10</sup> obstetrics and gynecology,<sup>11</sup> otolaryngology,<sup>12,13</sup> and plastic surgery.<sup>14</sup> Citation analyses have also been conducted to evaluate the scientific performance of authors,<sup>15</sup> journals,<sup>16,17</sup> and countries.<sup>18</sup>

Although there has been a top-citation analysis in general dentistry<sup>19</sup>; in some subspecialties of dentistry, such as orthodontics,<sup>20</sup> endodontics,<sup>21</sup> and periodontology<sup>22</sup>; and in specific dental fields such as dental traumatology<sup>23</sup> and human cleft lip and palate research,<sup>24</sup> no such assessment exists in the field of dental implantology. The aim of this study was to conduct a bibliometric analysis of the top-cited articles pertaining to implant dentistry published in "Dentistry, Oral Surgery, and Medicine" journals and to analyze the main characteristics covering publication year, journals, authors, countries, institutions, and field of study.

## MATERIALS AND METHODS

The methodology provided in the present study was based on the Science Citation Index Expanded database accessed via the Web of Science Core Collection before/and on October 30, 2015. According to Journal Citation Reports of edition year 2014, 88 journals were included under the Institute of Science Information Web of Science subject category "Dentistry, Oral Surgery and Medicine." The keyword "implant\*" was searched in the topic field (including article title, abstract, author, keywords, and Key Words Plus) in Web of Science Core Collection from 1900 to October 2015. No time, language, or any other limitation was applied in the investigation. To limit the search only to relevant studies, the authors used the filter of the "front page," meaning that only articles that contain the indicated keywords on the front page, title, abstract, and author keywords were included. Two independent investigators evaluated the results and selected the 100 top-cited articles dedicated to dental implant research. In case of discrepancy, consensus was reached by involvement of a third investigator. The articles were then ranked by number of citations using the option "Times cited-highest to lowest" listed on the Web of Science and were downloaded into spreadsheet software using Microsoft Excel 2010.

These articles were further reviewed with regard to publication name, number of citations, publication

year, number of authors, institution of the first author (single institution, interinstitutionally, multiuniversity, international collaborative articles), and country of the first author (for the purposes of the research, the institution and the country of the first author was considered as the country of the origin of the article). Furthermore, mean citations per year values (with reference to the year 2015) for all publications were calculated to account for the time bias that is inherent to bibliometric studies. It is known that the simple assessment of absolute citation number favors older papers and risks excluding more recent influential publications.

Each article was further analyzed, and basic information was collected, including article type (clinical research, basic science article, and review), study design, level of evidence, and field of study. Clinical study design included randomized controlled trial (RCT), cohort, case control, cross-sectional study, case series, and case reports. A basic science article was further categorized to biomechanics, in vivo (animal research), or in vitro study. The level of evidence of each article was determined based on criteria published by the Oxford Centre for Evidence-Based Medicine.<sup>25</sup> Finally, papers were characterized according to their field of study into subject areas related to dental implant research. Each publication could be assigned to one or more categories.

## RESULTS

A total of 25,057 documents were identified in the initial search. Among them, 578 were cited more than 100 times. The number of citations of the 100 articles selected varied between 199 and 2,229 (Table 1).<sup>26–125</sup> The mean number of citations per article was 321.

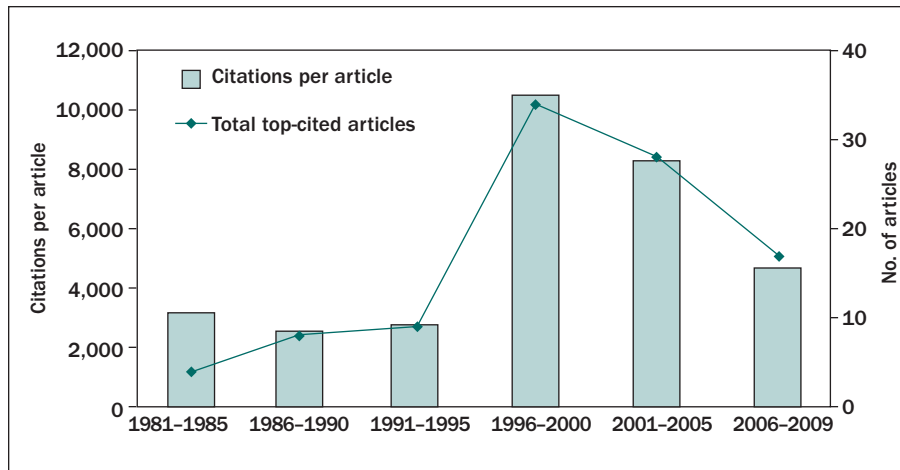
Although it is beyond the scope of this article to analyze each article separately, the subject of the most cited articles shows major trends in dental implant dentistry. The most cited paper, with 2,229 citations and with the topmost growth rate of 64 citations annually, was the study of Adell et al about the rehabilitation of the edentulous jaw using osseointegrated implants, which was published in the *International Journal of Oral Surgery* in 1981.<sup>26</sup> Besides the evaluation and standardization of the surgical protocol and prosthetic techniques, they observed the clinical results achieved on 895 implants for 5 to 9 years (Table 1, rank: 1). The following article, having 736 citations and a smaller mean growth rate of 39 citations per year, was a multicenter study about 2,359 ITI implants placed in 1,003 patients, published in 1997 by Buser et al in *Clinical Oral Implants Research*.<sup>27</sup> One of the concluding remarks stating that "non submerged ITI implants

**Table 1 The 100 Top-Cited Articles in Implant Dentistry**

Rank	Article	Citations	Mean citations
1	Adell et al <sup>26</sup>	2,229	63.68
2	Buser et al <sup>27</sup>	736	38.73
3	Marx et al <sup>28</sup>	698	63.45
4	Jaffin and Berman <sup>29</sup>	605	24.20
5	Esposito et al <sup>30</sup>	579	32.17
6	Le Guéhennec et al <sup>31</sup>	570	63.33
7	Esposito et al <sup>32</sup>	555	30.83
8	Buser et al <sup>33</sup>	503	41.92
9	Schropp et al <sup>34</sup>	464	35.69
10	Buser et al <sup>35</sup>	449	17.27
11	Quirynen and Bollen <sup>36</sup>	433	20.62
12	Albrektsson and Wennerberg <sup>37</sup>	412	34.33
13	Berglundh et al <sup>38</sup>	401	28.64
14	Tarnow et al <sup>39</sup>	401	21.11
15	Anitua <sup>40</sup>	394	23.18
16	Buser et al <sup>41</sup>	391	15.04
17	Albrektsson et al <sup>42</sup>	391	13.96
18	Lindquist et al <sup>43</sup>	370	18.50
19	Smith and Zarb <sup>44</sup>	369	13.67
20	Schnitman et al <sup>45</sup>	366	19.26
21	Berglundh et al <sup>46</sup>	366	14.64
22	Meredith et al <sup>47</sup>	362	18.10
23	Miyawaki et al <sup>48</sup>	361	27.78
24	Scarfe et al <sup>49</sup>	351	35.10
25	Schroeder et al <sup>50</sup>	350	10
26	Meredith <sup>51</sup>	345	19.17
27	Whitman et al <sup>52</sup>	343	18.05
28	Jensen et al <sup>53</sup>	338	18.78
29	Davies <sup>54</sup>	333	18.50
30	Wennerberg et al <sup>55</sup>	329	15.67
31	Kasemo <sup>56</sup>	327	9.91
32	Jung et al <sup>57</sup>	323	40.38
33	Wennerberg and Albrektsson <sup>58</sup>	315	39.38
34	Cochran et al <sup>59</sup>	314	22.43
35	Lekholm et al <sup>60</sup>	312	18.35
36	Berglundh and Lindhe <sup>61</sup>	306	15.30
37	Araújo et al <sup>62</sup>	305	27.73
38	Berglundh et al <sup>63</sup>	302	23.23
39	Geng et al <sup>64</sup>	302	20.13
40	Zarb and Schmitt <sup>65</sup>	300	11.54
41	Aghaloo and Moy <sup>66</sup>	299	33.22
42	Roberts et al <sup>67</sup>	299	9.34
43	Lindhe and Meyle <sup>68</sup>	298	37.25
44	Isidor <sup>69</sup>	293	14.65
45	Manicone et al <sup>70</sup>	291	32.33
46	Tarnow et al <sup>71</sup>	288	18
47	Lazzara and Porter <sup>72</sup>	287	28.7
48	Botticelli et al <sup>73</sup>	286	23.83
49	Albrektsson <sup>74</sup>	285	10.18
50	Goodacre et al <sup>75</sup>	278	21.38

**Table 1 The 100 Top-Cited Articles in Implant Dentistry Cont.**

Rank	Article	Citations	Mean citations
51	Cochran et al <sup>76</sup>	275	14.47
52	Berglundh and Lindhe <sup>77</sup>	271	14.26
53	Zitzmann and Berglundh <sup>78</sup>	269	33.63
54	Buser et al <sup>79</sup>	267	22.25
55	Quirynen et al <sup>80</sup>	257	18.36
56	Zitzmann et al <sup>81</sup>	257	13.53
57	Goodacre et al <sup>82</sup>	256	15.06
58	Del Fabbro et al <sup>83</sup>	255	21.25
59	Buser et al <sup>84</sup>	250	12.5
60	Abrahamsson et al <sup>85</sup>	245	12.25
61	Sánchez et al <sup>86</sup>	244	18.77
62	Gapski et al <sup>87</sup>	242	18.62
63	Pjetursson et al <sup>88</sup>	240	26.67
64	Hermann et al <sup>89</sup>	238	12.53
65	Meredith et al <sup>90</sup>	238	12.53
66	Chiapasco et al <sup>91</sup>	236	12.42
67	Karoussis et al <sup>92</sup>	235	18.08
68	Albrektsson and Wennerberg <sup>93</sup>	233	19.42
69	Kan et al <sup>94</sup>	233	17.92
70	Cheng et al <sup>95</sup>	230	19.17
71	Pjetursson et al <sup>96</sup>	228	28.5
72	Teughels et al <sup>97</sup>	228	22.8
73	Mericske-Stern et al <sup>98</sup>	228	10.36
74	Pjetursson et al <sup>99</sup>	227	18.92
75	Piattelli et al <sup>100</sup>	223	13.12
76	Kent and Block <sup>101</sup>	221	08.19
77	Choquet et al <sup>102</sup>	219	14.6
78	Fontijn-Tekamp et al <sup>103</sup>	217	13.56
79	Brånemark et al <sup>104</sup>	217	10.33
80	Roberts et al <sup>105</sup>	217	8.04
81	Roos-Jansåker et al <sup>106</sup>	216	21.6
82	Kan et al <sup>107</sup>	216	16.62
83	Lascaia et al <sup>108</sup>	215	17.92
84	Abrahamsson et al <sup>109</sup>	214	17.83
85	Randow et al <sup>110</sup>	213	12.53
86	Klokkevold et al <sup>111</sup>	213	11.21
87	Szmukler-Moncler et al <sup>112</sup>	211	13.19
88	Lekovic et al <sup>113</sup>	210	11.05
89	McAllister and Haghghat <sup>114</sup>	208	23.11
90	Wetzel et al <sup>115</sup>	208	9.91
91	Hermann et al <sup>116</sup>	206	13.73
92	Misch <sup>117</sup>	205	10.79
93	Abrahamsson et al <sup>118</sup>	204	10.74
94	Hebel and Gajjar <sup>119</sup>	204	10.74
95	Heitz-Mayfield <sup>120</sup>	203	25.38
96	Chiapasco et al <sup>121</sup>	203	20.3
97	Park et al <sup>122</sup>	203	20.3
98	Chen et al <sup>123</sup>	201	16.75
99	Becker et al <sup>124</sup>	200	9.1
100	Pontoriero et al <sup>125</sup>	199	9.05



**Fig 1** Number of articles and citations per article in implant dentistry.

maintain survival and success rates well above 90% for observation periods up to 8 years” reveals that research interests emphasize the implant success rates and elucidates why this paper remains among the highest cited articles in dental implant literature. The third most cited paper, published in 2005 by Marx et al in the *Journal of Oral and Maxillofacial Surgery*,<sup>28</sup> described 119 cases of bisphosphonate-related bone exposure, and received 698 citations (mean citation rate increase: 63 citations annually) in very few years.

In terms of the citations per year, five articles ranking third, sixth, eighth, 32nd, and 33rd had greater mean growth rate than the Buser et al study<sup>27</sup> (rank: 2). The common feature of these articles is the publication year (all published after 2004). Indeed, the paper of Le Guéhennec et al (rank: 6) published in 2007,<sup>31</sup> which describes the different surfaces and methods that enhance implant osseointegration, collected 570 citations in 8 years, presenting a high citation rate increase (63 citations annually).

The 100 top-cited articles were published in the past 29 years from 1981 to 2009, with 12 published before 1990, 43 between 1991 and 2000, and 45 between 2001 and 2009. Figure 1 illustrates the distribution of these 100 articles over the years and their citations per publication. The three most productive years were 1997 (15 articles), 2004 (11 articles), and 2003 (9 articles). As articles need time to accumulate citations, neither of the most cited articles were published in the most recent 5 years (2010 to 2015). Eighty-eight percent of the most cited articles were published after 1991.

The Journal Citation Reports 2014 indexes 88 journals with citation references under the subcategory “Dentistry, Oral Surgery, and Medicine.” The majority of the highly cited articles were published in 18 journals with impact factors ranging from 0.358 to 4.139. *Clinical Oral Implants Research* published the highest number of top-cited papers ( $n = 32$ ), followed by the

*International Journal of Oral & Maxillofacial Implants* with 14 and the *Journal of Clinical Periodontology* with 11 (Table 2). The *Journal of Periodontology* and the *Journal of Prosthetic Dentistry* contributed 10 and 8 articles to the list, respectively, despite their high impact factors.

The number of authors ranged from 1 to 16. Eight articles were written by a single author and 16 by two authors. Twenty-six and 27 articles were published by three and four authors, respectively, while the other 23 publications were attributed to five or more investigators. A total of 264 authors contributed to the highly cited publications; 217 (82.2%) and 26 (9.8%) of them published one and two top-cited papers, respectively. Table 3 lists the top 21 authors with three or more highly cited papers. Although Niklaus P. Lang had no articles as first author, he was the most cited author with 12 out of 100 articles, followed by Daniel Buser and Tord Berglundh with 10 articles each, Jan Lindhe with 9 articles, and Tomas Albrektsson with 6 publications (Table 3).

Altogether, the 100 highly cited articles originated from 19 countries (Table 4). The United States had the largest number of top-cited publications ( $n = 29$ ). Sweden and Switzerland published 23 and 17 articles, respectively, whereas Belgium and Italy contributed five articles each to the list. The highly productive institutions appear in Table 5, with the University of Göteborg of Sweden (19 articles) and the University of Bern of Switzerland (13 articles) leading the list. Loma Linda University in California, University of Leuven in Belgium, and University of Texas Health Science Center at San Antonio produced four articles each. Concerning the collaboration type, 51 articles came from independent institutions, 7 from interinstitutional collaborations within the same university, 14 from multiuniversity collaboration within the same country, and 28 articles were the product of international collaborations.

**Table 2 Dental Journals in Which the 100 Top-Cited Articles Were Published**

Journal name	2014 journals' impact factor	No. of articles included in the top 100
<i>Clinical Oral Implants Research</i>	3.889	32
<i>International Journal of Oral &amp; Maxillofacial Implants</i>	1.451	14
<i>Journal of Clinical Periodontology</i>	4.010	11
<i>Journal of Periodontology</i>	2.706	10
<i>Journal of Prosthetic Dentistry</i>	1.753	8
<i>International Journal of Prosthodontics</i>	1.464	4
<i>Journal of Oral &amp; Maxillofacial Surgery</i> <sup>a</sup>	1.425	4
<i>American Journal of Orthodontics &amp; Dentofacial Orthopedics</i>	1.382	3
<i>International Journal of Periodontics &amp; Restorative Dentistry</i>	1.415	3
<i>European Journal of Oral Sciences</i>	1.488	2
<i>Journal of Dental Research</i>	4.139	2
<i>Angle Orthodontist</i>	1.225	1
<i>Dental Materials</i>	3.769	1
<i>Dentomaxillofacial Radiology</i>	1.390	1
<i>International Journal of Oral Surgery</i> <sup>b</sup>	1.565	1
<i>Journal of Dentistry</i>	2.749	1
<i>Journal of Maxillofacial Surgery</i>	2.933	1
<i>Journal of the Canadian Dental Association</i>	0.358	1

<sup>a</sup>Continued as *Journal of Cranio-Maxillofacial Surgery*.

<sup>b</sup>Continued as *International Journal of Oral and Maxillofacial Surgery*.

**Table 4 Countries of Origin of the 100 Top-Cited Articles in Implant Dentistry**

Country	No. of articles
USA	29
Sweden	23
Switzerland	17
Belgium	5
Italy	5
United Kingdom	3
Australia	2
Brazil	2
Canada	2
Denmark	2
France	2
Germany	1
Japan	1
Iceland	1
Netherlands	1
Singapore	1
South Korea	1
Spain	1
Taiwan	1

**Table 3 Authors of the Top-Cited Articles**

Author	First author	Coauthor	Total
Lang NP	0	12	12
Buser D	6	4	10
Berglundh T	5	5	10
Lindhe J	1	8	9
Albrektsson T	4	2	6
Cochran DL	2	3	5
Abrahamsson I	3	1	4
Pjetursson BE	3	1	4
Kan JYK	2	2	4
Wennerberg A	2	2	4
Lekholm U	1	3	4
Brägger U	0	4	4
Rungcharassaeng K	0	4	4
Schenk RK	0	4	4
Zwahlen M	0	4	4
Hermann JS	2	1	3
Quirynen M	2	1	3
Tarnow DP	2	1	3
Meredith N	0	3	3
Thomsen P	0	3	3
van Steenberghe D	0	3	3

**Table 5 Institutions of Origin with Two or More Top-Cited Articles in Implant Dentistry**

Institution	No. of articles
University of Göteborg	19
University of Bern	13
Loma Linda University	4
University of Leuven	4
University of Texas Health Science Center at San Antonio	4
University of Bristol	3
University of California Los Angeles	3
University of Milan	3
University of Zurich	3
Aarhus University	2
New York University	2
University of Toronto	2

**Table 6 Study Design of the 100 Top-Cited Articles in Implant Dentistry**

Study design	Level of evidence	No. of articles
<b>Clinical</b>		
RCT	(EL 2)	2
Cohort	(EL 3)	6
Case series	(EL 4)	19
Poor quality cohort	(EL 4)	9
Cross sectional	(EL 4)	6
Total		42
<b>Review</b>		
Narrative	(EL 5)	18
Systematic	(EL 1)	7
Total		25
<b>Basic</b>		
In vivo	(EL 5)	19
In vitro	(EL 5)	2
Total		21
<b>Proceedings papers</b>		12

**Table 7 Field of Study of Top-Cited Articles**

Field of study	No. (%)
Peri-implant tissue healing and health	30 (24)
Implant success/failure	24 (19.2)
Biomechanics	21 (16.8)
Augmentation procedures and grafts	19 (15.2)
Implant loading	11 (8.8)
Surgical aspects	5 (4)
Esthetics	4 (3.2)
Orthodontic implants	4 (3.2)
Prosthodontic aspects	3 (2.4)
Preoperative imaging CBCT	2 (1.6)
Impact of patient's general health	2 (1.6)

Forty-two articles were classified as clinical research, 25 were reviews of the literature, and 21 were basic research projects. The remaining 12 studies were proceedings papers. The most common methodologic designs were uncontrolled case series (19 articles), basic in vivo animal studies (19 articles), followed by narrative review articles (18 articles). Twenty-one observational studies, including nine poor quality cohort, six cohort, and six cross-sectional studies, were identified in the top 100 list. Seven and two papers out of the top 50 were considered as level I or II evidence, consisting of systematic reviews and RCTs, respectively (Table 6). None of the top 100 articles was categorized as a meta-analysis.

The top 11 subject areas covered in highly cited papers of implant literature (presented as percentage of all published articles) were peri-implant tissue healing and health (24%; 8% of them assigned peri-implant disease, 5.6% osseointegration, and 4% peri-implant soft tissues), implant success/failure (19.2%), biomechanics (16.8%; including implant surface [10.4%] and implant stability [4.8%]). Furthermore, augmentation procedures and grafts (15.2%); implant loading (8.8%); surgical issues (4%), including immediate implant placement (3.2%); esthetics (3.2%); orthodontic implants (3.2%); prosthodontic topics (2.4%); preoperative imaging, particularly cone beam computed tomography (1.6%); and impact of patient's general health (1.6%) ranged among the top issues (Table 7).

## DISCUSSION

The field of implant dentistry is an ever-changing domain with new developments occurring every day. From the late 20th century to the present day, implant dentistry has evolved into an evidence-based clinical science. The purpose of the present study was to identify the most cited articles in the field of implant dentistry in "Dentistry, Oral Surgery and Medicine" journals. According to the definition adapted by the Journal Citation Reports, for the journals included under the subcategory "Dentistry, Oral Surgery and Medicine," the subcategory "covers resources on the anatomy, physiology, biochemistry, and pathology of the teeth and oral cavity. Thus, this category of journals covers a wide variety of sub-disciplines ranging from basic sciences to clinical specialties. Specifically, it includes resources on periodontal disease, dental implants, oral and maxillofacial surgery, oral pathology, as well as on community and public health dentistry, and pediatric dentistry."<sup>3</sup>

Although the number of times a published paper is cited is not indicative of its scientific value, it displays its influence in the progress of the respective research field. Nonetheless, the number of citations for an article depends not only on its scientific significance, but also on the research field that it covers. Thus, a paper related to cardiology (331 to 3,484)<sup>5</sup> may have more citations than a paper related to dentistry (326 to 2,050),<sup>19</sup> although both of them have the same scientific significance. The top 100 articles in implant dentistry were cited between 199 and 2,229 times. This range is higher than what was observed in other dental fields such as endodontology in 2011 (87 to 554),<sup>21</sup> periodontology in 2007 (100 to 346),<sup>22</sup> and orthodontics in 2013 (89 to 545).<sup>20</sup> The most highly cited articles were published in a variety of journals, 18 in all. More than half (67) of these articles were published in four

major journals: *Clinical Oral Implants Research*, *International Journal of Oral & Maxillofacial Implants*, *Journal of Clinical Periodontology*, and *Journal of Periodontology*. The first two journals are dedicated solely to dental implant research, while the second ones cover the field of implant and periodontal research.

Consistent with many other citation analyses,<sup>9,20,21</sup> the majority of the most cited publications (29%) originated from academic institutions in the United States, which is attributed to the large number of researchers and adequate research budgets for scientific investigation. Although the United States is the leading country in the number of medical research publications, there were an increasing number of highly cited publications (61 articles) by authors residing in Europe. It is also worth noting that only eight articles originating from the United States resulted from international collaborations, while the rest of them were produced either by one institution (14 articles) or by multicentered collaborations (one paper from interinstitutional collaboration and six from multiuniversity collaboration). The University of Göteborg and the University of Bern published five international collaborative articles each.

The most highly cited articles in implant dentistry were in the field of clinical science (42%), which is in accordance with the majority of citation analysis in dentistry<sup>19</sup> and in other medical disciplines, which reports the dominance of clinical rather than basic science articles.<sup>6,14,17,20</sup> This also reflects the surgical nature of implant dentistry, which emphasizes surgical technique. Contrary to the present results, basic research was leading the top-cited list in the field of endodontics,<sup>21</sup> whereas review articles were the dominant research type in the bibliometric analysis of cardiovascular literature.<sup>5</sup> The high percentage (37%) of reviews and proceedings papers among the highly cited papers in implant dentistry might be attributed to the preference of authors to cite the reviewed knowledge instead of the original research articles. In the present analysis regarding the levels of evidence, the majority of articles were of levels IV and V, consisting of uncontrolled case series, narrative reviews, and basic research papers. Surprisingly, there were only two RCTs and seven systematic reviews. Coinciding with the tendency observed in dentistry<sup>19,20,22</sup> and in other surgical disciplines,<sup>11,14</sup> in implant dentistry, research with a higher number of citations does not correlate with a high level of evidence.

The fields of study of the highly cited articles normally vary from one decade to another and reflect scientific interests in a certain period. In the present analysis, peri-implant tissue healing and health was the predominant research subject. The majority of studies that fell into this category were studies that evaluated peri-implant diseases, peri-implant tissue

healing, particularly osseointegration and peri-implant soft tissues. The second most common research area was implant success/failures, including survival rates and complications. Biomechanical topics, including implant surface and stability studies, were represented adequately among the cited subjects and were followed at a small distance by augmentation procedures and grafts. Coverage of loading topics was higher than other fields such as surgical and prosthodontic topics, esthetics, and orthodontic implants. The least extensively cited subjects were preoperative imaging and the impact of patient's general health.

Although the authors tried not to eliminate results of the study by applying the least possible exclusion criteria, the inherent limitations of citation analyses were inevitable. First and foremost, this type of analysis is usually beneficial for older publications, which have the advantage of time and are proceeding in the citation ranking, while recent innovative publications are often omitted.<sup>126</sup> Indeed, almost half of the top-cited articles (48%) in implant dentistry were published in the past 15 years. According to the present results, a minimum publication period of 6 to 15 years is required for an article to accumulate a sufficient number of citations and become citation classics. However, the authors tried to minimize the effect of time by assessing the mean citations per year. They observed that articles published the last 10 years presented high annual citation growth rates. This can be explained by the fact that older and even "true classics" articles are progressively cited less often, since their information is being adopted by the current knowledge through time.

Secondly, only one electronic medical bibliographic resource was investigated, which might have affected the final top list. Indeed, it has been shown that a lot of significant differences exist between different databases.<sup>127,128</sup> Additionally, the search tools used to gather bibliographic data do not take into consideration self-citation by a journal or an author or the potential bias of authors who prefer citing articles from colleagues or from the journal in which the paper will be published.<sup>129</sup> Last but not least, the search of the highly cited work was restricted to journals belonging to the subcategory "Dentistry, Oral Surgery and Medicine." In other words, some influential papers with a high number of citations published in other nondental scientific journals were unavoidably excluded by the methodology used in this investigation. For example, an animal study by Buser et al about the influence of different surface characteristics on bone integration of titanium implants, with 989 citations, was not included, as it was published in a journal categorized in the research area of Engineering and Materials Science.<sup>130</sup> For the same reason, a review paper by Szmukler-Moncler et al, which evaluated the effect of time loading and

micromotion on the bone-implant interface, was also excluded. In spite of the 353 citations, the paper was published in a nondental journal and unavoidably was not included.<sup>131</sup> Brånemark's influential paper published in 1983 in the *Journal of Prosthetic Dentistry* and cited more than 700 times has also been omitted as it lacks an abstract and keywords.<sup>1</sup>

## CONCLUSIONS

This bibliometric analysis provides insight into the progress and the interesting trends of dental implant research over the last 30 years. Obviously, this is a dynamic list that is changing over time, according to scientific interests and prevalent research tendency that has evolved over the decades. It is interesting that the topics of "peri-implant tissue healing and health" and "implant success/failure" were well represented in the top 100 articles. Clinical science articles published in high-impact specialized journals are most likely to be cited in the field of implant dentistry. It is recommended that dentists who claim expertise in implant dentistry should acknowledge all these important articles on this list. It will also be interesting to see if the growing demand for evidence-based dentistry will influence the quality of implant research articles in the future, and eventually, the top 100 list will include more high-level evidence studies.

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