

Clear aligners: A network and bibliometric analysis of 50 pivotal articles

Vincenzo Grassia^{1,A,D–F}, Adriana Fiori^{2,B}, Federica Diodati^{2,B}, Babak Sayahpour^{3,C,E}, Abdolreza Jamilian^{4,5,C,E}, Niccolò Giuseppe Armogida^{6,B}, Fabrizia d'Apuzzo^{1,D}, Ludovica Nucci^{7,A,F}

¹ Multidisciplinary Department of Medical-Surgical and Dental Specialties, University of Campania “Luigi Vanvitelli”, Naples, Italy

² Postgraduate Orthodontic Program, University of Campania “Luigi Vanvitelli”, Naples, Italy

³ Department of Orthodontics, Goethe University Frankfurt, Germany

⁴ Department of Orthodontics, Dental School, Craniomaxillofacial Research Center, Tehran Medical Sciences Branch, Islamic Azad University of, Iran

⁵ City of London Dental School, University of Bolton, London, UK

⁶ Department of Neuroscience, Reproductive Sciences and Dentistry, University of Naples Federico II, Italy

⁷ Department of Mental and Physical Health and Preventive Medicine, University of Campania “Luigi Vanvitelli”, Naples, Italy

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;

D – writing the article; E – critical revision of the article; F – final approval of the article

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Address for correspondence

Niccolò Giuseppe Armogida

E-mail: ng.armogida@gmail.com

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Abstract

Background. A bibliometric analysis uses statistical and mathematical methods to analyze the published literature, extracting meaningful information that helps to identify trends, assess research impact, and visualize key data patterns through graphs and trendlines.

Objectives. The aim of the study was to list the top 50 papers on clear aligners, evaluate them critically and apply a bibliometric analysis to investigate the achievements and prospects in this field of study.

Material and methods. A computerized database search (Scopus) was conducted on September 24, 2023, to find articles on clear aligners published in the scientific literature between 2013 and 2023. The top 50 cited manuscripts were chosen. Author-based characteristics were obtained from the Scopus database. The dataset from Clarivate™ InCites Benchmarking & Analytics™ and Journal Citation Reports (JCR) was used to determine parameters based on journals and articles. To improve the visual analysis, the keywords were collected systematically from the chosen articles.

Results. The database search produced a directory of the 50 most often cited articles out of 1,405 papers. Of the 50 most frequently cited works on clear aligners, 35 (70.0%) were original research studies and 15 (30.0%) were reviews. The keyword–network analysis indicated ‘removable orthodontic appliance’ as the most important and repetitive keyword.

Conclusions. The results of the present bibliometric study indicated that clear aligner therapy (CAT)-related papers received increasing citations. The study determined the most influential articles by highlighting their authors and the journals in which the papers were published.

Keywords: bibliometric analysis, orthodontics, network analysis, clear aligner, clear aligner treatment

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Highlights

- The number of research papers on dental aligners and their citations have been steadily increasing year over year.
- Advancement in clear aligner therapy (CAT) relies heavily on well-designed RCTs, yet these make up only a small percentage of the top 50 most cited CAT studies.
- Many studies, particularly in vitro and laboratory-based studies, contribute only slightly to the scientific evidence.
- Three major journals account for 54% of all CAT publications.
- According to the keyword co-occurrence network (KCN), the primary research areas with regard to CAT are bio-mechanics, the physical characteristics of materials, the predictability of tooth movements, and the impact of CAT on periodontal health.

Introduction

Since Dr. H. Kesling developed a set of thermoplastic tooth positioners to gradually achieve teeth alignment in 1946, clear aligners have been used in orthodontics.

The introduction of new materials, dental attachments, tooth movement staging, interproximal enamel reduction, and the use of inter-arch elastics to handle several kinds of malocclusion have all contributed to a significant change in the handling over the last 15 years.^{1–6}

Nowadays, clear aligner therapy (CAT) is an effective alternative to the conventional fixed appliances (FA) in orthodontics because of rapid advancement in technology and computer-aided design and manufacturing (CAD/CAM).^{7–9}

Adult patients prefer clear aligners for their comfort and esthetics. This is why the demand for aligners has greatly increased. All over the world, there are numerous brands of clear aligners, each with distinctive features and efficacy.^{3,10–12}

As a consequence of the technological progress, there have been a lot of research projects and publications regarding clear aligners, which may make it more difficult for researchers to obtain accurate data.^{13,14}

Citations indicate a relationship between authors, research teams, study subjects, or nations. They are a tool for measuring the influence and frequently the quality of a publication in a certain field. Furthermore, mapping bibliometric networks with a graphical analysis can offer a clear and thorough summary of a sizable dataset.¹⁵

A bibliometric analysis is a mathematical and statistical method of quantitative measurement to assess the quality of publications within a scientific research area. Several details on authors, journals and articles might be highlighted through this process; moreover, a visual network analysis might be provided for the keywords of these articles.¹⁶

As far as we know, network and bibliometric analyses have been used in different dentistry fields, although surveys on clear aligners have not been carried out recently.^{15,17}

Thus, the goal of the present study was to carry out a bibliometric analysis of the 50 most often cited articles on clear aligners to allow a clearer view and to improve research on this topic.

Material and methods

Search strategy

On September 24, 2023, two authors independently conducted a database search to find papers on clear aligners published in the scientific literature considering the last 10 years (from 2013 to 2023), as shown in Fig. 1.

The keywords used in the Scopus database (Elsevier, Amsterdam, the Netherlands) for the advanced search were: (“orthodontic” OR “orthodontic treatment” OR “orthognathic”) AND (“clear aligner” OR “attachments” OR “3d printed aligner” OR “digital set up” OR “digital planning” OR “customized aligner” OR “thermoforming aligner” OR “digital models” OR “clear aligner treatment” OR “clear aligner therapy” OR “invisible orthodontics”). Scopus was chosen to narrow the publication time of papers and locate all possibly relevant research, independent of the kind of publishing. As reported in the literature, Scopus allows access to articles in all fields.¹⁸ The database is easy to search and covers more journals than PubMed® and the Web of Science, adding more precise information regarding citations and authors.

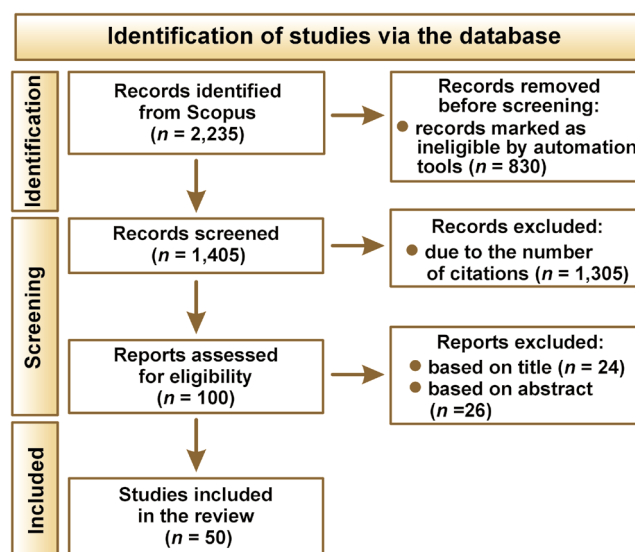


Fig. 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of the study

Each author downloaded the complete records of the publications retrieved from Scopus into a Microsoft Excel spreadsheet (Microsoft Corp., Redmond, USA). At this stage, the papers were independently screened by 2 reviewers (A.F and F.D.) according to titles and abstracts to determine the eligibility of the studies, excluding any papers that did not directly relate to clear aligners. In case of disagreement, a third reviewer contributed to reaching a consensus (V.G.). The 2 authors then carried out full-text screening. All the articles not concerning clear aligners were excluded. Therefore, out of the remaining papers, only the 50 papers on clear aligners most often cited in the literature were included in the bibliometric analysis.

The sample comprised papers on all types of clear aligners, regardless of the brand.

Data extraction

Article-based bibliometric parameters

The following article-based bibliometric data was extracted using the Scopus database: title; author(s); journal; keywords; publication year; study design; total number of citations; and the mean number of citations/year.

Journal-based bibliometric parameters

The journal-based bibliometric data listed below was gathered using Clarivate™ InCites Benchmarking & Analytics™ and Journal Citation Reports (JCR): the 2022 Journal Impact Factor (JIF), an indicator of the importance of a journal, derived from the data indexed in the Web of Science Core Collection (if available); quartile with regard to the category “Dentistry, Oral Surgery & Medicine”; Eigenfactor Score (EF), measuring the number of times the articles from the journal published in the past 5 years have been cited in the JCR year; Normalized Eigenfactor Score (nEF), using journal year rescaling; Article Influence Score (AI), which normalizes EF by determining the average influence of the journal’s articles over the first 5 years after publication; 5-Year Journal Impact Factor (5-JIF), considered as the average number of times the articles from the journal published in the past 5 years have been cited in the JCR year; and Immediacy Index, the count of citations in the current year to the journal that reference content in this same year.

Author-based bibliometric parameters

With the help of the Scopus database, the following author-based bibliometric parameters were extracted: name; affiliation; country; H-index; number of articles among the top 50 articles about clear aligners; and number of citations of the papers which made up the top 50 articles about clear aligners.

Results

Articles

From the research query, 2,235 papers were found. With regard to the years 2013–2023, 1,405 papers were found through applying a limiting filter; they were collected from the most cited to the least cited ones.

Table 1 details the top 50 articles on clear aligners.^{1,2,4–10,13,14,19–57}

Of the 50 articles, 24 were about Invisalign® (Align Technology, San Jose, USA), while the remaining 26 were about unspecified clear aligners.

A total of 35 (70%) articles were original articles, and the remaining 15 (30%) were reviews. Among the 35 original papers, 14 were prospective studies, with 2 RCTs (28%), 12 were retrospective studies (24%), 6 were in vitro studies (12%), 2 were finite element analysis studies (4%), and 1 study had a cross-sectional design (2%). Among the reviews, 7 were systematic reviews (14%), 6 were reviews (12%), and only 2 were meta-analyses (4%). Further details are shown in Fig. 2.

The oldest article was from 2013 and the most recent papers were from 2021. The year 2020 was the publication year for as many as 11 papers, whereas 2015 was the year with the greatest number of citations (Fig. 3). The most often cited paper about clear aligners has collected 289 citations and was published by *Angle Orthodontist* in 2015; it is a systematic review titled: “Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review.”⁴ The second most often cited article is titled “Treatment outcome and efficacy of an aligner technique – regarding incisor torque, premolar derotation, and molar distalization”; it is a retrospective study published in 2014 by *BMC Oral Health*, which has been cited 144 times.¹⁴ The third article is a retrospective study reporting 113 citations; it is titled “Forces and moments generated by removable thermoplastic aligners: Incisor

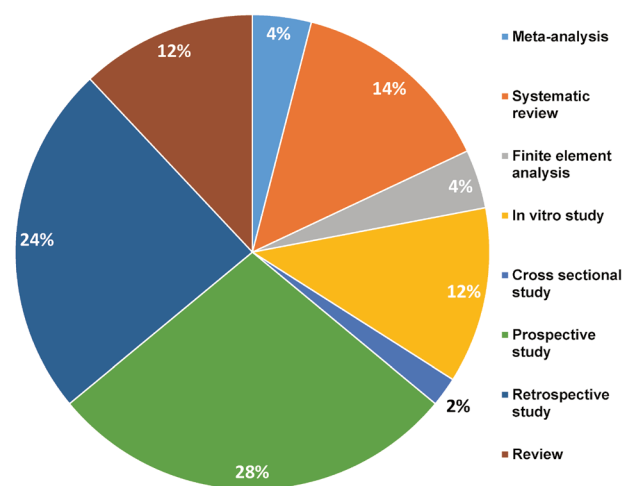


Fig. 2. Study design distribution for the 50 most cited articles on clear aligner therapy (CAT)

Table 1. The 50 most cited articles on clear aligners therapy (CAT)

Ranking	Title	Author(s)	Journal	Publication year	Study design	Total number of citations	Mean number of citations/year
1	Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review ⁴	Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL	Angle Orthodontist	2015	systematic review	289	32.1
2	Treatment outcome and efficacy of an aligner technique – regarding incisor torque, premolar derotation and molar distalization ¹⁴	Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C	BMC Oral Health	2014	retrospective study	144	14.4
3	Forces and moments generated by removable thermoplastic aligners: Incisor torque, premolar derotation, and molar distalization ¹³	Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C	American Journal of Orthodontics and Dentofacial Orthopedics	2014	retrospective study	113	11.3
4	Clear aligners in orthodontic treatment ¹⁹	Weir T	Australian Dental Journal	2017	review	109	15.6
5	Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign ⁷	Haouili N, Kravitz ND, Vaid NR, Ferguson DJ, Makki L	American Journal of Orthodontics and Dentofacial Orthopedics	2020	prospective study	99	24.8
6	Efficiency, effectiveness and treatment stability of clear aligners: A systematic review and meta-analysis ⁸	Zheng M, Liu R, Ni Z, Yu Z	Orthodontics and Craniofacial Research	2017	systematic review and meta-analysis	90	12.9
7	Initial force systems during bodily tooth movement with plastic aligners and composite attachments: A three-dimensional finite element analysis ²⁰	Gomez JP, Peña FM, Martínez V, Giraldo DC, Cardona CI	Angle Orthodontist	2015	finite element analysis	88	9.7
8	Periodontal health during clear aligners treatment: A systematic review ²¹	Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL	European Journal of Orthodontics	2015	systematic review	84	9.3
9	Effectiveness of clear aligner therapy for orthodontic treatment: A systematic review ⁹	Robertson L, Kaur H, Fernandes Fagundes NC, Romanyk D, Major P, Mir CF	Orthodontics and Craniofacial Research	2020	systematic review	77	19.3
10	A comparison of treatment effectiveness between clear aligner and fixed appliance therapies ²³	Ke Y, Zhu Y, Zhu M	BMC Oral Health	2019	systematic review	74	14.8
11	Accuracy of clear aligners: A retrospective study of patients who needed refinement ²²	Charalampakis O, Iliadi A, Ueno H, Oliver DR, Kim KB	American Journal of Orthodontics and Dentofacial Orthopedics	2018	retrospective study	74	12.3
12	Analysis of pain level in cases treated with Invisalign aligner: Comparison with fixed edgewise appliance therapy ²⁴	Fujiyama K, Honjo T, Suzuki M, Matsuoka S, Deguchi T	Progress in Orthodontics	2014	prospective study	71	7.1
13	The predictability of transverse changes with Invisalign ²⁵	Houle JP, Piedade L, Todescan R Jr., Pinheiro FH	Angle Orthodontist	2017	retrospective study	70	10.0
14	A systematic review of the accuracy and efficiency of dental movements with Invisalign ^{®10}	Galan-Lopez L, Barcia-Gonzalez J, Plasencia E	Korean Journal of Orthodontics	2019	systematic review	66	13.2
15	Periodontal health status in patients treated with the Invisalign [®] system and fixed orthodontic appliances: A 3 months clinical and microbiological evaluation ²⁶	Levrini L, Mangano A, Montanari P, Margherini S, Caprioglio A, Abbate GM	European Journal of Dentistry	2015	prospective study	63	7.0
16	Mechanical and geometric properties of thermoformed and 3D printed clear dental aligners ²⁷	Jindal P, Juneja M, Siena FL, Bajaj D, Breedon P	American Journal of Orthodontics and Dentofacial Orthopedics	2019	in vitro study	62	12.4
17	Periodontal health during orthodontic treatment with clear aligners and fixed appliances: A meta-analysis ²⁸	Jiang Q, Li J, Mei L, Du J, Levrini L, Abbate GM, Li H	Journal of the American Dental Association	2018	meta-analysis	57	9.5

Ranking	Title	Author(s)	Journal	Publication year	Study design	Total number of citations	Mean number of citations/year
18	Effects of variable attachment shapes and aligner material on aligner retention ²⁹	Dasy H, Dasy A, Asatrian G, Rózsa N, Lee HF, Kwak JH	Angle Orthodontist	2015	in vitro study	56	6.2
19	Clear aligners generations and orthodontic tooth movement ³⁰	Hennessy J, Al-Awadhi EA	Journal of Orthodontics	2016	prospective study	55	6.8
20	Variables affecting orthodontic tooth movement with clear aligners ³¹	Chisari JR, McGorray SP, Nair M, Wheeler TT	American Journal of Orthodontics and Dentofacial Orthopedics	2014	prospective study	50	5.0
21	Comparison of achieved and predicted tooth movement of maxillary first molars and central incisors: First premolar extraction treatment with Invisalign ³²	Dai FF, Xu TM, Shu G	Angle Orthodontist	2019	retrospective study	47	9.4
22	Salivary concentrations of Streptococcus mutans and Lactobacilli during an orthodontic treatment. An observational study comparing fixed and removable orthodontic appliances ³³	Mummolo S, Tieri M, Nota A, Caruso S, Darvizeh A, Albani F, Gatto R, Marzo G, Marchetti E, Quinzi V, Tecco S	Clinical and Experimental Dental Research	2020	prospective study	46	11.5
23	Salivary levels of Streptococcus mutans and Lactobacilli and other salivary indices in patients wearing clear aligners versus fixed orthodontic appliances: An observational study ³⁴	Mummolo S, Nota A, Albani F, Marchetti E, Gatto R, Marzo G, Quinzi V, Tecco S	PLoS One	2020	prospective study	46	11.5
24	Accuracy of interproximal enamel reduction during clear aligner treatment ²	De Felice ME, Nucci L, Fiori A, Flores-Mir C, Perillo L, Grassia V	Progress in Orthodontics	2020	retrospective study	45	11.3
25	Impact of molar teeth distalization with clear aligners on occlusal vertical dimension: A retrospective study ³⁵	Caruso S, Nota A, Ehsani S, Maddalone E, Ojima K, Tecco S	BMC Oral Health	2019	retrospective study	44	8.8
26	The oral microbiota changes in orthodontic patients and effects on oral health: An overview ³⁶	Contaldo M, Lucchese A, Lajolo C, Rupe C, Di Stasio D, Romano A, Petrucci M, Serpico R	Journal of Clinical Medicine	2021	review	39	13.0
27	Clear aligner orthodontic therapy of rotated mandibular round-shaped teeth: A finite element study ³⁷	Cortona A, Rossini G, Parrini S, Deregibus A, Castroflorio T	Angle Orthodontist	2020	finite element analysis	39	9.8
28	Design of the Invisalign system performance ³⁸	Morton J, Derakhshan M, Kaza S, Li C	Seminars in Orthodontics	2017	review	39	5.8
29	Prevalence and severity of apical root resorption during orthodontic treatment with clear aligners and fixed appliances: A cone beam computed tomography study ³⁹	Li Y, Deng S, Mei L, Li Z, Zhang X, Yang C, Li Y	Progress in Orthodontics	2020	retrospective cohort study	38	9.5
30	Clear aligner treatment: Different perspectives between orthodontists and general dentists ¹	d'Apuzzo F, Perillo L, Carrico CK, Castroflorio T, Grassia V, Lindauer SJ, Shroff B	Progress in Orthodontics	2019	cross-sectional study	38	7.6
31	Which orthodontic appliance is best for oral hygiene? A randomized clinical trial ⁴⁰	Chhibber A, Agarwal S, Yadav S, Kuo CL, Upadhyay M	American Journal of Orthodontics and Dentofacial Orthopedics	2018	prospective study (RCT)	37	6.2
32	YouTube as a source of information about orthodontic clear aligners ⁴¹	Ustdal G, Guney AU	Angle Orthodontist	2020	review	36	9.0
33	Efficiency of upper arch expansion with the Invisalign system ⁴²	Zhou N, Guo J	Angle Orthodontist	2020	retrospective study	36	9.0
34	Movement of anterior teeth using clear aligners: A three-dimensional, retrospective evaluation ⁴⁴	Tepedino M, Paoloni V, Cozza P, Chimenti C	Progress in Orthodontics	2018	retrospective study	35	5.8

Ranking	Title	Author(s)	Journal	Publication year	Study design	Total number of citations	Mean number of citations/year
35	Root resorption during orthodontic treatment with Invisalign®. A radiometric study ⁴³	Gay G, Ravera S, Castroflorio T, Garino F, Rossini G, Parrini S, Cugliari G, Deregibus A	Progress in Orthodontics	2017	prospective study	35	5.0
36	Direct 3D printing of clear orthodontic aligners: Current state and future possibilities ⁴⁶	Tartaglia GM, Mapelli A, Maspero C, Santaniello T, Serafin M, Farronato M, Caprioglio A	Materials	2021	review	34	11.3
37	Pain level between clear aligners and fixed appliances: A systematic review ⁴⁷	Cardoso PC, Espinosa DG, Mecnas P, Flores-Mir C, Normando D	Progress in Orthodontics	2020	systematic review	34	8.5
38	Colour stabilities of three types of orthodontic clear aligners exposed to staining agents ⁴⁵	Liu CL, Sun WT, Liao W, Lu WX, Li QW, Jeong Y, Liu J, Zhao ZH	International Journal of Oral Science	2016	in vitro study	34	4.3
39	Forces and moments delivered by PET-G aligners to an upper central incisor for labial and palatal translation ⁴⁸	Elkholy F, Panchaphongsaphak T, Kilic F, Schmidt F, Lapatki BG	Journal of Orofacial Orthopedics	2015	in vitro study	34	3.8
40	Thickness of orthodontic clear aligners after thermoforming and after 10 days of intraoral exposure: A prospective clinical study ⁴⁹	Bucci R, Rongo R, Levatè C, Michelotti A, Barone S, Razonale AV, D'Antò V	Progress in Orthodontics	2019	prospective study	33	6.6
41	In vitro cytotoxicity of different thermoplastic materials for clear aligners ⁵⁰	Martina S, Rongo R, Bucci R, Razonale AV, Valletta R, D'Antò V	Angle Orthodontist	2019	in vitro study	33	6.6
42	Invisible orthodontics part 1: Invisalign ⁵¹	Malik OH, McMullin A, Waring DT	Dental Update	2013	review	33	3.0
43	Comparison of pain perception, anxiety, and impacts on oral health-related quality of life between patients receiving clear aligners and fixed appliances during the initial stage of orthodontic treatment ⁵²	Gao M, Yan X, Zhao R, Shan Y, Chen Y, Jian F, Long H, Lai W	European Journal of Orthodontics	2021	prospective study	31	10.3
44	Outcomes of clear aligner treatment with and without Dental Monitoring: A retrospective cohort study ⁵⁵	Hansa I, Katyal V, Ferguson DJ, Vaid N	American Journal of Orthodontics and Dentofacial Orthopedics	2021	retrospective study	30	10.0
45	Incidence of white spot lesions among patients treated with clear aligners and traditional braces ⁵³	Buschang PH, Chastain D, Keylor CL, Crosby D, Julien KC	Angle Orthodontist	2019	prospective study	30	6.0
46	Changes in roughness and mechanical properties of Invisalign® appliances after one- and two-weeks use ⁵⁴	Papadopoulou AK, Cantele A, Polychronis G, Zinelis S, Eliades T	Materials	2019	prospective study	30	6.0
47	Class II malocclusion correction with Invisalign: Is it possible? ⁵⁷	Patterson BD, Foley PF, Ueno H, Mason SA, Schneider PP, Kim KB	American Journal of Orthodontics and Dentofacial Orthopedics	2021	retrospective study	29	9.6
48	Forces and moments generated by aligner-type appliances for orthodontic tooth movement: A systematic review and meta-analysis ⁶	Iliadi A, Koletsis D, Eliades T	Orthodontics and Craniofacial Research	2019	systematic review	29	5.8
49	A randomized clinical trial comparing mandibular incisor proclination produced by fixed labial appliances and clear aligners ⁵⁶	Hennessy J, Garvey T, Al-Awadhi EA	Angle Orthodontist	2016	prospective study (RCT)	29	3.6
50	Mechanical properties of thermoplastic polymers for aligner manufacturing: In vitro study ⁵	Tamburrino F, D'Antò V, Bucci R, Alessandri-Bonetti G, Barone S, Razonale AV	Dentistry Journal	2020	in vitro study	28	7.0

RCT – randomized controlled trial.

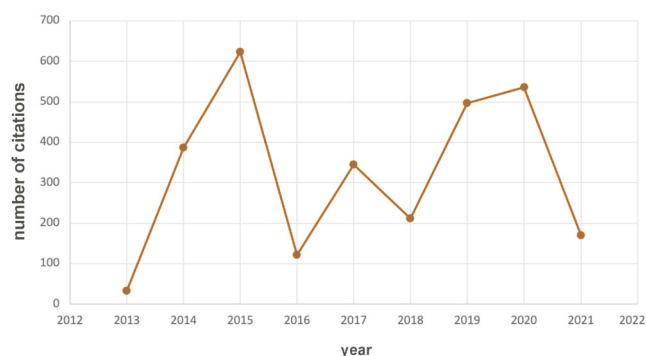


Fig. 3. Total citations per year (2013–2021)

torque, premolar derotation, and molar distalization” and was published by *American Journal of Orthodontics and Dentofacial Orthopedics* in 2014.¹³

Further details are shown in Table 1.

Number of citations

The 50 articles obtained a total of 2,862 citations. As shown in Fig. 3, 2015 was the year with the greatest number of citations, when an important systematic review headed “Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review” was

published.⁴ The article with the greatest average number of citations per year (32.1) is the first on the list, published in 2015 and it is a systematic review.⁴ However, the article titled “Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign” was published in 2020 and had a mean of 24.75 citations per year.⁷

Journals

Table 2 shows that the top 50 referenced papers on clear aligners were published in 20 different scientific journals. *Angle Orthodontist* had the most citations of any scientific journal ($n = 753$; 26.31% of total citations). This journal also published the most manuscripts from among the 50 most referenced papers ($n = 11$; 22%).

Furthermore, Table 2 illustrates the range of the 2021 JIF from 24.9 (*International Journal of Oral Science*) to 1.0 (*Australian Dental Journal*) for the scientific journals which published the 50 most often cited articles on clear aligners in the Web of Science, while the 5-JIF varied between 13.7 (*International Journal of Oral Science*) and 1.16 (*Seminars in Orthodontics*). Out of the 20 scientific journals, 80% were in the category “Dentistry, Oral Surgery & Medicine”, according to the JCR dataset.

Further details are shown in Table 2.

Table 2. Journals which published the 50 most cited articles on clear aligner therapy (CAT) ranked in descending order according to the total number of citations

Ranking	Journal	JIF (2021)	Quartile	EF	nEF	AI	5-JIF	Immediacy Index	Number of manuscripts	Number of citations
1	Angle Orthodontist	2.7	Q2	0.00401	0.86338	NA	3.212	0.683	11	753
2	American Journal of Orthodontics and Dentofacial Orthopedics	2.7	Q2	0.00630	1.35622	0.742	3.345	0.579	8	494
3	Progress in Orthodontics	3.2	Q2	0.00177	0.38166	0.866	3.782	0.220	8	329
4	BMC Oral Health	3.7	Q3	0.00831	178.663	NA	3.916	0.419	3	262
5	Orthodontics and Craniofacial Research	3.0	Q2	0.00121	0.14161	NA	1.954	0.433	3	196
6	European Journal of Orthodontics	3.1	Q2	0.00314	0.67639	0.799	3.166	1.000	2	115
7	Australian Dental Journal	1.0	Q3	0.00265	0.30928	NA	1.731	0.269	1	109
8	Korean Journal of Orthodontics	1.4	Q4	0.00109	0.23432	0.544	2.043	0.415	1	66
9	Materials	3.7	Q3	0.07687	16.52407	0.541	4.042	0.835	2	64
10	European Journal of Dentistry	3.1	Q2	0.00314	0.67639	0.799	3.166	1.000	1	63
11	Journal of the American Dental Association	3.7	Q2	0.00451	0.97067	1.064	4.065	1.556	1	57
12	Journal of Orthodontics	NA	NA	0.00084	0.18110	0.442	NA	NA	1	55
13	Clinical and Experimental Dental Research	NA	NA	0.00096	0.20750	0.330	NA	NA	1	46
14	PLoS One	3.8	NA	0.84726	182.12875	0.974	4.069	0.801	1	46
15	Journal of Clinical Medicine	5.0	NA	0.07171	15.41548	1.084	5.098	0.792	1	39
16	Seminars in Orthodontics	1.3	Q4	0.00047	0.10135	0.311	1.156	1.250	1	39
17	International Journal of Oral Science	24.9	Q1	0.00411	0.88483	2.629	13.721	0.952	1	34
18	Journal of Orofacial Orthopedics	2.3	Q3	0.00098	0.21107	0.477	2.249	0.125	1	34
19	Dental Update	–	–	–	–	–	–	–	1	33
20	Dentistry Journal	NA	Q2	0.0017	0.35702	NA	NA	NA	1	28

JIF – Journal Impact Factor; EF – Eigenfactor Score; nEF – Normalized Eigenfactor Score; AI – Article Influence Score; 5-JIF – 5-Year Journal Impact Factor. NA – data not available. Quartiles refer to the category “Dentistry, Oral Surgery & Medicine” in the Web of Science.

Authors, institutions and countries

To identify the most productive authors on the topic, information about all authors (201) was downloaded from Scopus and imported into an Excel file. Among the most productive authors, G. Rossini, M. Simon, J. Hennessy, and S. Mummolo were listed as the first authors twice.

Keywords network analysis

Based on the cooccurrence map of keywords, concepts like “clear aligners”, “orthodontic tooth movement” and “removable orthodontic appliance” occupied the larger and centrally positioned nodes (Fig. 4).

Discussion

This bibliometric analysis aimed to update the previous analysis,¹⁵ expanding the research to clear aligners in general. A sample size of 50 articles was chosen following other comparable publications¹⁵ to obtain an adequate amount of information and to create a graph with significant trendline data. The last 10 years have been chosen to analyze the most recent articles of greater interest for clinicians and researchers.

It is worth noting that the most cited type of article is a systematic review, a product that is at the apex of scientific evidence, and is therefore a reference for researchers and clinicians. The same type of article in the previous bibliometric analysis reached the 3rd rank with 83 citations.¹⁵ The particular systematic review sums up the literature on the efficacy of clear aligners.⁴ At the 2nd and 3rd place, there are two retrospective clinical studies.^{13,14} They focus on the predictability of critical movements with aligners.

It is important to observe that the 50 most cited articles do not include articles of great scientific interest, which, being recent, still have to reach many citations to fall into the first 50.^{58–61} The year 2015 was the year with

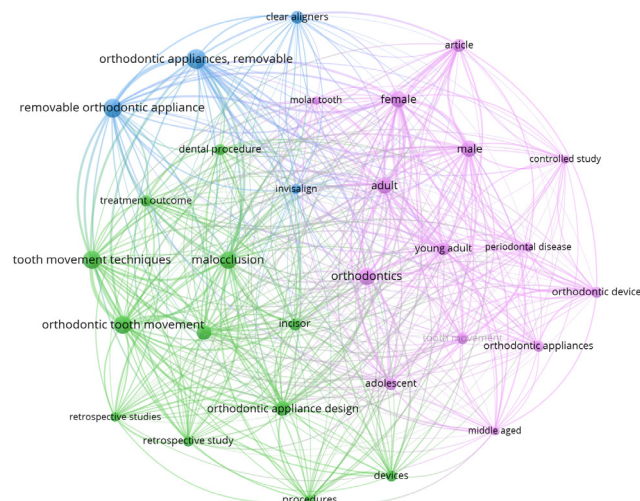


Fig. 4. Keyword co-occurrence network (KCN)

the greatest number of citations, although 2020 featured a high number of citations as well, almost equal to 2015, despite a short time span between 2020 and 2023, which was probably related to the high number of articles published. The results show that the pandemic period was very advantageous for scientific production.

Time may affect the citation ranking of articles. Thus, at the top of the list may be the oldest studies, while high-quality original articles published in recent years may be underrated. For this reason, the average number of citations per year was calculated.

There is a wide range of journals in which the articles were published (20). This shows that no journal has developed a specificity in the subject. On the one hand, the dispersion of scientific production is a limitation; on the other hand, it creates diversification in the advertising field.

It is challenging to figure out the function of each author who contributed to the top 50 publications mentioned, which showed an average of more than 4 authors per piece. We evaluated each author's overall number of citations, the total number of papers they had published, their standing in the author list, and the connection between

Table 3. Ten authors contributing to the 50 most cited articles on clear aligner therapy (CAT)

Ranking	Author	Affiliation	Country	H-index	Number of articles	First author	Co-author	Last author	Citations
1	Castroflorio T	University of Turin	Italy	26	5	0	4	1	39
2	Jung BA	University Hospital Freiburg	Germany	13	2	0	2	0	38
3	Deregibus A	University of Turin	Italy	24	4	0	3	1	35
4	Rossini G	University of Turin	Italy	15	4	2	2	0	34
5	Parrini S	University of Turin	Italy	10	4	0	4	0	33
6	Debernardi CL	University of Turin	Italy	18	2	0	0	2	32
7	Bourauel C	University of Bonn	Germany	39	2	0	0	2	29
8	Kravitz ND	private practice	USA	17	1	0	1	0	26
9	Wheeler TT	University of Florida	USA	24	1	0	0	1	21
10	Keilig L	University of Bonn	Germany	22	2	0	2	0	19

productivity and the researcher's level of expertise. The bibliometric indicator under consideration is the H-index, which measures the effectiveness of a scientist's studies while considering the publication volume and visibility.

Nearly all of the most often quoted pieces were from Central Europe, but there were also some from the USA and China. In most cases, citations come from institutions that are located in the author's country of origin. The top 2 institutions with the most citations are both in Central Europe – in Germany (University Hospital Freiburg) and Italy (University of Turin). Neal D. Kravitz is renowned in the USA for garnering numerous awards from his private practice. Half of the top 10 authors on the list are Italian authors who are affiliated with the University of Turin.

Table 3 provides more information.

A keyword co-occurrence network (KCN) is a useful tool for mapping to investigate the connections between keywords in the literature, and comprehend the knowledge structure and components of a scientific area.^{16,17} Keywords are a set of terms that allow correct indexing in computerized databases, facilitating research in the scientific literature.

The required minimum quantity of keyword occurrences in the analysis dataset was set at 7. The occurrences of each keyword and the overall strength of the link were tabulated. The keywords were mapped using VOSviewer (Centre for Science and Technology Studies, Leiden University, the Netherlands). The nodes of the generated network stand for keywords, while their edges indicate keyword associations. Similar keywords were grouped in clusters of the same color. The sizes of the nodes indicate how frequently the terms occur. The degree of connection between the nodes is indicated by the thickness and length of the lines.

Keywords like “clear aligners”, “orthodontic tooth movement” and “removable orthodontic appliance” occupied the larger and centrally positioned nodes. The keyword “removable orthodontic appliance” had significant weight in the keyword map. This orthodontic appliance has become widespread among adult patients, as it is comfortable, esthetic and allows more practical oral hygiene. This is why the keyword “periodontal disease” also carries significant weight. The term “orthodontic tooth movement” was mentioned in multiple research investigations that looked into the predictability of particular results. The term “clear aligner” was used frequently, indicating that there is increasing interest in testing this kind of device, while the presence of the term “Invisalign” was reduced, since the selected articles concerned treatment with any type of clear aligners (Fig. 4).

Limitations

The main issue is that the bibliometric analysis is very variable over time. The results may change, depending on the month.

The articles have been sorted in descending order according to the number of citations, but this parameter is not sufficient to assess the value of an article.

Citations are affected by time, so high-quality but more recent articles may be underreported.

Also, there may be a bias due to self-citations.

Furthermore, another important limitation is the challenge of evaluating researchers' contributions accurately. It would be essential to evaluate the actual contribution.

Conclusions

The results of the present bibliometric study indicated that CAT-related papers received increasing citations. The study determined the most influential articles by highlighting their authors and the journals in which the papers were published.

Ethics approval and consent to participate

Not applicable.

Data availability

The datasets supporting the findings of the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

Use of AI and AI-assisted technologies

Not applicable.

ORCID iDs

Vincenzo Grassia  <https://orcid.org/0000-0002-6671-2380>
 Adriana Fiori  <https://orcid.org/0009-0001-0049-9644>
 Federica Diodati  <https://orcid.org/0000-0002-1565-1186>
 Babak Sayahpour  <https://orcid.org/0000-0002-8319-7261>
 Abdolreza Jamilian  <https://orcid.org/0000-0002-8841-0447>
 Niccolò Giuseppe Armogida  <https://orcid.org/0000-0002-3259-3045>
 Fabrizia d'Apuzzo  <https://orcid.org/0000-0003-0291-9339>
 Ludovica Nucci  <https://orcid.org/0000-0002-7174-7596>

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