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# Top 50 Articles on Clear Aligner Treatment: Annual Citation-Based Bibliometric Analysis

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**ABSTRACT**

**Objective:** This study aims to identify the most influential articles on orthodontic clear aligners based on annual citation rates. Citation performance and trends in the field were evaluated through bibliometric analysis. **Materials and Methods:** A search in Scopus on September 15, 2024, yielded 54,988 articles and reviews, with the top 50 selected. Two authors independently reviewed the articles, resolving any disagreements with a third author. VOSviewer and Biblioshiny R-package were used for bibliometric analysis and visualization. Data were processed and visualized, with Excel used for data tabulation. **Results:** In the ranking based on annual citation rates, Italy was the leading country, while The Angle Orthodontist emerged as the top-ranked journal. Among institutions, the University of Turin ranked first. Among the authors, Castroflorio T. and Deregibus A. stood out. Invisalign was the most frequently used keyword, and systematic reviews were the most common type of study. **Conclusion:** The annual citation rate provides a more dynamic measure of an article's scientific potential and impact compared to traditional total citation counts. This metric is particularly important for assessing the immediate influence of studies on rapidly advancing technologies and innovative treatment methods, as it reflects the speed at which research contributes to literature and gains attention in the short term.

**Keywords:** Bibliometrics, Clear Aligner Appliances, Orthodontics.

## Şeffaf Plak Tedavilerinde En Etkili 50 Makale: Yıllık Atıf Tabanlı Bibliyometrik Analiz

**ÖZ**

**Amaç:** Bu çalışma, ortodontide şeffaf plaklarla ilgili en etkili makaleleri yıllık atıf oranlarına göre belirlemeyi amaçlamaktadır. Alandaki atıf performansı ve eğilimler, bibliyometrik analiz yoluyla değerlendirilmiştir. **Gereç ve Yöntem:** 15 Eylül 2024 tarihinde Scopus veri tabanında yapılan aramada 54.988 makale ve derleme elde edilmiş, bunlardan en çok yıllık atıf alan ilk 50'si çalışmaya dahil edilmiştir. İki araştırmacı makaleleri bağımsız olarak incelemiş, görüş ayrılıkları üçüncü bir yazar aracılığıyla çözülmüştür. Bibliyometrik analiz ve görselleştirme için VOSviewer ve Biblioshiny R paketi kullanılmıştır. Veriler işlenmiş, görselleştirilmiş ve tablo haline getirmek için Excel programı kullanılmıştır. **Bulgular:** Yıllık atıf oranlarına göre yapılan sıralamada İtalya en önde gelen ülke olarak öne çıkarken, The Angle Orthodontist en üst sıradaki dergi olmuştur. Kurumlar arasında Torino Üniversitesi birinci sırada yer almıştır. Yazarlar arasında ise Castroflorio T. ve Deregibus A. dikkat çekmiştir. En sık kullanılan anahtar kelime "Invisalign" olurken, sistematik derlemeler en yaygın çalışma türü olmuştur. **Sonuç:** Yıllık atıf oranı, bir makalenin bilimsel potansiyelini ve etkisini geleneksel toplam atıf sayısına kıyasla daha dinamik bir şekilde yansıtmaktadır. Bu metrik, özellikle hızla gelişen teknolojiler ve yenilikçi tedavi yöntemlerine ilişkin çalışmaların anlık etkisini değerlendirmede önemlidir; çünkü araştırmanın literatüre katkı sağlama ve kısa vadede dikkat çekme hızını ortaya koymaktadır.

**Anahtar Kelimeler:** Bibliometri, Şeffaf Plak Apareyleri, Ortodonti.

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## INTRODUCTION

Clear Aligner Therapy (CAT) has a long history in orthodontics. Clear aligners were first introduced by Kesling in 1946 (Kesling, 1946) In 1999, Align Technology® (Santa Clara, California) developed the modern clear aligner treatment protocol by integrating advanced technology. Recent developments in applied biomechanics and successes in biomaterial design and engineering have led to the adoption of this treatment as a suitable technique for addressing various clinical conditions (Bruni et al, 2021). The advantages of clear aligner therapy, such as patient comfort and acceptance (Cardoso et al, 2020), maintenance of oral hygiene (Jiang et al, 2018), aesthetics (Alansari et al, 2019) and clinician convenience, have contributed to a significant increase in publications and research activities in this field in recent years (Bruni et al, 2021). Keeping up with current developments in orthodontics is crucial for enhancing the quality of clinical practice and meeting patients' increasing expectations by effectively adapting to rapidly advancing technologies. However, the ever-increasing number of published articles (Adobes Martin et al, 2020) presents a significant challenge for both researchers and clinicians in identifying studies of the highest quality and greatest clinical effectiveness. Therefore, systematically evaluating the existing literature and providing comprehensive insights to readers through bibliometric analyses are becoming increasingly important (Papadopoulos and Gkiaouris 2007; Gandedkar et al, 2019). Bibliometrics is widely used to evaluate scientific research both quantitatively and qualitatively. Bibliometric analysis involves collecting, obtaining, and analyzing measurable information related to published scientific articles. Bibliometric analyses evaluate the citation performance, impact, and contributions of scientific publications within a specific field, thereby facilitating the identification of exemplary studies and thematic trends. They also uncover connections between authors, research groups, research topics, and countries (Charalampakis et al, 2018). Analyzing high-impact publications is particularly crucial for understanding advancements in clear aligner therapy, as well as for identifying studies that significantly influence the direction of future research (Gutiérrez-Salcedo et al, 2018). A common approach in the existing literature is to evaluate the most impactful articles in orthodontics based on their total citation counts (Hui et al, 2013; Fernandes et al, 2022). Nevertheless, it is expected that older publications will accumulate a higher number of citations. The annual citation rate provides a more dynamic measure of an article's scientific potential and impact than traditional total citation counts. This study aims to identify the most influential articles related to orthodontic clear aligners by ranking them based on their annual citation rates. To date, no study has evaluated publications on orthodontic clear aligners by ranking them according to their annual citation rate. Using bibliometric analysis, the study examines the citation performance of these publications, author contributions, and trends in research areas. This analysis provides a comprehensive method for evaluating the scientific impact of research on orthodontic clear aligners and highlights the most significant studies in literature.

## MATERIALS AND METHODS

In the Scopus database, a search was conducted on September 15, 2024, using the query ALL ( "aligner*" ) AND ( LIMIT-TO (DOCTYPE , "ar" ) OR LIMIT-TO (DOCTYPE , "re" ) ) AND ( EXCLUDE (PUBYEAR , 2025 ) ), including articles and reviews and excluding publications from 2025, with the search performed in all fields. There are no linguistic constraints. A total of 54,988 publications were exported. An Excel formula was developed to calculate the annual citation rate, and the publications were ranked accordingly [Total number of citations of the article / (2024 – publication year of the article +1)]. Specifically, approximately 99.11% of journals indexed in Web of Science are also included in Scopus, whereas only 33.93% of Scopus-indexed journals appear in Web of Science (Singh et al, 2021). Given that our study focuses specifically on identifying the top 50 influential publications, the Scopus database was preferred due to its broader coverage. To identify relevant articles, two researchers independently reviewed the publications ranked according to their annual citation rates. Initially, articles were evaluated based on their titles and abstracts. In cases of uncertainty, the full texts were examined to determine relevance to the study topic. The lists compiled by both researchers were subsequently compared by a third researcher. Any discrepancies were discussed and resolved through an online meeting involving all three researchers, resulting in the final selection of the top 50 articles. Following this selection, the two researchers conducted an additional online meeting to classify the articles according to topic areas and study types. The titles, abstracts, and, when necessary, the full texts of the articles were thoroughly examined to ensure accurate identification of the topic areas and study types. In this study, VOSviewer (Center for Science and Technology Studies, Leiden University) and Bibliometrix Biblioshiny R-package software programs were used to perform the bibliometric analysis and visualization of the obtained data. VOSviewer was utilized to create maps for authors or journals based on co-citation data and for keywords based on co-occurrence data. The software provides an advanced viewer that enables a detailed examination of the bibliometric maps (Van Eck and Waltman, 2010). VOSviewer version 1.6.20 was downloaded from the official website of the program. To prevent the software from misreading the exported .csv data set, the data were opened and adjusted using Microsoft Excel (Microsoft, Inc., Redmond, Washington). For example, the name “Vaid N.” was corrected to “Vaid N.R.” resulting in an increase in the author’s publication count from 2 to 3. Biblioshiny R-package is a unique open-

source tool designed for conducting scientific mapping analyses. It supports the recommended workflow for performing bibliometric analyses. Programmed in the R language, this tool is flexible, easily upgradable, and works seamlessly with other statistical R packages, making it particularly valuable in the continuously evolving field of bibliometrics (Aria and Cuccurullo, 2017). Data were exported in ".bib" format for use in this software, processed by the program, and visualizations were generated. Microsoft Excel was used for the preparation of data tables. As the research did not involve clinical studies or patient data, ethical approval was not required. Titles and abstracts were read for the correct identification of the thematic field, and in cases where it was necessary, the full article was reviewed.

**Ethical approval**

Since no human or animal materials were used in the study, ethical approval was not required.

**RESULTS**

Based on annual citation rates, examines articles published between 2009 and 2024. The highest number of articles was published in 2017, with a noticeable decline observed in 2023 (Figure 1).

The top 50 most influential articles ranked by annual citation rate are shown in Table 1.

Among the journals with the most published articles, the American Journal of Orthodontics and Dentofacial Orthopedics ranks first (11 articles, 1,580 citations), followed by Angle Orthodontist (10 articles, 1,367 citations), and Progress in Orthodontics (6 articles, 611 citations). In terms of the total annual citation rates, the journals were ranked as follows: The Angle Orthodontist (150.36), American Journal of Orthodontics and Dentofacial Orthopedics (121.07), and Progress in Orthodontics (101.75) (Table 2).

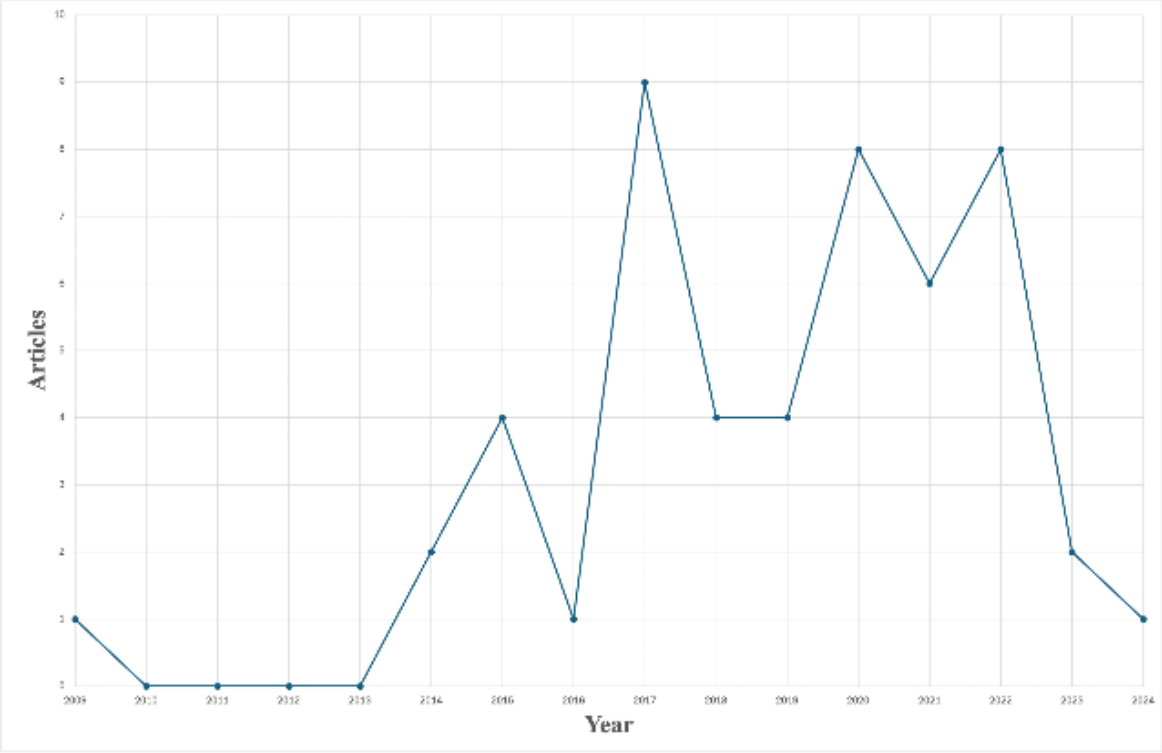


**Figure 1. Distribution of the top 50 articles ranked by annual citation rate by year.**

**Table 1. Top 50 most cited articles ranked by annual citation rate.**

| No | Title | Authors | Year of Publications | Total Citations | Citations Per Year | Thematic Fields | Type of Studies | Source Title | Correspond Author's Country |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review | Rossini G., Parrini S., Castroflorio T., Deregibus A., Debernardi C.L. | 2015 | 448 | 44.8 | The Effectiveness of Clear Aligners | Systematic review | Angle Orthodontist | Italy |
| 2 | Advances in orthodontic clear aligner materials | Bichu Y.M., Alwafi A., Liu X., Andrews J., Ludwig B., Bichu A.Y., Zou B. | 2023 | 79 | 39.5 | Comparison of the Different Clear Aligner Materials | Narrative literature review | Bioactive Materials | Canada |
| 3 | Has Invisalign improved? A prospective follow-up study on the efficacy of tooth movement with Invisalign | Haouili N., Kravitz N.D., Vaid N.R., Ferguson D.J., Makki L. | 2020 | 196 | 39.2 | The Effectiveness of Clear Aligners | Prospective study | American Journal of Orthodontics and Dentofacial Orthopedics | USA |
| 4 | Effectiveness of clear aligner therapy for orthodontic treatment: A systematic review | Robertson L., Kaur H., Fagundes N.C.F., Romanyk D., Major P., Flores-Mir C. | 2020 | 159 | 31.8 | The Effectiveness of Clear Aligners | Systematic review | Orthodontics and Craniofacial Research | Canada |
| 5 | Clear aligners in orthodontic treatment | Weir T. | 2017 | 210 | 26.25 | Comparison of the Different Clear Aligner Products | Narrative literature review | Australian Dental Journal | Australia |
| 6 | Clinical effectiveness of Invisalign® orthodontic treatment: a systematic review | Papadimitriou A., Mousoulea S., Gkantidis N., Kloukos D. | 2018 | 183 | 26.14 | The Effectiveness of Clear Aligners | Systematic review | Progress in Orthodontics | Switzerland |
| 7 | Direct 3D printing of clear orthodontic aligners: Current state and future possibilities | Tartaglia G.M., Mapelli A., Maspero C., Santaniello T., Serafin M., Farronato M., Caprioglio A. | 2021 | 104 | 26 | Comparison of the Different Clear Aligner Materials | Narrative literature review | Materials | Italy |
| 8 | How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign | Kravitz N.D., Kusnoto B., BeGole E., Obrez A., Agran B. | 2009 | 399 | 24.94 | The Effectiveness of Clear Aligners | Prospective clinical study | American Journal of Orthodontics and Dentofacial Orthopedics | USA |
| 9 | A comparison of treatment effectiveness between clear aligner and fixed appliance therapies | Ke Y., Zhu Y., Zhu M. | 2019 | 143 | 23.83 | The Effectiveness of Clear Aligners | Systematic review | BMC Oral Health | China |

**Table 1. (Continued). Top 50 most cited articles ranked by annual citation rate.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **10** | Treatment outcome and efficacy of an aligner technique - regarding incisor torque, premolar derotation and molar distalization | Simon M., Keilig L., Schwarze J., Jung B.A., Bourauel C. | 2014 | 253 | 23 | The Effectiveness of Clear Aligners | Prospective study | BMC Oral Health | Germany |
| **11** | Biomechanics of clear aligners: hidden truths & first principles | Upadhyay M., Arqub S.A. | 2022 | 68 | 22.67 | Drawbacks of Clear Aligners | Narrative literature review | Journal of the World Federation of Orthodontists | USA |
| **12** | Efficiency, effectiveness and treatment stability of clear aligners: A systematic review and meta-analysis | Zheng M., Liu R., Ni Z., Yu Z. | 2017 | 167 | 20.88 | Comparison of the Effectiveness of Clear Aligners and Conventional Systems | Systematic review | Orthodontics and Craniofacial Research | China |
| **13** | Clinical effectiveness of clear aligner treatment compared to fixed appliance treatment: an overview of systematic reviews | Yassir Y.A., Nabbat S.A., McIntyre G.T., Bearn D.R. | 2022 | 62 | 20.67 | The Effectiveness of Clear Aligners | Systematic review | Clinical Oral Investigations | Iraq |
| **14** | Mechanical and geometric properties of thermoformed and 3D printed clear dental aligners | Jindal P., Juneja M., Siena F.L., Bajaj D., Breedon P. | 2019 | 122 | 20.33 | Comparison of the Different Clear Aligner Materials | Comparative experimental study | American Journal of Orthodontics and Dentofacial Orthopedics | United Kingdom |
| **15** | Treatment outcome with orthodontic aligners and fixed appliances: A systematic review with meta-analyses | Papageorgiou S.N., Koletsi D., Iliadi A., Peltomaki T., Eliades T. | 2020 | 101 | 20.2 | Comparison of the Effectiveness of Clear Aligners and Conventional Systems | Systematic review | European Journal of Orthodontics | Switzerland |
| **16** | A systematic review of the accuracy and efficiency of dental movements with invisalign® | Galan-Lopez L., Barcia-Gonzalez J., Plasencia E. | 2019 | 118 | 19.67 | Comparison of the Effectiveness of Clear Aligners and Conventional Systems | Systematic review | Korean Journal of Orthodontics | Spain |
| **17** | Accuracy of clear aligners: A retrospective study of patients who needed refinement | Charalampakis O., Iliadi A., Ueno H., Oliver D.R., Kim K.B. | 2018 | 136 | 19.43 | The Effectiveness of Clear Aligners | Retrospective study | American Journal of Orthodontics and Dentofacial Orthopedics | USA |
| **18** | Association of orthodontic force system and root resorption: A systematic review | Roscoe M.G., Meira J.B.C., Cattaneo P.M. | 2015 | 189 | 18.9 | Root Resorption | Systematic review | American Journal of Orthodontics and Dentofacial Orthopedics | Denmark |

**Table 1. (Continued) Top 50 most cited articles ranked by annual citation rate.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **19** | Predictability of orthodontic tooth movement with aligners: effect of treatment design | Castroflorio T., Sedran A., Parrini S., Garino F., Reverdito M., Capuozzo R., Mutinelli S., Grybauskas S., Vaitiekūnas M., Deregibus A. | 2023 | 37 | 18.5 | The Effectiveness of Clear Aligners | Prospective study | Progress in Orthodontics | Italy |
| **20** | 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 | Gao M., Yan X., Zhao R., Shan Y., Chen Y., Jian F., Long H., Lai W. | 2021 | 73 | 18.25 | Comparison of the Effectiveness of Clear Aligners and Conventional Systems | Comparative cohort study | European Journal of Orthodontics | China |
| **21** | Prevalence of temporomandibular disorders in clear aligner patients using orthodontic intermaxillary elastics assessed with diagnostic criteria for temporomandibular disorders (DC/TMD) axis II evaluation: A cross-sectional study | Uzunçıbuk H., Marrapodi M.M., Meto A., Ronsivalle V., Cicciù M., Minervini G. | 2024 | 18 | 18 | İntermaxillary Elastics and Temporomandibular Disorder Symptoms in Clear Aligner Patients | Cross-sectional study | Journal of Oral Rehabilitation | Türkiye-Italy |
| **22** | Treatment of Class III Malocclusion and Anterior Crossbite with Aligners: A Case Report | Inchingolo A.D., Patano A., Coloccia G., Ceci S., Inchingolo A.M., Marinelli G., Malcangi G., Di Pede C., Garibaldi M., Ciocia A.M., Mancini A., Palmieri G., Rapone B., Piras F., Cardarelli F., Nucci L., Bordea I.R., Scarano A., Lorusso F., Giovanniello D., Costa S., Tartaglia G.M., Di Venere D., Dipalma G., Inchingolo F. | 2022 | 50 | 16.67 | The Effectiveness of Clear Aligners | Case report | Medicina (Lithuania) | Romania-Italy |
| **23** | Effect of clear aligner wear protocol on the efficacy of tooth movement: A randomized clinical trial | Al-Nadawi M., Kravitz N.D., Hansa I., Makki L., Ferguson D.J., Vaid N.R. | 2021 | 66 | 16.5 | The Effectiveness of Clear Aligners | Randomized clinical trial | Angle Orthodontist | South Africa |
| **24** | Thermo-mechanical properties of 3D printed photocurable shape memory resin for clear aligners | Lee S.Y., Kim H., Kim H.-J., Chung C.J., Choi Y.J., Kim S.-J., Cha J.-Y. | 2022 | 48 | 16 | Comparison of the Different Clear Aligner Materials | Comparative experimental study | Scientific Reports | South Korea |
| **25** | Stress relaxation properties of four orthodontic aligner materials: A 24-hour in vitro study | Lombardo L., Martines E., Mazzanti V., Arreghini A., Mollica F., Siciliani G. | 2017 | 126 | 15.75 | Comparison of the Different Clear Aligner Materials | Experimental study | Angle Orthodontist | Italy |

**Table 1. (Continued) Top 50 most cited articles ranked by annual citation rate.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **26** | Maxillary molar distalization with aligners in adult patients: A multicenter retrospective study | Ravera S., Castroflorio T., Garino F., Daher S., Cugliari G., Deregibus A. | 2016 | 141 | 15.67 | The Effectiveness of Clear Aligners | Retrospective study | Progress in Orthodontics | Italy |
| **27** | Clear aligner orthodontic therapy of rotated mandibular round-shaped teeth: A finite element study | Cortona A., Rossini G., Parrini S., Deregibus A., Castroflorio T. | 2020 | 78 | 15.6 | Finite Element Method | Methodological study | Angle Orthodontist | Italy |
| **28** | Forces and moments generated by removable thermoplastic aligners: Incisor torque, premolar derotation, and molar distalization | Simon M., Keilig L., Schwarze J., Jung B.A., Bourauel C. | 2014 | 171 | 15.55 | The Effectiveness of Clear Aligners | Experimental study | American Journal of Orthodontics and Dentofacial Orthopedics | Germany |
| **29** | Comparison of achieved and predicted tooth movement of maxillary first molars and central incisors: First premolar extraction treatment with Invisalign | Dai F.-F., Xu T.-M., Shu G. | 2019 | 93 | 15.5 | The Effectiveness of Clear Aligners | Retrospective study | Angle Orthodontist | China |
| **30** | The oral microbiota changes in orthodontic patients and effects on oral health: An overview | Contaldo M., Lucchese A., Lajolo C., Rupe C., Di Stasio D., Romano A., Petruzzi M., Serpico R. | 2021 | 62 | 15.5 | Microbiological Changes that Accompany Orthodontic Treatment | Narrative literature review | Journal of Clinical Medicine | Italy |
| **31** | Effects of Composite Attachments on Orthodontic Clear Aligners Therapy: A Systematic Review | Nucera R., Dolci C., Bellocchio A.M., Costa S., Barbera S., Rustico L., Farronato M., Militi A., Portelli M. | 2022 | 46 | 15.33 | The Effectiveness of Clear Aligners | Systematic review | Materials | Italy |
| **32** | How accurate is Invisalign in nonextraction cases? Are predicted tooth positions achieved? | Grünheid T., Loh C., Larson B.E. | 2017 | 121 | 15.13 | The Effectiveness of Clear Aligners | Clinical study | Angle Orthodontist | USA |
| **33** | The predictability of transverse changes with Invisalign | Houle J.-P., Piedade L., Todescan R., Pinheiro F.H.S.L. | 2017 | 119 | 14.88 | The Effectiveness of Clear Aligners | Retrospective study | Angle Orthodontist | Canada |
| **34** | Predictability of orthodontic movement with orthodontic aligners: a retrospective study | Lombardo L., Arreghini A., Ramina F., Huanca Ghislanzoni L.T., Siciliani G. | 2017 | 114 | 14.25 | The Effectiveness of Clear Aligners | Retrospective study | Progress in Orthodontics | Italy |

**Table 1. (Continued) Top 50 most cited articles ranked by annual citation rate.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **35** | Outcomes of clear aligner treatment with and without Dental Monitoring: A retrospective cohort study | Hansa I., Katyal V., Ferguson D.J., Vaid N. | 2021 | 57 | 14.25 | The Effectiveness of Clear Aligners | Retrospective study | American Journal of Orthodontics and Dentofacial Orthopedics | United Arab Emirates |
| **36** | Initial force systems during bodily tooth movement with plastic aligners and composite attachments: A three-dimensional finite element analysis | Gomez J.P., Peña F.M., Martínez V., Giraldo D.C., Cardona C.I. | 2015 | 142 | 14.2 | Finite Element Method | Methodological study | Angle Orthodontist | Colombia |
| **37** | Efficiency of upper arch expansion with the Invisalign system | Zhou N., Guo J. | 2020 | 71 | 14.2 | The Effectiveness of Clear Aligners | Retrospective study | Angle Orthodontist | China |
| **38** | Management of overbite with the Invisalign appliance | Khosravi R., Cohanim B., Hujoel P., Daher S., Neal M., Liu W., Huang G. | 2017 | 113 | 14.13 | The Effectiveness of Clear Aligners | Retrospective study | American Journal of Orthodontics and Dentofacial Orthopedics | USA |
| **39** | Pain level between clear aligners and fixed appliances: a systematic review | Cardoso P.C., Espinosa D.G., Mecenas P., Flores-Mir C., Normando D. | 2020 | 69 | 13.8 | Comparison of the Effectiveness of Clear Aligners and Conventional Systems | Systematic review | Progress in Orthodontics | Brazil |
| **40** | Class II malocclusion correction with Invisalign: Is it possible? | Patterson B.D., Foley P.F., Ueno H., Mason S.A., Schneider P.P., Kim K.B. | 2021 | 55 | 13.75 | The Effectiveness of Clear Aligners | Retrospective study | American Journal of Orthodontics and Dentofacial Orthopedics | USA |
| **41** | 'Invisible' orthodontics by polymeric 'clear' aligners molded on 3D-printed personalized dental models | Yu X., Li G., Zheng Y., Gao J., Fu Y., Wang Q., Huang L., Pan X., Ding J. | 2022 | 41 | 13.67 | Comparison of the Different Clear Aligner Materials | Experimental study | Regenerative Biomaterials | China |
| **42** | Periodontal health during orthodontic treatment with clear aligners and fixed appliances: A meta-analysis | Jiang Q., Li J., Mei L., Du J., Levrini L., Abbate G.M., Li H. | 2018 | 95 | 13.57 | Comparison of the Effectiveness of Clear Aligners and Conventional Systems | Systematic review | Journal of the American Dental Association | China |
| **43** | Accuracy of interproximal enamel reduction during clear aligner treatment | De Felice M.E., Nucci L., Fiori A., Flores-Mir C., Perillo L., Grassia V. | 2020 | 67 | 13.4 | The Effectiveness of Clear Aligners | Retrospective study | Progress in Orthodontics | Italy |
| **44** | Accuracy of orthodontic models prototyped for clear aligners therapy: A 3D imaging analysis comparing different market segments 3D printing protocols | Venezia P., Ronsivalle V., Rustico L., Barbato E., Leonardi R., Lo Giudice A. | 2022 | 40 | 13.33 | Comparison of the Different Clear Aligner Materials | Experimental study | Journal of Dentistry | Italy |

**Table 1. (Continued) Top 50 most cited articles ranked by annual citation rate.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **45** | Evaluation of Invisalign treatment effectiveness and efficiency compared with conventional fixed appliances using the Peer Assessment Rating index | Gu J., Tang J.S., Skulski B., Fields H.W., Beck F.M., Firestone A.R., Kim D.-G., Deguchi T. | 2017 | 104 | 13 | Comparison of the Effectiveness of Clear Aligners and Conventional Systems | Retrospective study | American Journal of Orthodontics and Dentofacial Orthopedics | USA |
| **46** | Effects of thermoforming on the physical and mechanical properties of thermoplastic materials for transparent orthodontic aligners | Ryu J.-H., Kwon J.-S., Jiang H.B., Cha J.-Y., Kim K.-M. | 2018 | 91 | 13 | Comparison of the Different Clear Aligner Materials | Systematic multiscale analysis | Korean Journal of Orthodontics | South Korea |
| **47** | Clear aligners for maxillary anterior en masse retraction: a 3D finite element study | Jiang T., Wu R.Y., Wang J.K., Wang H.H., Tang G.H. | 2020 | 65 | 13 | Finite Element Method | Methodological study | Scientific Reports | China |
| **48** | Braces versus Invisalign®: Gingival parameters and patients' satisfaction during treatment: A cross-sectional study | Azaripour A., Weusmann J., Mahmoodi B., Peppas D., Gerhold-Ay A., Van Noorden C.J.F., Willershausen B. | 2015 | 129 | 12.9 | Oral Hygiene During Clear Aligner Treatment | Methodological study | BMC Oral Health | Germany |
| **49** | Discomfort associated with Invisalign and traditional brackets: A randomized, prospective trial | White D.W., Julien K.C., Jacob H., Campbell P.M., Buschang P.H. | 2017 | 103 | 12.88 | Comparison of the Effectiveness of Clear Aligners and Conventional Systems | Prospective trial | Angle Orthodontist | USA |
| **50** | The effects of aligner overtreatment on torque control and intrusion of incisors for anterior retraction with clear aligners: A finite-element study | Liu L., Song Q., Zhou J., Kuang Q., Yan X., Zhang X., Shan Y., Li X., Long H., Lai W. | 2022 | 38 | 12.67 | The Effectiveness of Clear Aligners | Methodological study | American Journal of Orthodontics and Dentofacial Orthopedics | China |

**Table 2. Ranking of the journals contributing the most according to the total annual citation rate (with more than two publications).**

| Source | Number of articles | Total annual citations rates | Number of citations |
|---|---|---|---|
| **Angle Orthodontist** | 10 | 150.36 | 1367 |
| **American Journal of Orthodontics and Dentofacial Orthopedics** | 11 | 121.07 | 1580 |
| **Progress in Orthodontics** | 6 | 101.75 | 611 |
| **BMC Oral Health** | 3 | 59.73 | 525 |

The countries with the most published articles are Italy (14 articles, 1,426 citations), the USA (12 articles, 1,597 citations), and China (11 articles, 956 citations) (Figure 2). The leading institutions are the University of Milan (4 articles, 314 citations), University of Campania Luigi Vanvitelli (4 articles, 197 citations), and University of Turin (3 articles, 667 citations). In terms of total annual citation rates, the countries were ranked as follows: Italy (255.95), the USA (220.8), and China (198.4) (Table 3).

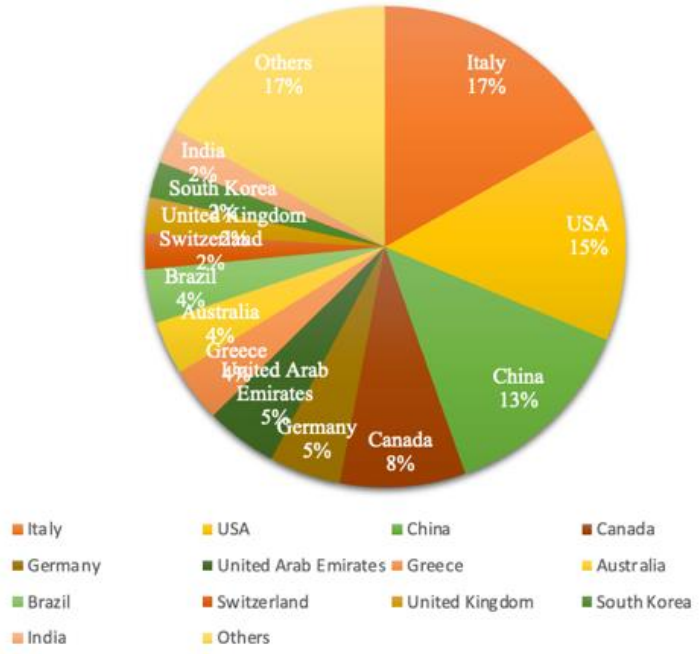


**Figure 2. The contributing countries with more than two publications.**

**Table 3. Ranking of the countries contributing the most according to the total annual citation rate (with more than two publications).**

| Country or Region | Number of articles | Total annual citations rates | Number of citations |
|---|---|---|---|
| **Italy** | 14 | 255.95 | 1426 |
| **USA** | 12 | 220.8 | 1597 |
| **China** | 11 | 198.4 | 956 |
| **Canada** | 7 | 142.61 | 727 |
| **United Arab Emirates** | 4 | 109.45 | 398 |
| **Germany** | 4 | 90.94 | 632 |
| **Australia** | 3 | 80 | 346 |
| **Greece** | 3 | 65.76 | 420 |
| **Brazil** | 3 | 46.45 | 313 |

Regarding institutions, the highest total annual citation rates were recorded by the University of Turin (76.06), the University of Milan (72.24), and the European University College (69.95), respectively (Table 4).

**Table 4. Ranking of the institutions contributing the most according to the total annual citation rate (with more than two publications).**

| Source Title | Number of articles | Total annual citations rates | Number of citations |
|---|---|---|---|
| **University of Turin** | 4 | 76.06 | 667 |
| **University of Milan** | 4 | 72.24 | 314 |
| **European University College** | 3 | 69.95 | 319 |
| **University of Campania Luigi Vanvitelli** | 3 | 63.56 | 197 |
| **University of Alberta** | 3 | 59 | 295 |
| **Shanghai Jiao Tong University** | 3 | 50.49 | 249 |
| **University of Ferrara** | 3 | 48.5 | 277 |

The most prolific authors include Castroflorio T. and Deregibus A., each with 4 articles and 704 citations, followed by Kravitz N.D. with 3 articles and 661 citations. In terms of total annual citation rates, the authors were identified as follows: Castroflorio T. (94.56), Deregibus A. (94.56), and Kravitz N.D. (80.63) (Table 5).

**Table 5. Ranking of the authors contributing the most according to the total annual citation rate (with more than two publications).**

| Authors | Number of articles | Total annual citation rates | Number of citations |
|---|---|---|---|
| **Castroflorio T.** | 4 | 94.56 | 704 |
| **Deregibus A.** | 4 | 94.56 | 704 |
| **Kravitz N.D.** | 3 | 80.63 | 661 |
| **Parrini S.** | 3 | 78.9 | 563 |
| **Ferguson D.J.** | 3 | 69.95 | 319 |
| **Vaid N.R.** | 3 | 69.95 | 319 |
| Flores-Mir C. | 3 | 59 | 295 |

The most common author keywords were Invisalign, Orthodontics, and Clear aligners (Figure 3).


**Figure 3. Word cloud of keywords. In the word cloud, the size of each word represents its frequency of occurrence in the analyzed articles; larger words appeared more frequently among the author keywords.**

The author keyword network is visualized in Figure 4.

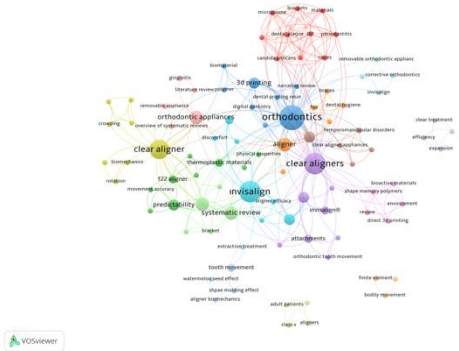


**Figure 4. Network structure of the author's keywords. Node size reflects the frequency of occurrence; larger nodes indicate more frequently used keywords. Lines represent co-occurrence relationships.**

The most common study types were systematic reviews (12 articles), followed by retrospective studies (11 articles) and narrative literature reviews (5 articles) (Table 6).

**Table 6. Study types of the top 50 most cited articles ranked by annual citation rate.**

| Type of study | Number of articles |
|---|---|
| **Systematic review** | 12 |
| **Retrospective study** | 11 |
| **Narrative literature review** | 5 |
| **Methodological study** | 5 |
| **Experimental study** | 4 |
| **Prospective study** | 3 |
| **Comparative experimental study** | 2 |
| **Cross-sectional study** | 1 |
| **Systematic multiscale analysis** | 1 |
| **Randomized clinical trial** | 1 |
| **Prospective clinical study** | 1 |
| **Comparative cohort study** | 1 |
| **Case report** | 1 |
| **Prospective Trial** | 1 |
| **Clinical study** | 1 |

The most frequent thematic fields were "The Effectiveness of Clear Aligners" (25 articles) and "Comparison of the Effectiveness of Clear Aligners and Conventional Systems" (8 articles) (Table 7).

**Table 7. Thematic fields of the top 50 most cited articles ranked by annual citation rate.**

| Thematic Field | Number of articles |
|---|---|
| **The effectiveness of clear aligners** | 25 |
| **Comparison of the effectiveness of clear aligners and conventional systems** | 8 |
| **Comparison of the different clear aligner materials** | 8 |
| **Finite element method** | 3 |
| **Intermaxillary elastics and temporomandibular disorder symptoms in clear aligner patients** | 1 |
| **Microbiological changes that accompany orthodontic treatment** | 1 |
| **Comparation of the different clear aligner products** | 1 |
| **Oral hygiene during clear aligner treatment** | 1 |
| **Drawbacks of clear aligners** | 1 |
| **Root resorption** | 1 |

**DISCUSSION**

Three major databases—Google Scholar, Scopus, and Web of Science (WoS)—are commonly utilized for bibliometric analyses. Among these, Scopus is the most widely employed database due to its reliable information collection and advanced analytical tools (Martínez et al, 2008). The utilization of the Scopus database in our study ensured reliable data collection and provided a robust foundation for the analysis. These databases have been extensively compared through direct coverage comparisons (Gavel & Iselid, 2008; Mongeon & Paul-Hus, 2016) as well as citation-based comparative studies (Martín-Martín et al, 2018). In studies comparing the two databases, it has been shown that while Scopus offers broader journal coverage, Web of Science is more selective in the journals it indexes. Specifically, approximately 99.11% of journals indexed in Web of Science are also included in Scopus, whereas only 33.93% of Scopus-indexed journals appear in Web of Science (Singh et al, 2021). The average annual citation rate is an essential metric, accurately reflecting the scientific potential of newer articles that have not yet accumulated high total citation counts (Bruni et al, 2021; Seglen, 1998). It is widely recognized that influential articles typically reach their peak recognition within 10-20 years of publication (Seglen, 1998). This phenomenon often leads to the underestimation of the potential impact of newly published studies. While evaluations based on total citation counts generally highlight classical, well-established areas, our study, utilizing annual citation rates, better reflects current trends in orthodontics literature and emphasizes the increasing importance of innovative treatment methods. The annual citation rate is a critical bibliometric indicator that can reveal the future scientific potential of a paper, even if it has not yet received significant citations in its early stages. This metric highlights how quickly a paper contributes to the literature and the level of attention it garners in the short term. Unlike the traditional total citation count, the annual citation rate dynamically measures a paper's influence from the time of publication, which is especially crucial in evaluating the impact of new research in rapidly advancing fields (Bruni et al, 2021; Seglen, 1998; Montori et al, 2003). The data reveal a notable distinction between the American Journal of Orthodontics and Dentofacial Orthopedics (AJO-DO) and the Angle Orthodontist. Although AJO-DO appears to lead in terms of volume and overall impact, with 11 articles and a total of 1,580 citations, its annual citation average of 121.07 suggests that while some of its publications received considerable attention at the time of release, their scientific influence may have diminished over time. In contrast, the Angle Orthodontist, with 10 articles and 1,367 citations, not only approaches AJO-DO in terms of total citations but also demonstrates a higher annual citation rate of 150.36. This indicates that its publications have retained their relevance and continue to make a dynamic contribution to the field. These findings suggest that in recent years, the Angle Orthodontist has hosted more sustainable and current publications related to clear aligner therapy. Furthermore, the consistent ranking of these two journals at the top in previous bibliometric studies (Gutiérrez-Salcedo et al, 2018) underscores their longstanding leadership not only in various areas of orthodontics but also, as evidenced by the results of the present study, in the field of clear aligner therapy (Fernandes et al, 2022). Although Progress in Orthodontics has less than half the total number of citations compared to AJO-DO, its annual citation rate does not fall significantly behind. This suggests that Progress in Orthodontics has rapidly published studies addressing the evolving technology and increasing clinical adoption of clear aligner therapy. Country-wise, although Italy has received fewer total citations (1,426) despite producing a higher number of publications (14), it ranks first in terms of generating up-to-date and high-quality research, with an impressive annual citation rate of 255.95. In contrast, the United States, despite accumulating more total citations (1,597) with fewer publications (12), exhibits a lower average annual citation rate of 220.8. This clearly indicates that Italy's contributions are not only more consistent in terms of annual scientific impact but also play a pivotal role in shaping the contemporary literature on clear aligner therapy. Consequently, Italy emerges as a leading country not only in terms of publication quantity but also in quality, positioning itself as a central hub for scientific advancement and academic focus in the field of clear aligners. Institutional rankings generally exhibit a parallel trend between total citation counts and annual citation rates. Selvaraj (2024) emphasized that these institutions not only produce highly cited research but also actively participate in extensive international collaborations. It is particularly noteworthy that the University of Milan, despite having nearly half the total number of citations compared to the University of Turin, demonstrates a comparable annual citation rate. This indicates that the University of Milan has rapidly aligned itself with the most current literature on clear aligner therapy in recent years and has shown significant momentum in its academic productivity within this field.

In terms of authorship, a parallel alignment is observed between annual citation rates and total citation counts. Rossini et al.'s 2015 systematic review, with an annual citation rate of 44.8, ranks as the most influential study in this field. It provides a comprehensive evaluation of the effectiveness of clear aligners in orthodontic tooth movement, making it a key reference point in the literature. Bichu Y.M. et al.'s 2023 study, which compares various aligner materials, ranks second with an annual citation rate of 39.5. These results suggest that systematic reviews, in particular, receive substantial attention and are frequently cited in the field of clear aligner research.

It is observed that the studies ranked highest based on annual citation rates primarily focus on tooth movement in clear aligner therapy, while those ranked lower on the list tend to address topics such as the finite element method, comparisons of different clear aligner materials, disadvantages of clear aligner therapy, and oral hygiene during the treatment process. This suggests that although the methodologies employed may vary, clinical studies consistently attract sustained interest in the field. It was observed that the study published by Bichu Y.M. et al. in 2023 ranked 29th based on total citation count, with 79 citations, in the list we created according to annual citation rate; however, it rose to 2nd place with an average of 39.5 citations per year when ranked by annual citation average. If the evaluation had been based solely on total citation count, this important study, which receives a high number of citations on an annual basis, might have been overlooked. Similarly, although the 2015 study by Azaripour A. et al. (2015) ranked 15th in terms of total citations with 129 citations, it dropped to 48th place in the ranking based on annual citation rate, due to an annual average of 12.9 citations. This situation reveals that rankings based on annual citation rates more accurately reflect the current impact of a study. In addition to these findings, although a large number of articles were evaluated in our study using the Scopus database, one of the potential limitations is the possibility that certain relevant publications indexed in other databases—such as Web of Science (WoS), Dimensions, PubMed, Google Scholar, and the Cochrane Library—may have been omitted.

## CONCLUSION

In conclusion, while rankings based on total citation counts reflect the scientific impact of studies in the past, evaluations based on annual citation rates provide a clearer indication of current research trends and studies with the potential to shape the future direction of the field.

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**Conflict of interest**

Authors declare that they have no conflict of interest.

**Author Contributions**

**Plan, design:** AY**; Material, methods and data collection:** YSG, RE, AAAI**; Data analysis and comments:** YSG, AAAI**; Writing and corrections:** AY, RE**.**

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**Ethical Approval**

Since no human or animal materials were used in the study, ethical approval was not required.

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