RESEARCH ARTICLE
DOI: 10.26650/Tr-ENT.2024.1402073
The Turkish Journal of Ear Nose and Throat 2024;34(2):30-36

# Online Attention to Cochlear Implant Research: Altmetric and Bibliometric Analysis

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**Citation:** Tuz D, Değirmenci Uzun E. The Online Attention to Cochlear Implant Research: Altmetric and Bibliometric Analysis. Tr-ENT 2024;34(1):30-36. https://doi.org/10.26650/Tr-ENT.2024.1402073

## ABSTRACT

**Objective:** Assessing the quality of scientific publications accurately and objectively is critical. This study analyzes the most cited articles on cochlear implants using altmetrics (alternative metrics) and traditional metrics.
**Materials and Methods:** A basic search was conducted in the Web of Science database using the term "cochlear implant." The analysis included the year of publication, years since publication, number of citations, and average number of citations per year for each publication. Additionally, the impact factor (IF), 5-year IF, Q category of the journals, and altmetric scores (ASs) were evaluated.
**Results:** ASs showed significant correlations with the number of citations, IF, 5-year IF, and publication year. Notably, open-access articles constituted 68% of the total. However, no significant differences were observed between open-access and nonopen-access articles concerning citations (p=0.489) or ASs (p=0.735), respectively.
**Conclusion:** Although altmetrics are currently viewed as complementary to traditional metrics, it exhibits potential for increased importance over time.
**Keywords:** Audiology, cochlear implants, bibliometrics, social media, altmetric

## INTRODUCTION

Accurately and objectively assessing the quality of scientific papers is important. It assists researchers in selecting appropriate journals for publication, supports organizations in allocating funds, promotion, and faculty appointment decisions and furnishes healthcare practitioners with reliability ratings to improve patient care. Bibliometric quality indicators employ mathematical approaches to analyze and measure the impact of articles, journals, and other academic publications (1). Traditionally, article- and journal-level metrics, such as citation counts and impact factor (IF), have served as primary tools for evaluating research dissemination. However, altmetrics (alternative metrics) have emerged as unconventional means to assess the visibility and short-term social engagement of publications, complementing traditional bibliometric assessments that primarily gauge long-term impact (2).

The Altmetric Attention Score (AS), inaugurated in 2010, has swiftly gained prominence as a tool for assessing article impact (3, 4). The score reflects the frequency with which a publication is "mentioned" across various media platforms, including social media (e.g., Facebook and Twitter), newspapers, encyclopedias (e.g., Wikipedia), public policy papers, online reference managers (e.g., Mendeley and Connotea), multimedia sites (e.g., YouTube), and patents (4). Altmetrics captures audience engagements with research outputs beyond traditional citation metrics, including the complete area of interaction that clinical and scientific communities have with articles, presentations, and book chapters (5). Unlike traditional bibliometrics, altmetrics broaden the scope to include engagement from nonacademic audiences, such as patients and other interested individuals, thereby offering a more comprehensive evaluation of impact (5).

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**Submitted:** 08.12.2023 • **Accepted:** 29.03.2024 • **Published Online:** 24.04.2024

There is a growing expectation for scientists to extend their research communication beyond academic platforms (6). Presently, social media significantly influence individual's choices regarding health services and specialists. Many individuals turn to social media platforms for information concerning health conditions (7). A survey conducted in 2021 found that 11% of Americans utilized social media for health-related information (8). Furthermore, 25% of American social media users reported that information obtained on these platforms influenced their future healthcare decisions, with 32% expressing high or very high confidence in health information disseminated through social media (9). Consequently, experts should consider the methods and frequency with which their research is communicated via social media channels.

Cochlear implants (CIs) have long been a captivating and pertinent subject within the fields of audiology and otology. However, to the best of our knowledge, there is no literature examining traditional metrics and altmetrics concerning CIs. Therefore, the objective of this study is to analyze the top 100 most cited articles on CIs in terms of altmetrics and traditional metrics.

## MATERIAL and METHODS

The core collection databases of the Web of Science were accessed, and the keyword "cochlear implant" was input into the basic search section. Publications falling within the publication years 2011 and 2021 were selected. Articles were then ranked based on their citation count, from highest to lowest. This study focused on the top 100 most cited publications on CIs (see supplemental appendix for a list of articles; accessed on April 1, 2022). Inclusion criteria for this study included various subtopics related to CIs, including auditory performance, speech perception, music perception, localization, auditory memory and attention, neuroplasticity, electrophysiology, electrode properties and/or mapping parameters, language development and outcomes, cognitive, emotional, and social development, histopathology, etiology, epidemiology, depression and quality of life, auditory rehabilitation, genetics, and modeling. Topics unrelated to CIs and audiology, such as CI surgery and medical treatment options, were excluded. The evaluated parameters for each publication included the title, publication years, number of years since publication (NYP), number of citations, and average citations per year (ACY). Additionally, the IF for 2019, the 5-year IF, and the Q category of the journals in which the papers were published were examined. Information regarding article access type, study type, Scimago Journal and Country Rank category, and study population was also analyzed. ASs for the articles were obtained using the bookmark "Altmetric it!" Clicking on this bookmark presents users with a color representing the article's AS, visually indicating the types and frequency of attention garnered (Figure 1).

### Statistical Analysis

Statistical analyses were conducted using SPSS version 26 (IBM Corp., Armonk, NY, USA). Initially, visual methods (histograms and probability plots) and analytical methods (Kolmogorov–Smirnov and Shapiro–Wilk tests) were used to assess the normality of the variables. Given that the numerical data did not exhibit a normal distribution according to the Shapiro–Wilk test, descriptive statistics including the median and the 25%–75% interquartile range (IQR) were utilized. Categorical data are presented as numbers or percentages. Spearman's rank correlation analysis was performed to explore the relationships among AS, number of citations, ACY, IF, 5-year IF, year of publication, and NYP. The Mann–Whitney U test was used to compare the number of citations and AS between articles categorized as open access and those that were not. Additionally, the Mann–Whitney U test was used to assess differences in ASs across publication years. A p-value of <0.05 was considered statistically significant.

## RESULTS

Table 1 illustrates the correlations among AS, citation number, ACY, IF, 5-year IF, publication year, and NYP. Significant correlations were observed between AS and all variables except ACY and NYP. Moreover, significant correlations were found between the number of citations and AS, IF, and 5-year IF. ACY correlated with IF, 5-year IF, publication year, and NYP. Additionally, significant correlations were observed between IF and AS, citation number, ACY, 5-year IF, and publication year.

**Table 1: Correlation between traditional metrics and altmetrics**

| | AS | Time cited | ACY | IF | 5 year IF | Publication year | NYP |
|---|---|---|---|---|---|---|---|
| **AS** | 1 | **0.256*** | 0.018 | **0.320*** | **0.328*** | **0.264*** | 0.104 |
| **Time cited** | **0.256*** | 1 | 0.004 | **0.304*** | **0.308*** | 0.109 | −0.018 |
| **ACY** | −0.165 | 0.004 | 1 | **0.370*** | **0.288*** | **0.583*** | **0.583*** |
| **IF** | **0.320*** | **0.304*** | **0.288*** | 1 | **0.975*** | 0.096 | −0.110 |
| **5 year IF** | **0.328*** | **0.308*** | **0.288*** | **0.902*** | 1 | 0.112 | −0.083 |
| **Publication year** | **0.264*** | 0.109 | **0.583*** | 0.096 | 0.112 | 1 | **−0.996*** |
| **NYP** | 0.104 | −0.018 | **0.583*** | −0.110 | −0.083 | **−0.996*** | 1 |

The values above the diagonal consisting of 1 value extending from the top left to the bottom right represent the "r" value, and the values below represent the "p" value. ACY: Average citation per year, AS: Altmetric score, IF: Impact Factor, NYP: Number of years since publication. *Statistically significant.

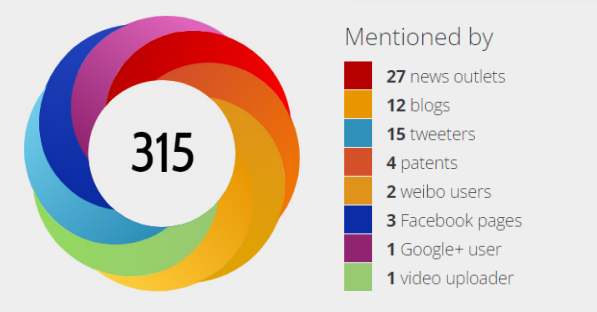


**Figure 1: Altmetric donut**

Similarly, 5-year IF significantly correlated with AS, citation number, ACY, and IF. Furthermore, publication year significantly correlated with AS, ACY, and NYP, whereas NYP correlated with ACY and publication year.

A Web of Science search yielded 11,680 articles on CIs published between 2011 and 2021. Among the top 100 articles, the number of citations ranged from 73 to 455. The median citation number was 91 (IQR: 80.0–113.0), whereas the median AS was 4 (IQR: 1–10). The article titled "Close-Field Electroporation Gene Delivery Using the Cochlear Implant Electrode Array Enhances the Bionic Ear" by Pinyon et al., published in Science Translational Medicine in 2014, boasted the highest AS (316) with 90 citations. Conversely, the article titled "Factors Affecting Open-Set Word Recognition in Adults with CIs" by Holden et al., published in Ear and Hearing in 2013 amassed the most citations (455) with an AS of 4.

Among the top 100 articles, the article and study types were evaluated, 74 were original research articles, and 26 were reviews. Table 2 displays the ASs and citation numbers of the top 100 articles by study type.

A total of 44 journals contributed to the publication of articles on CIs. Among them, Ear and Hearing and Otology & Neurotology had the most relevant publications, with 13 articles in the top 100, and had the highest IFs (3.57 and 2.311, respectively). According to the Scimago Journal and Country Rank category, there were 46 journals in Q1, 25 in Q2, 28 in Q3, and 1 in Q4. In Q1, the median AS was 5 (IQR: 1–21), and the median number of citations was 97.50 (IQR: 84–129.25). In Q2, Q3, and Q4, the median ASs were 3 (IQR: 2.0–7.0), 3 (1.0–5.75), and 0 (IQR: 0), respectively, and the median citations were 84 (IQR: 77.50–106.50), 89.50 (IQR: 78.25–101.0), and 88.0 (IQR: 88.0–88.0), respectively.

Among the top 100 articles, 12 were published in 2011, 19 in 2012, 28 in 2013, 21 in 2014, 8 in 2015, 8 in 2016, and 4 in 2017. No articles were published after 2017. Regarding publication years, 2014 had the article with the highest AS (316), while 2013 had the article with the highest number of citations (455) (Table 3). The median ASs of the publications before and after 2014 were 44.75 and 58.77, respectively. The difference in ASs before and after 2014 was statistically significant (p=0.017).

Open-access articles constituted 68% of the total. The median AS of open-access articles was 3 (IQR: 1–13.50), while for nonopen-access articles, it was 4.5 (IQR: 1–7.75). Similarly, the median number of citations for open-access articles was 90 (IQR: 80.25–107.75), compared to 96.5 (IQR: 79.25–130.75) for nonopen-access articles. However, no significant differences were found between open-access and nonopen-access articles regarding citations (p=0.489) or ASs (p=0.735).

Subtopics within the top 100 articles were analyzed, revealing 38 articles falling under the category of "auditory and music perception," making it the most prevalent subtopic. Following this, "electrode and/or implant properties" emerged as the next most common subtopic. Table 4 illustrates the ASs and citations of the top 100 articles organized by subtopics.

Furthermore, study populations were categorized into four groups: pediatric patients, adults, geriatric patients, and others (including animal experiments, medical devices,

**Table 2: Altmetric scores and citation numbers of top 100 articles, ranked according to the study types**

| Study type | Number of articles | Altmetrics scores | Citations |
|---|---|---|---|
| **All article** | 100 | 4 (1–10) | 91 (80–113) |
| **Original scientific paper** | 74 | 3 (1–6) | 90 (80–109) |
| **Prospective** | 17 | 6 (1–16) | 106 (86–106) |
| **Descriptive** | 10 | 4 (1–2) | 79 (74–142) |
| **Case-control** | 10 | 5 (0-NA) | 105 (88-NA) |
| **Cohort study** | 10 | 6 (0-NA) | 80 (72-NA) |
| **Retrospective** | 9 | 5 (3–26) | 87 (77–133) |
| **Cross-sectional** | 6 | 25 (16-NA) | 106 (91-NA) |
| **Animal study** | 6 | 4 (0.50–12) | 134 (103.75–242.25) |
| **Experimental** | 4 | 79.50 (79-NA) | 5 (1-NA) |
| **Methodological** | 2 | 27 (14–27) | 110.50 (88-NA) |
| **Review and meta-analysis** | 26 | 7 (3–20) | 103 (79–122) |

Median (25%-75% interquartile range) were used, NA: Not applicable.

**Table 3: Altmetric scores and citation numbers of top 100 articles, ranked according to published years**

| Published years of articles | Number of articles | Altmetrics scores | Citations |
|---|---|---|---|
| **2011** | 12 | 1 (0–3) | 78 (76–83) |
| **2012** | 19 | 4 (2–10) | 88 (79–112) |
| **2013** | 28 | 3 (1–8) | 101 (86–123) |
| **2014** | 21 | 4 (3–34) | 94 (84–109) |
| **2015** | 8 | 4 (2–11) | 96 (79–128) |
| **2016** | 8 | 8 (3–13) | 87 (79–104) |
| **2017** | 4 | 4 (3–13) | 96 (83–104) |
| **2018** | NA | NA | NA |
| **2019** | NA | NA | NA |
| **2020** | NA | NA | NA |
| **2021** | NA | NA | NA |

Median (25%–75% interquartile range) was used, NA: Not applicable

**Table 4: Altmetric scores and number of citations of top 100 articles, ranked according to the study subtopics**

| Study subtopics | Number of articles | Altmetrics scores | Citations |
|---|---|---|---|
| Auditory and music perception | 38 | 4 (1–16.25) | 91.50 (77.75–123) |
| Electrode and implant properties | 19 | 4 (1–10) | 91 (84–109) |
| Neuroplasticity and electrophysiology | 8 | 4.50 (1–47.75) | 100 (86–119.75) |
| Cognitive functions, emotional and behavioral development | 7 | 3 (2–5) | 84 (74–130) |
| Histopathology, etiology, epidemiology, and anatomy | 7 | 3 (0–8) | 81 (78–121) |
| Language outcomes | 6 | 13.50 (1-NA) | 114.50 (108-NA) |
| Depression and quality of life | 6 | 3.50 (0–6.75) | 86.50 (78.25–148) |
| Genetics and modeling | 4 | 4 (1.25–12) | 113 (87.25–114) |
| Auditory outcomes | 3 | 1.50 (1-NA) | 79.50 (75-NA) |
| Auditory rehabilitation | 2 | 81 (4-NA) | 95.50 (85-NA) |

Median (25%–75% interquartile range) was used, NA: Not applicable.

histopathological, cellular, etc.). Among these, 33 studies exclusively involved pediatric patients, 32 focused on adults, and 6 targeted geriatric patients. Additionally, 11 studies involved pediatric, adult, and geriatric populations, whereas 18 involved other populations. Median citation numbers for studies involving pediatric, adult, and geriatric populations were 85 (IQR: 80–107), 96 (IQR: 80–125), and 85 (IQR: 80–87), respectively. Median ASs for studies involving pediatric, adult, and geriatric populations were 4 (IQR: 1–14), 4 (IQR: 2–6), and 6 (IQR: 1–11), respectively. Interestingly, the category of "other populations" exhibited a median citation number of 305 and a median AS of 20.

## DISCUSSION

This study investigated the relationship between AS and traditional bibliometrics in the CI literature. To our knowledge, this analysis stands as the only exploration of this relationship within this specialty. Our findings showed an overall correlation between traditional bibliometrics and the innovative AS, shedding light on their interplay. Notably, a correlation was observed between the number of citations and journal IF, an anticipated outcome considering IF's reliance on citation counts for its calculation.

Maggio et al. conducted a study examining the relationship between altmetrics and traditional dissemination metrics in health professions education, noting a positive association between certain altmetric outcomes and citations (10). Additionally, they found that public accessibility positively influenced article access. While significant correlations between traditional metrics and altmetrics have been observed in various fields such as urology, plastic surgery, and pediatric surgery, some scholars argue against using AS as a direct substitute for traditional metrics in evaluating scientific literature impact (2, 11, 12). This standpoint may be influenced by several factors. Notably, AS values are subject to constant fluctuations over time, as highlighted by Collins et al. (1). Furthermore, AS does not include all online platforms, leaving gaps in online attention assessment. Moreover, disparities in online attention between scientific and lay communities remain poorly understood. Differential

levels of interest exhibited by these communities toward various article types may influence correlation outcomes. Consequently, online attention may yield favorable and detrimental effects. While contentious papers might not significantly impact the scientific community, they could increase public interest, consequently elevating AS. Articles accumulating numerous citations typically exert substantial influence within the scientific community by advancing knowledge, influencing practice changes, and often serving as foundational work for further research endeavors (13).

In this study, older articles did not accrue more citations, whereas more recent publications exhibited higher ASs. This observation was likely rooted in the assumption that older articles had more time for dissemination. However, numerous factors influence citation frequency beyond publication age. One such factor is the topical interest level; articles addressing less popular topics initially tend to gain fewer citations. As interest in a given topic grows over time, newer articles may attract more citations, potentially rendering older articles outdated. This phenomenon arises from the immediate measurability of online attention compared with the gradual accumulation of citations. Furthermore, articles published after 2014 demonstrated a higher median AS compared with those published before 2014, underscoring the increasing use of social media among academics, scientists, and healthcare professionals for disseminating scientific content (14). DeAtkine et al. examined the social media presence of otolaryngology residency programs and noted substantial growth in social media utilization in 2020 compared with previous years (15). This trend implies that scientific communities leverage social media platforms to engage with the public and potential patients, which holds significance for medical practitioners, researchers, and publishers. Additionally, social media platforms serve as effective marketing tools. Moreover, research indicates that incorporating infographics alongside article links enhances social media presence and amplifies article impact (16). Among the rampant dissemination of false information online, social media platforms play crucial roles in disseminating accurate medical information and fostering constructive dialogue (17, 18).

Open-access articles are readily accessible to all readers, leading to the expectation of increased readership and citation frequency (19, 20). Antelman et al. found that open-access publications across various fields, such as philosophy, political science, engineering, and mathematics, exhibited higher citation rates than nonopen-access articles (19). Similarly, Silva et al., in a study of 4,022 sports science articles, observed a stronger correlation between AS and citation numbers than between AS and IF or open-access status (21). However, contrary to these expectations, our study revealed that open-access status did not significantly impact AS or citation numbers. Patel et al. also reported similar findings, indicating no discernible differences in ASs between open-access and nonopen-access articles (22). These findings suggest that while open access may enhance visibility within the academic community, it did not necessarily translate to increased media attention (22).

Regarding CI subtopics, our analysis identified auditory and music perception, electrode and/or implant properties, neuroplasticity, and electrophysiological studies as the most prevalent themes among the top 100 articles. However, studies on neuroplasticity, genetics, in vivo animal testing, bioinformatics, and computational models were more likely to be published and cited in journals with higher IFs. This inclination could be attributed to the innovative findings yielded by studies employing molecular methodologies, potentially leading to treatments with significant clinical implications, thereby increasing the likelihood of publication in high-ranking journals (23, 24).

Despite our findings indicating a correlation between IF and certain aspects of article visibility, it is crucial to acknowledge that our study did not aim to equate IF with the quality of individual articles. The IF has deviated from its original purpose of gauging the journal's influence and no longer serves as an accurate measure of the scientific merit of each article (25). Indeed, a high IF rating may not necessarily correlate with the number of citations received by published papers (26). It is widely recognized that a small fraction of highly influential papers that contribute disproportionately to a journal's citations may primarily drive its high IF (27, 28). Consequently, rather than relying solely on bibliometric indicators, the quality and impact of any study should be evaluated based on its scientific and/or societal significance (29).

Furthermore, it is important to interpret the findings of this study cautiously. First, our study's scope was confined to original research articles and systematic reviews categorized under CI, potentially excluding broader ENT, audiology, or multidisciplinary journals. In addition, certain audiology subtopics, such as surgery, were not included in our analysis, possibly resulting in the omission of certain frequently cited articles. Therefore, it is conceivable that certain influential articles within the media and scientific community were overlooked. However, our study design reduced the impact of inherent biases in IF calculations on research endpoints by focusing solely on audiology papers (30). Notably, IF calculations are susceptible to manipulation, particularly through the inclusion of noncitable items such as editorials and commentaries, which may inflate the total citation count but are not factored into the baseline of IF calculation (31, 32).

In this study, correlations between AS and traditional metrics were observed, highlighting the growing significance of media in science communication and the encouragement of media coverage for scientific articles. As altmetrics gain popularity, they complement traditional citation-based metrics, reflecting a broader spectrum of research impact. Bibliometrics, which lies at the core of scientific research data analysis, is widely accepted as a valid and reliable method for research evaluation, offering advantages such as quantifying scholarly output (13). However, it lacks indicators of different types of research output, limiting its scope in comprehensively evaluating influence. While bibliometric indicators are viewed as objective and transparent, appropriate statistical methods must be

employed due to their numerical nature and highly skewed distributions (5). One notable limitation is the time required to acquire bibliometric data, with reliable impact estimation typically taking 3 years after publication (13). Altmetrics have emerged as a solution to this challenge, offering early impact data (33) and addressing the lack of systematic procedures for identifying and evaluating societal impact (34). These metrics, available immediately after publication or presentation, serve as early indicators of potential long-term influence, capturing societal effects beyond the academic community. Altmetrics also offers the advantage of quantifying information beyond standard outputs such as conference presentations and gray literature, including diverse outputs such as YouTube videos (34). However, challenges remain in utilizing altmetrics in decision-making processes (33, 34) and ethical considerations, such as the potential introduction of bias through Twitter bots, must be addressed (34).

Documenting the scientific and clinical impact of research is increasingly vital across disciplines, including audiology. Alternative impact metrics supplement bibliometrics, reflecting further research influence (5). With metric methodologies evolving in the modern technological era, researchers should familiarize themselves with new bibliometrics and other metrics necessary for submission to employers or institutions (5).

### Methodological considerations/limitations

Methodological considerations and limitations are inherent in this study. First, its retrospective nature presents a limitation, as current trends may diverge from those observed during data collection. In addition, the findings may not be generalizable to articles in other specialties or those published outside the study period. The selection of time frames could have influenced the results, and controlling for these variables could have enhanced the reliability of AS estimation. Furthermore, while altmetrics are effective at detecting early impacts, the analysis only included the top 100 most cited papers. Consequently, the inability to access AS data for papers published after 2017 represents another limitation in terms of revealing early impacts. Nevertheless, newer publications exhibited higher ASs, indicating a potential trend worth exploring further.

## CONCLUSION

This study marks the first analysis of ASs among the 100 most cited articles in the field of CI. The predominant subtopics among the most cited articles pertained to factors influencing speech perception in adults, whereas the article with the highest AS focused on genetics. Original research articles comprised the majority (74%) of the analyzed articles, with systematic reviews and meta-analyses accounting for the remaining 26%. Notably, open-access articles constituted 68% of the total. While articles categorized in Q1 journals exhibited higher citation numbers and ASs, those in Q2, Q3, and Q4 displayed similar metrics. The study revealed significant correlations between traditional metrics and altmetrics, indicating that more frequently cited publications were associated with higher ASs. This underscores the complementary nature of altmetrics to traditional metrics, with their importance anticipated to increase over time.

**Peer Review:** Externally peer-reviewed.

**Author Contributions:** Conception/Design of Study- D.T.; Data Acquisition- D.T., E.D.U.; Data Analysis/Interpretation- D.T., E.D.U.; Drafting Manuscript- D.T., E.D.U.; Critical Revision of Manuscript- D.T., E.D.U.; Final Approval and Accountability- D.T.; Material or Technical Support- D.T., E.D.U.; Supervision- D.T., E.D.U.

**Conflict of Interest:** The authors have no conflict of interest to declare.

**Financial Disclosure:** The authors declared that this study has received no financial support.

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