MARPE and SARPE in orthodontics: past developments, current trends, and future perspectives – a bibliometric analysis

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Introduction: This study aimed to comparatively evaluate the evolution, current status, and emerging trends of research on miniscrew-assisted rapid palatal expansion (MARPE) and surgically assisted rapid palatal expansion (SARPE).
Methods: Articles and reviews related to MARPE and SARPE were retrieved from the Scopus database. A total of 202 publications on MARPE and 347 on SARPE were analyzed using bibliometric methods. Bibliometric analyses were performed with the *Bibliometrix (R)* and *VOSviewer* software. The relationships between the number of publications, citation counts, and gross domestic product (GDP) per capita were examined using Pearson correlation and linear regression analyses ($P < 0.05$).
Results: The number of MARPE-related publications showed an average annual increase of 38.86% (SARPE: 10.38%). The mean number of citations per publication was 20.16 in the SARPE field and 13.53 in the MARPE field. The annual citation rate was 2.53 for MARPE and 1.64 for SARPE. Regarding publication output, the United States, Brazil, and South Korea were the leading countries in MARPE research, whereas Brazil, Turkey, and Germany were most prominent in SARPE. A strong positive correlation was found between GDP per capita and the mean number of citations per article (MARPE r = 0.73; SARPE r = 0.70).
Conclusions: The SARPE field possesses an established literature base primarily focused on surgical procedures. In contrast, MARPE has rapidly emerged as a growing field characterized by its minimally invasive nature and digital-oriented advancements.
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Introduction

Maxillary transverse deficiency is a prevalent form of malocclusion, occurring in approximately 21% of pediatric patients and around 10% of adults.[1] When left untreated, maxillary constriction may extend beyond dental malocclusion, potentially contributing to esthetic, functional, and respiratory impairments. Consequently, its effective correction is crucial for enhancing facial esthetics and optimizing both oral and nasal functions.[2]

Traditionally, rapid maxillary expansion (RME) performed with tooth-borne appliances has been a reliable and widely used method in pediatric and adolescent patients. However, in skeletally mature individuals, the efficacy of conventional RME diminishes as a result of midpalatal suture fusion.[3]

Despite the lack of a definitive consensus on the chronological age of midpalatal suture fusion, it is generally accepted that rapid maxillary expansion (RME) is most effective before the age of 15.[4]

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Angelieri et al.[5] assessed midpalatal suture maturation using cone-beam computed tomography (CBCT) and proposed a five-stage classification (A–E). Based on this system, RME is deemed contraindicated in patients exhibiting stage D or E maturation.[5]

The inability to effectively perform RME in adult patients prompted researchers to seek alternative treatment modalities. As a result, the concept of disrupting sutural resistance via osteotomies, termed Surgically Assisted Rapid Palatal Expansion (SARPE), was developed and implemented.[6] Surgically Assisted Rapid Palatal Expansion (SARPE) is an osteogenic separation procedure comprising four distinct stages: the surgical phase (osteotomy), latency period, distraction phase, and consolidation phase. Importantly, the surgical component of SARPE remains without a standardized protocol, and a universally accepted 'gold standard' technique has not yet been established.[7]

Although SARPE carries the potential risk of severe complications, it is predominantly regarded as a procedure associated with minor or mild adverse events.[8] Nonetheless, the invasive character of SARPE has led clinicians to explore the feasibility of non-surgical approaches in young adults.

The use of miniscrews in the palatal region was first introduced in 1996.[9] Subsequently, miniscrew-assisted appliances were designed for use in conjunction with SARPE.[10–12] In 2010, Wilmes et al.[13] introduced a hybrid expansion appliance supported by both bone and teeth. Dr. Won Moon and colleagues later developed a MARPE appliance, specifically the Maxillary Skeletal Expander (MSE), which utilizes four miniscrews for skeletal anchorage, incorporating a hybrid design with tooth-borne bands for stabilization.[14–17] Although MARPE is the most recently introduced treatment modality in terms of historical development, it appears to occupy a position between RME and SARPE in the indication hierarchy. These two treatment approaches, which address similar patient profiles, can be considered complementary rather than mutually exclusive. Examining the past, present, and future of these two modalities from a broad perspective—not as 'alternatives' but as 'contributions' to conventional methods—may guide the evolution of future innovations and adjunctive treatments.

In the present study, a bibliometric analysis of publications on MARPE and SARPE was conducted separately, with the aim of elucidating the evolution, current status, and emerging trends in these fields. Analyses based on researchers, countries, institutions, keywords, and journals are expected to contribute both to mapping the existing literature and to providing guidance for future research directions.

Materials and methods

Data collection

The present study was conducted based on bibliometric data obtained from the Scopus database (Elsevier BV, Amsterdam, The Netherlands). Separate search strategies were developed for MARPE and SARPE. The following query was used for MARPE:

TITLE-ABS-KEY("miniscrew assisted rapid palatal expansion" OR "marpe" OR "microimplant assisted rapid palatal expansion" OR "temporary anchorage device assisted expansion" OR "miniscrew assisted expansion" OR "tad assisted expansion" OR "miniscrew assisted rapid maxillary expansion" OR "microimplant assisted rapid maxillary expansion") AND (DOCTYPE(ar) OR DOCTYPE(re)).

For SARPE, the query was as follows:

TITLE-ABS-KEY("surgically assisted rapid palatal expansion" OR "SARPE" OR "surgically assisted expansion" OR "surgical assisted rapid maxillary expansion" OR "sarme" OR "surgically assisted rapid maxillary expansion (sarme)") AND (LIMIT-TO(DOCTYPE,"ar") OR LIMIT-TO(DOCTYPE,"re")).

Only original research and review articles published in English were included, while case reports, letters, editorial articles, and conference abstracts were excluded. The searches were performed on September 15, 2025. The advanced search yielded 283 publications for MARPE and 481 publications for SARPE

Data processing

Two independent researchers (M.S. and A.Y.) screened the articles based on titles and abstracts, and ineligible studies were excluded. The exclusion criteria were: (1) publications unrelated to the topic; (2) opinion articles, editorials, conference reports, and case reports/series; (3) books; and (4) retracted publications. The two researchers achieved a Cohen's

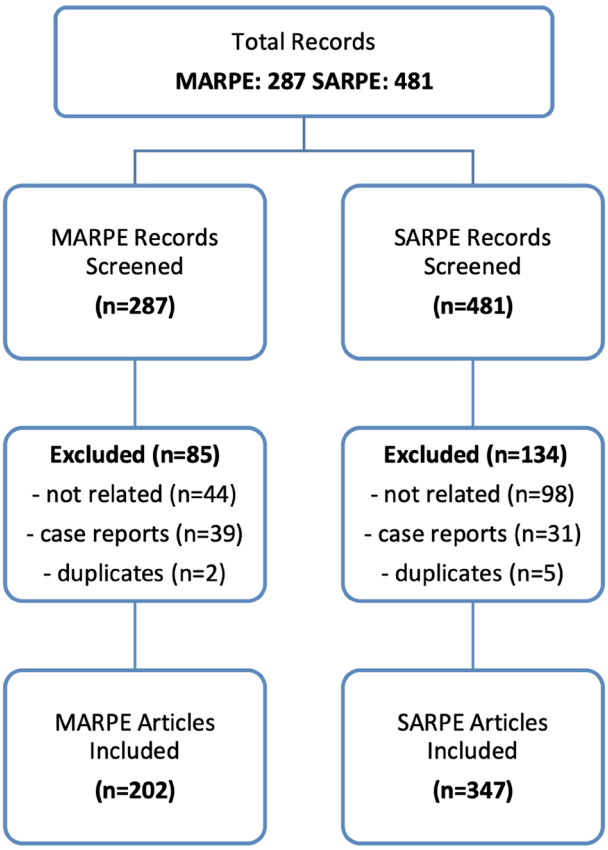


Figure 1. Flow diagram of the protocol of the study.

kappa agreement score of 0.97, indicating a high level of concordance. Discrepancies in the final selection of certain articles were resolved through evaluation by a third researcher (H.C.). Ultimately, 202 records were included for MARPE and 347 for SARPE (Figure 1).

Bibliographic data were exported from the Scopus database in CSV, RIS, and BibTeX formats. The exported fields included authors, title, year, source journal, citation count, document type, DOI, abstract, references, keywords, and affiliation information.

Data analysis

Bibliometric analyses were performed using the Bibliometrix R-package (version 4.2.1) and VOSviewer (version 1.6.19). For statistical tests and additional visualizations, Python (version 3.10) was utilized with the pandas, scipy, matplotlib, and networkx libraries. Tables were generated from data processed with pandas. Keyword co-occurrence network analysis was conducted using VOSviewer, while other graphs were produced with matplotlib.

To evaluate the relationship between countries' scientific output and economic indicators, per capita gross domestic product (GDP) data were obtained from the World Bank's World Development Indicators database.[15] The associations between GDP and the number of publications, total citations, and average citations per article were analyzed using Pearson correlation analysis. Additionally, simple linear regression was applied to examine trends among variables, with a significance level set at $P < 0.05$. In addition to the bibliometric metrics, the top-cited articles were qualitatively analyzed to extract key clinical themes and guidelines presented in the discussion section.

RESULTS

Comparison of key metrics

The main metrics of the relevant literature are presented as a radar chart in Figure 2. For MARPE, 202 publications across 67 journals were identified, whereas 347 publications across 110 journals were found for SARPE. In terms of citation performance, SARPE publications exhibited a higher mean number of citations per article (20.16) compared to MARPE (13.53); however, MARPE publications received more citations on an annual basis (2.53 vs. 1.64). Among MARPE publications, 171 were original articles and 31 were reviews, while SARPE included 312 original articles and 35 reviews.

Annual publication volume analysis

The annual percentage growth rate for MARPE was 38.86%, whereas it was 10.38% for SARPE (Figure 2). Figure 3 illustrates the temporal trends of publications in the SARPE and MARPE fields. SARPE studies followed an 'S'-shaped trend with a steady increase over the years, while MARPE publications showed a rapid acceleration, particularly in the last five years. Furthermore, when examining the proportion of MARPE publications relative to the total number of MARPE and SARPE publications in a given year (depicted by the blue line), the dramatic rise of MARPE becomes evident. The MARPE-to-total publication ratio exceeded 50% in 2019 and, except for 2020, remained above 50% in subsequent years.

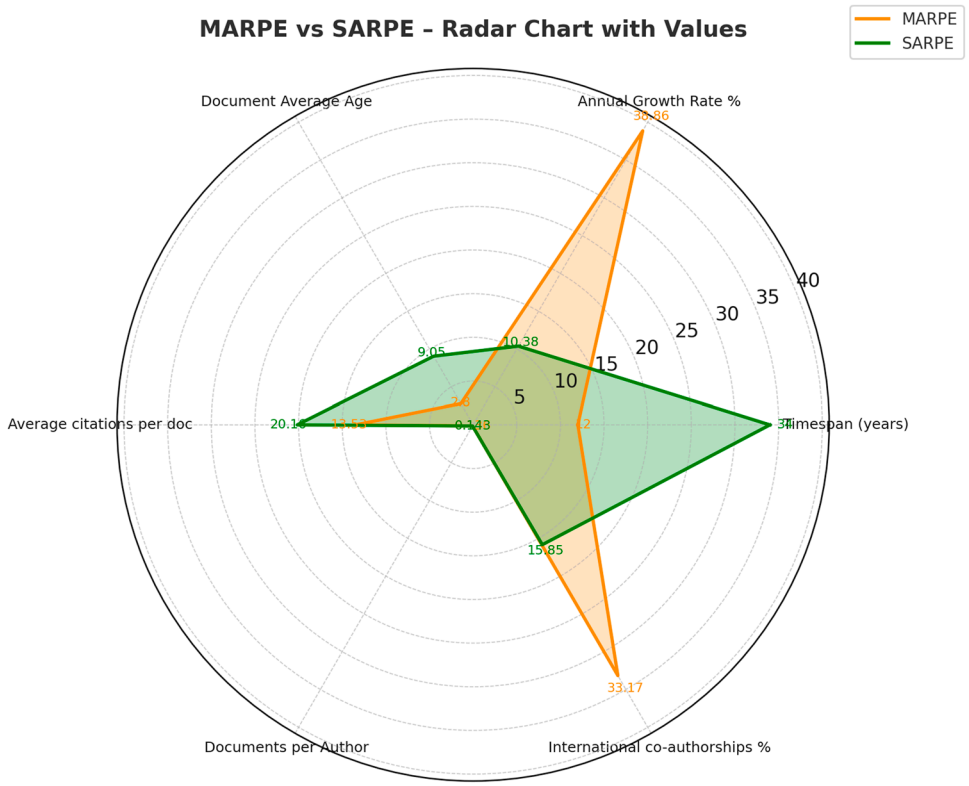


Figure 2. A bibliometric comparison of MARPE and SARPE literature based on key indicators.

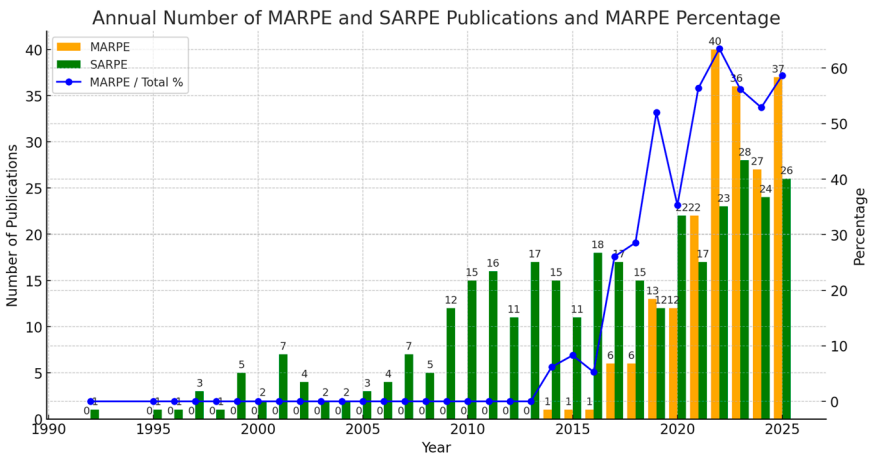


Figure 3. Annual Number of MARPE and SARPE Publications and MARPE Proportion. Orange bars represent MARPE publications, and green bars represent SARPE publications. The blue line depicts the annual proportion of MARPE publications relative to the total combined number of MARPE and SARPE publications in each year.

Authors' analysis

A total of 3,903 authors contributed to the 549 publications in the respective fields (1,484 for MARPE; 2,419 for SARPE). Table I lists the top 10 most cited authors in the MARPE and SARPE domains. In MARPE research, the author with the highest total citations was Moon, Won (834 citations), followed by Lee, Kee-joon (516) and Machado, André Wilson (388). A significant portion of these publications originated from universities in South Korea and Brazil. In the SARPE field, the most cited author was Mommaerts, Maurice Y. (470 citations), with Koudstaal, Maarten Jan (352) and Wolvius, Eppo Bonne (352) sharing the second

Table I. Top 10 most cited authors in MARPE and SARPE research

MARPE						
Rank	Author	Total citations	Pubs	Research article/review	Cit/pub	University
1	Moon, Won	834	15	12/3	55.6	Ajou University, South Korea.
2	Lee, Kee-joon	516	11	10/1	46.9	Yonsei University College of Dentistry, Korea
3	MacHado, André Wilson	388	3	2/1	129.3	Universidade Federal do Paraná, Brazil
4	Choi, Yoon Jeong	315	5	5/0	63.0	Yonsei University College of Dentistry, Korea
5	Park, Youngchel	298	3	3/0	99.3	Yonsei University College of Dentistry, Korea
6	Suzuki, Selly Sayuri	261	6	5/1	43.5	Faculdade São Leopoldo Mandic, Brazil
7	Dominguez-Mompell, Ramon	246	6	5/1	41.0	Universidad Rey Juan Carlos, Spain
8	Moschik, Christoph E.	240	4	3/1	60.0	Universidade Federal do Paraná, Brazil
9	Brunetto, Daniel Paludo	238	4	3/1	59.5	Universidade Federal do Paraná, Brazil
10	Choi, Sunghwan	233	8	7/1	29.1	Yonsei University College of Dentistry, Korea
SARPE						
Rank	Author	Total citations	Pubs	Research article/review	Cit/pub	University
1	Mommaerts, Maurice Y.	470	4	3/1	117.5	Radboud University Medical Center, Netherlands
2	Koudstaal, Maarten Jan	352	6	5/1	58.7	Erasmus MC, Netherlands
3	Wolvius, Eppo Bonne	352	6	5/1	58.7	Erasmus MC, Netherlands
4	Van Der Wal, Karel G.H.	340	3	3/0	113.3	Erasmus MC, Netherlands
5	Schulten, Alcuin J.M.	327	2	2/0	163.5	Erasmus MC, Netherlands
6	Politis, Constantinus	278	11	11/0	25.3	KU Leuven, Belgium
7	Suri, Lokesh	272	1	0/1	272.0	Tufts University, USA
8	Taneja, Parul	272	1	0/1	272.0	Tufts University, USA
9	Pereira, Max Domingues	228	11	11/0	20.7	Universidade Federal de São Paulo, Brazil
10	Prahl-Andersen, Birte	226	1	1/0	226.0	Erasmus MC Sophia Children's Hospital, Netherlands

position. Researchers from the Netherlands and Belgium were particularly prominent in SARPE studies.

Countries' analysis

The top 10 countries in terms of publication output in the MARPE and SARPE fields are shown in Figure 4. For SARPE, Brazil (68), Turkey (53), and Germany (38) had the highest number of publications, whereas for MARPE, the ranking was the United States (34), Brazil (34), and South Korea (33). Although some countries had relatively low publication counts, they demonstrated high average citations per article, notably the Netherlands and Belgium. The United States exhibited high average citations in both MARPE and SARPE domains.

No significant correlation was observed between the number of publications and countries' per capita gross domestic product (GDP), and the correlation between total citations and GDP was weak. However, a strong and significant correlation was found between average citations per article and GDP (Table II). While countries with middle-to-low GDP, such as Brazil, generated a high number of publications, high-GDP countries like the United States, Belgium, and the Netherlands produced fewer but more highly cited publications.

Journals' analysis

Figure 5 depicts the journals with the highest number of publications in MARPE and SARPE fields over the years. In the MARPE literature, the American Journal of Orthodontics and Dentofacial Orthopedics had the highest number of publications (26), followed by Korean Journal of Orthodontics (15) and Progress in Orthodontics (12). Notably, the publication counts in these three journals increased rapidly after 2020.

In the SARPE field, the most prolific journals were the International Journal of Oral and Maxillofacial Surgery (38 publications), Journal of Oral and Maxillofacial Surgery (26 publications), and Journal of Cranio-Maxillofacial Surgery (26 publications). Additionally, the orthodontics-focused journal American Journal of Orthodontics and Dentofacial Orthopedics (26 publications) also made a noteworthy contribution.

Citation analysis

Tables III and IV present the most cited articles in the MARPE and SARPE domains. In both fields, a substantial portion of highly cited publications were review articles. In terms of total citations, the most cited SARPE article received 272 citations, whereas the top MARPE article received 175 citations. However, when considering annual citation rates, MARPE publications achieved higher values; for instance, a MARPE article published in 2017 reached the highest annual citation rate of 19.4 citations/year. Furthermore, clinical research articles were more prominent in MARPE, whereas SARPE literature was dominated by review articles.

Keyword analysis

Keywords reflect trends and focal points within a research field.[18] The keyword co-occurrence networks for MARPE and SARPE are shown in Figures 6 and 7. In the MARPE literature, the most central keywords were "palatal expansion" and "palatal expansion technique", followed by clinical and methodological terms such as "adult", "adolescent", "cone beam computed tomography (CBCT)", and "diagnostic imaging". The term "miniscrew assisted rapid palatal expansion (MARPE)" was also frequently used as a keyword. In the SARPE literature, "palatal expansion" was the primary keyword, but associated terms were more surgically oriented. The most frequently occurring terms included "surgery", "osteotomy", "surgical technique", and "orthognathic surgery". Demographic descriptors such as "adult", "male", and "female" were also frequently employed.

Discussion

The present bibliometric analysis delineates the evolution of MARPE and SARPE literature. Our findings indicate that MARPE has exhibited a remarkable acceleration, particularly over the past decade, whereas SARPE maintains a more established but relatively stable publication volume. This pattern can be attributed to MARPE's minimally invasive nature, its provision of a surgical alternative for young adults, its compatibility with digital technologies, and its innovative design. Citation analysis further supports this observation, as highly cited SARPE publications are predominantly review articles,

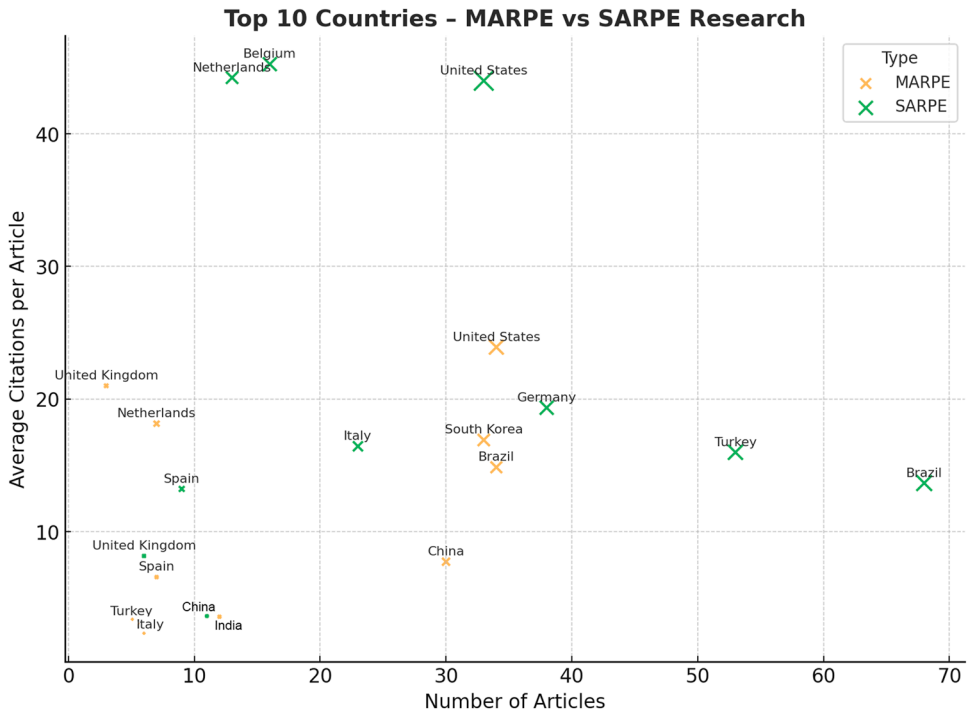


Figure 4. Top 10 countries with the highest number of publications in the fields of MARPE and SARPE. The vertical axis represents the average citations per article, and the horizontal axis represents the total number of publications.

Table II. Correlation between gross domestic product (GDP) per capita and MARPE/SARPE research (Top 10 Countries)

Field	Variable	Pearson r	*P*-value*	Interpretation
MARPE	Articles ↔ GDP	–0.02	0.95	No correlation
	Total Citations ↔ GDP	0.37	0.29	Weak, not significant
	Avg. Citations/Article ↔ GDP	0.73	0.018*	Strong, significant positive correlation
SARPE	Articles ↔ GDP	–0.40	0.25	No correlation
	Total Citations ↔ GDP	0.32	0.37	Weak, not significant
	Avg. Citations/Article ↔ GDP	0.70	0.023*	Strong, significant positive correlation

*$P<0,05$.

whereas clinical research articles predominate in MARPE.

Keyword analyses further support this distinction. In MARPE, clinical and methodological terms such as "CBCT," "diagnostic imaging," and "palatal expansion technique" are prevalent, whereas in SARPE, surgically oriented terms such as "surgery," "osteotomy," and "surgical technique" dominate. This indicates that MARPE research focuses primarily on imaging and biomechanics, while SARPE is centered on surgical procedures.[16,17] Furthermore, MARPE publications exhibit higher annual citation rates, suggesting that current scientific trends are increasingly oriented toward MARPE.

Won Moon and his team have conducted extensive MARPE research, leading the field with 15 publications and 834 citations. Looking at his research trajectory, his work has evolved from initial finite element analyses[19] to clinical protocols (MSE), effectively establishing the biomechanical foundations of non-surgical expansion in adults.[18,20,21] This suggests that his high citation count is not

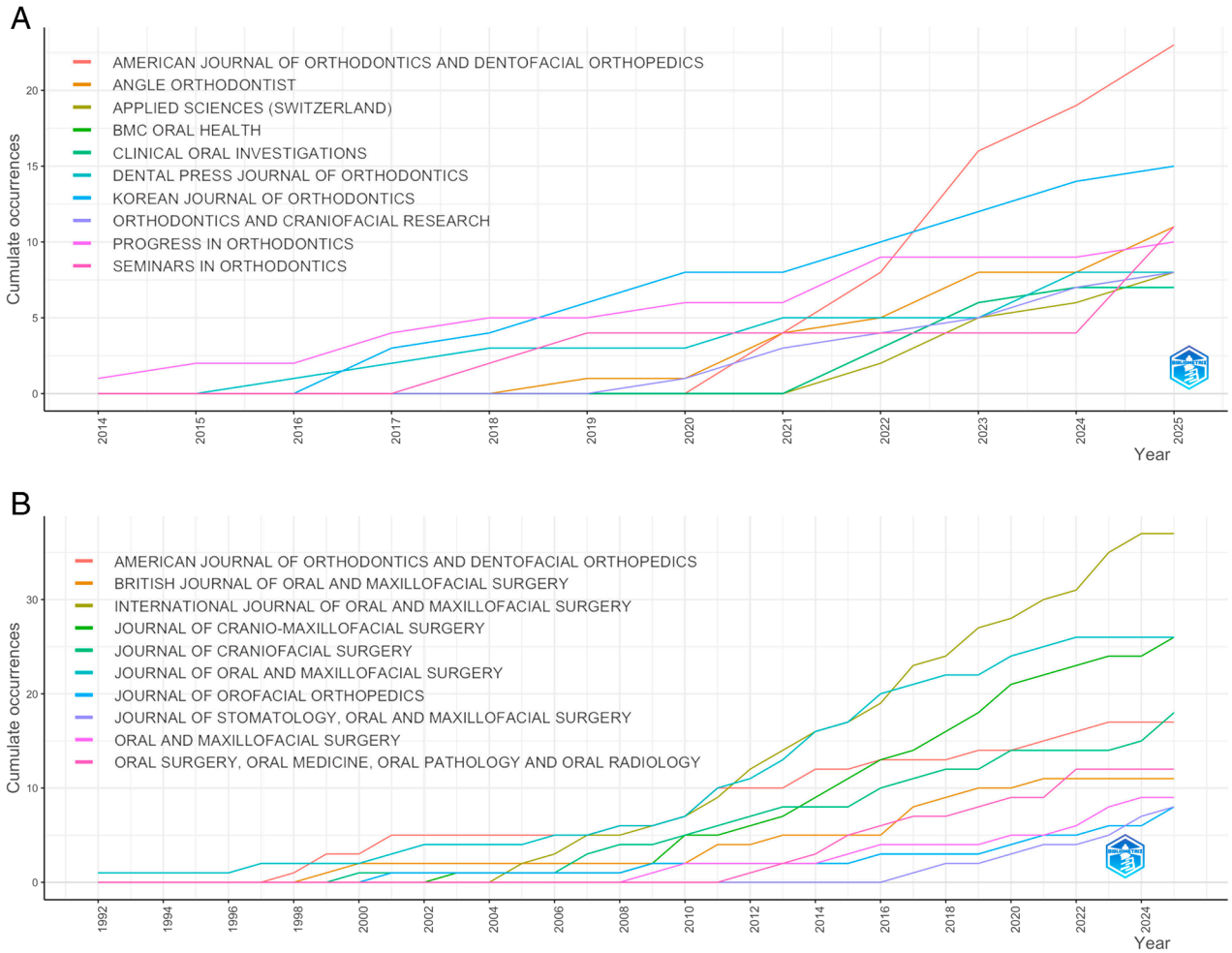


Figure 5. Cumulative publication trends of the most productive journals in MARPE (A) and SARPE (B) research.

merely a result of publication volume, but rather stems from his role in shifting the paradigm from "surgically-assisted" to "miniscrew-assisted" treatments. Following Won Moon, Lee Kee-joon is the most cited author and served as the first author of the earliest MARPE publication. In a case report published in 2010, the treatment of a 20-year-old patient with maxillary transverse deficiency and mandibular prognathism using a four-screw, tooth-bone-supported expansion appliance is described.[22,23]

The prominence of Kee-Joon Lee and Yoon Jeong Choi from Yonsei University (South Korea) highlight a distinct 'Eastern' school of thought focused on miniscrew biomechanics. The strong presence of these authors in the top rankings suggests that clinicians seeking evidence on the biomechanical limits of bone-borne expansion should look towards the South Korean literature. In contrast, the SARPE network is dominated by European surgeons like Maurice Y. Mommaerts and Constantinus Politis. Persistently high citation rates indicate that, despite the rise of MARPE, SARPE has not completely lost its clinical importance in the management of skeletal discrepancies. Thus, the bibliometric data reveals a clear dichotomy: the 'innovation authority' currently resides in the USA and South Korea (MARPE), while the 'surgical authority' remains rooted in Europe (SARPE).

At the country level, MARPE research primarily originates from universities in South Korea and Brazil, whereas SARPE has exerted a strong scientific impact in Western European countries, particularly the Netherlands and Belgium. No significant relationship was observed between the number of publications and GDP; however, a strong correlation was found between average citations per article and

Table III. Most cited papers in MARPE research (ranked by total citations and citations per year)

Title	Authors, Year, Journal	DOI	Citation	Citation per Year
Non-surgical treatment of transverse deficiency in adults using MARPE	DP, 2017, Dent. Press J. Orthod.	10.1590/2177-6709.22.1.110-125.sar	175	19.44
The effects of micro-implant assisted rapid palatal expansion (MARPE)	M, 2014, Prog. Orthod.	10.1186/s40510-014-0052-y	158	13.17
Changes in the midpalatal and pterygopalatine sutures after MARPE	D, 2017, Prog. Orthod.	10.1186/s40510-017-0188-7	143	15.89
Skeletal and dentoalveolar changes after miniscrew-assisted rapid palatal expansion	J, 2017, Korean J. Orthod.	10.4041/kjod.2017.47.2.77	142	15.78
Stability of dental, alveolar, and skeletal changes after MARPE	H, 2017, Korean J. Orthod.	10.4041/kjod.2017.47.5.313	89	9.89
		According to Citation per Year		
Title	Authors, Year, Journal	DOI	Citation	Citation per Year
Non-surgical treatment of transverse deficiency in adults using MARPE	DP, 2017, Dent. Press J. Orthod.	10.1590/2177-6709.22.1.110-125.sar	175	19.44
Efficacy of Miniscrew-Assisted Rapid Palatal Expansion (MARPE) in adults	A, 2021, Eur. J. Orthod.	10.1093/ejo/cjab005	86	17.20
Changes in the midpalatal and pterygopalatine sutures after MARPE	D, 2017, Prog. Orthod.	10.1186/s40510-017-0188-7	143	15.89
Skeletal and dentoalveolar changes after miniscrew-assisted rapid palatal expansion	J, 2017, Korean J. Orthod.	10.4041/kjod.2017.47.2.77	142	15.78
The effects of micro-implant assisted rapid palatal expansion (MARPE)	M, 2014, Prog. Orthod.	10.1186/s40510-014-0052-y	158	13.17

Table IV. Most cited papers in SARPE research (ranked by total citations and citations per year)

Title	Authors, Year, Journal	DOI	Citation	Citation per Year
Surgically assisted rapid palatal expansion: A literature review	L, 2008, Am. J. Orthod. Dentofac. Orthop.	10.1016/j.ajodo.2007.01.021	272	15.11
Surgically assisted rapid maxillary expansion (SARME): A review of the literature	MJ, 2005, Int. J. Oral Maxillofac. Surg.	10.1016/j.ijom.2005.04.025	226	10.76
Transpalatal distraction as a method of maxillary expansion	MY, 1999, Br. J. Oral Maxillofac. Surg.	10.1054/bjom.1999.0127	212	7.85
Surgically assisted rapid palatal expansion: An outpatient technique with long-term stability	RA, 1992, J. Oral Maxillofac. Surg.	10.1016/0278-2391(92)90352-Z	199	5.85
Surgically assisted rapid maxillary expansion: a comparison of technique, response, and stability	WM, 1997, Angle Orthod.	10.1043/0003-3219(1997)067 < 0309:SARMEA > 2.3.CO;2	176	6.07
According to Citation per Year				
Title	Authors, Year, Journal	DOI	Citation	Citation per Year
Surgically assisted rapid palatal expansion: A literature review	L, 2008, Am. J. Orthod. Dentofac. Orthop.	10.1016/j.ajodo.2007.01.021	272	15.11
Surgically assisted rapid maxillary expansion (SARME): A review of the literature	MJ, 2005, Int. J. Oral Maxillofac. Surg.	10.1016/j.ijom.2005.04.025	226	10.76
Surgically assisted rapid maxillary expansion: An anatomic biomechanical study	PH, 2020, Int. J. Oral Maxillofac. Surg.	10.1016/j.ijom.2019.08.011	63	10.50
Microimplant assisted rapid palatal expansion in adults: A systematic review	CB, 2021, Am. J. Orthod. Dentofac. Orthop.	10.1016/j.ajodo.2020.03.024	50	10.00
Transpalatal distraction as a method of maxillary expansion	MY, 1999, Br. J. Oral Maxillofac. Surg.	10.1054/bjom.1999.0127	212	7.85

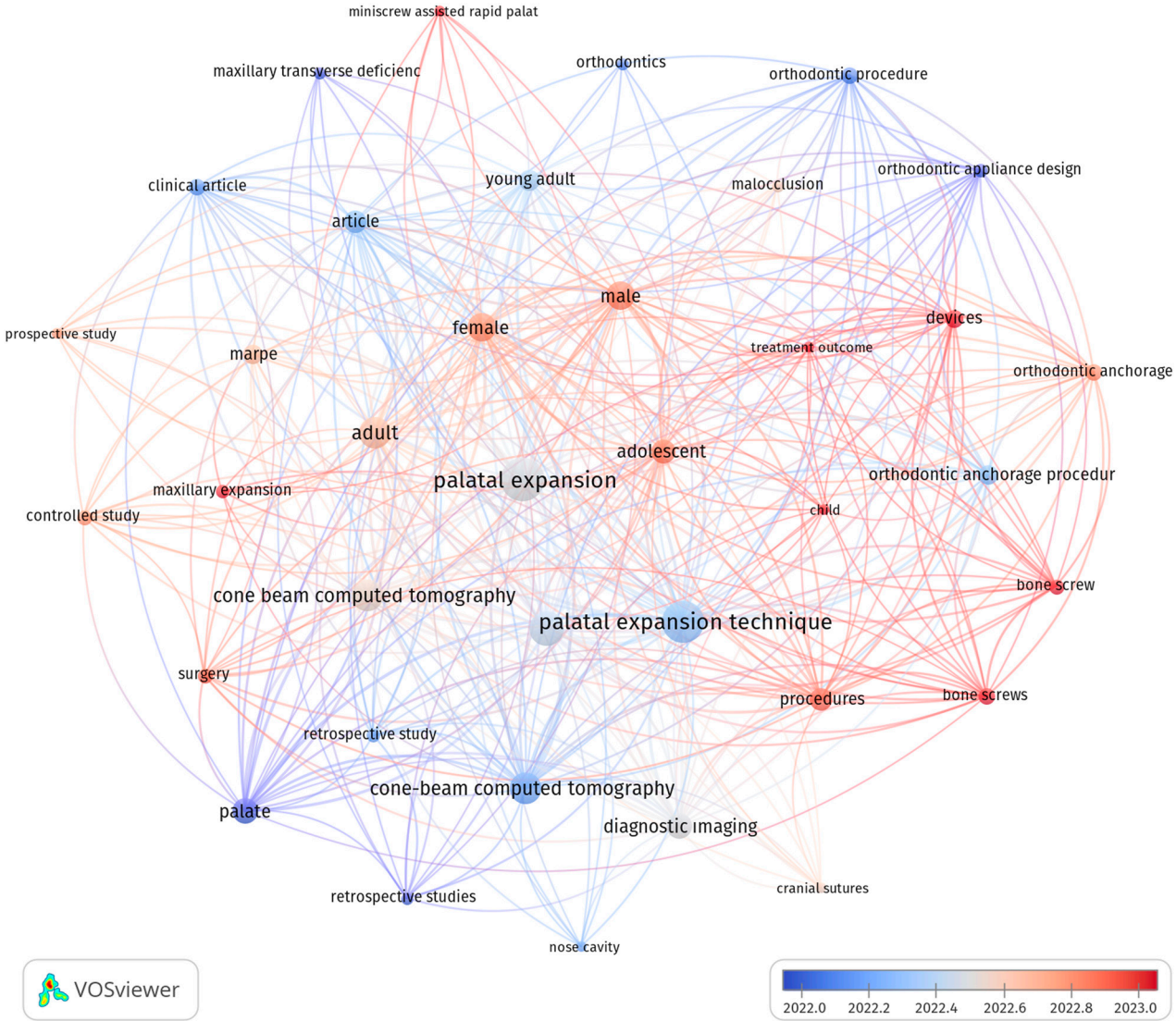


Figure 6. Keyword co-occurrence network in MARPE literature.

GDP. This finding suggest that economic capacity may influence citation impact and visibility more than solely publication quantity.[24] When Figure 4 and Table I are considered together, it is apparent that countries with high publication and citation counts often have one or more authors listed among the most cited. Notably, no authors from Turkey appear in Table I, indicating that research outputs in Turkey are distributed among multiple authors rather than concentrated in a few individuals.

The geographical analysis reveals significant trends regarding the origin of influential research. The USA's leadership in publication count aligns with its historical role in developing appliance designs (e.g., MSE). However, the noteworthy position of South Korea in the MARPE field (ranking 3rd) compared to its lower activity in SARPE indicates a specific regional expertise in miniscrew-assisted orthodontics. This suggests that South Korean institutions, particularly Yonsei University, have become the primary hubs for research on 'pure' bone-borne expansion without surgical assistance. Furthermore, Brazil's unique position as a top producer in both SARPE (1st) and MARPE (2nd) indicates a highly active clinical environment that bridges both worlds. Unlike the US or Korea, which lean heavily towards specific modalities, Brazilian research appears to offer extensive comparative data, making it a critical source

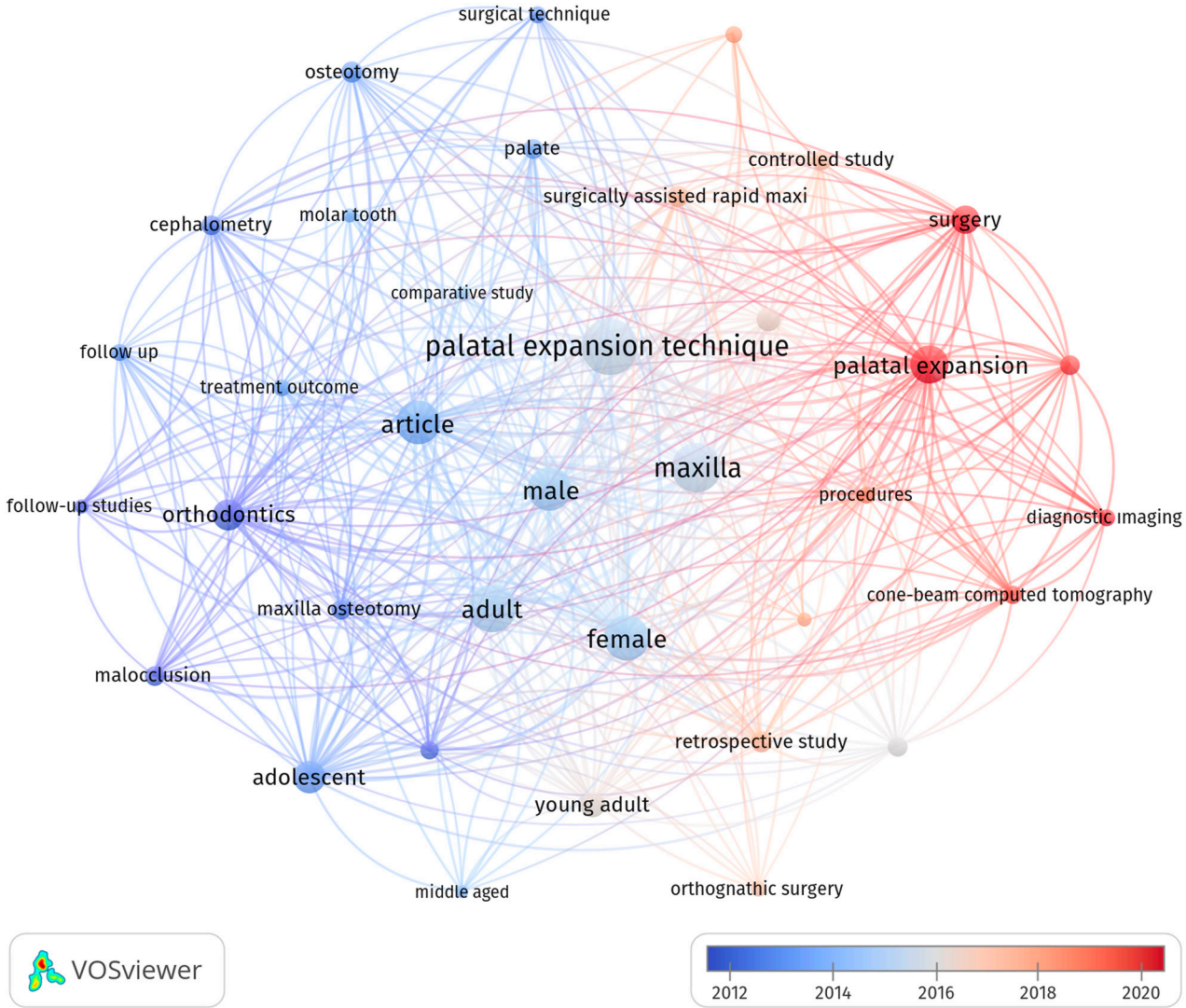


Figure 7. Keyword co-occurrence network in SARPE literature.

for studies evaluating the transition from surgical to non-surgical protocols.

Journal distribution analysis revealed that MARPE publications are concentrated in orthodontics-focused journals, whereas SARPE publications are predominantly featured in maxillofacial surgery journals.

The efficacy of MARPE varies across patients, with success rates influenced by factors such as the degree of midpalatal suture fusion, surrounding maxillary suture widths, palatal bone thickness, and implant positioning.[25] Although key terms like "bone thickness" and "suture" appear infrequently, their recent emergence in the literature indicates that this area is open to new research. In MARPE studies, "nose cavity" is among the 30 most frequently used keywords (Figure 7), though it has not been widely employed in recent years, suggesting that future investigations centered on the "nose cavity" may be a promising avenue for MARPE research.

In contrast, keyword analysis in SARPE shows that research topics have remained relatively consistent over time, though terminology has evolved—for instance, the earlier use of "adolescent" has largely been replaced by "young adults" (Figure 6). MARPE offers a non-surgical option for young adults, whereas

SARPE remains necessary in cases involving older patients, high sutural resistance, or elevated risk of failure. Looking forward, MARPE is expected to become increasingly widespread through the use of personalized 3D-printed appliances, digital treatment planning, and minimally invasive modifications

Clinical Implications and Evidence-Based Guidelines

Based on the keyword analyses and highly cited studies, the following comparative guidelines emerge to guide clinicians and inspire future researchers:

Re-defining the "Borderline" Patient: The bibliometric data shows a surge in keywords like "young adult" and "skeletal maturation." (Figure 7). Clinically, this corresponds to the findings of Brunetto et al.[14] who reported a 96.33% success rate in opening the midpalatal suture in patients with a mean age of 26.1 years. Similarly, the systematic review by Kapetanović et al.[4] confirmed a 92.5% success rate in late adolescents and adults, suggesting that chronological age alone should no longer be viewed as an absolute contraindication for non-surgical expansion. Thus, the "age limit" is not a rigid wall but a gradient that MARPE has significantly extended.

However, beyond chronological age, factors such as circummaxillary suture thickness, midpalatal suture maturation stage, and appliance design are key determinants of the expansion procedure. It has been reported that treatment failures can occur even when all these factors appear favorable.[4,25,26] The central position and recency (red color) of keywords like "adult", "adolescent", and "child" in Figure 7 support the complexity of this decision-making process. Consequently, while MARPE is the first line of treatment for young adults, SARPE remains the necessary alternative for cases where high sutural resistance leads to failure or where massive expansion is required.[23,27]

Morbidity vs. Predictability Trade-off: SARPE remains the traditional method of choice for skeletally mature patients with massive skeletal discrepancies, due to its consistent ability to enlarge the apical base.[28] However, this comes with surgical invasiveness and morbidity. In contrast, the MARPE literature highlights terms like "safety" and "minimally invasive." The trade-off is clear: MARPE offers a superior patient-reported outcome profile but carries a risk of technical failure (e.g., screw breakage/tipping) that is virtually non-existent in osteotomy-assisted SARPE.[29] Furthermore, the prominent clustering of terms like 'CBCT' and 'diagnostic imaging' in our analysis suggests that the integration of digital planning is increasingly mitigating these technical risks by ensuring precise bicortical engagement.

Periodontal and Airway Outcomes: Both modalities offer advantages over tooth-borne RME. Huang et al. confirmed that MARPE minimizes buccal tipping, a benefit historically attributed only to SARPE.[30] Regarding respiratory function, Koudstaal et al.[28] established SARPE's efficacy in increasing nasal volume. Interestingly, recent MARPE studies suggest that the bicortical anchorage facilitates a parallel expansion pattern, which some authors posit may yield respiratory benefits comparable to, or potentially even more favorable than, those traditionally associated with SARPE. This suggests that for respiratory indications, the choice may be driven more by patient preference and invasiveness tolerance than by efficacy differences alone.[14]

Long-Term Stability and Relapse: While SARPE has established long-term stability data, the "stability" keyword cluster in MARPE research is still maturing.[21,31] However, recent longitudinal studies indicate that the skeletal nature of MARPE expansion—characterized by the parallel separation of the midpalatal suture—offers promising retention outcomes.[4,30] Clinicians should note that while dental relapse (tipping relapse) is common in tooth-borne expanders, the skeletal gain from MARPE appears stable after 1 year of retention.[30] Nevertheless, compared to the rigid bony callus formed after SARPE osteotomies, the suture remodeled by MARPE may require prolonged retention periods to prevent skeletal rebound.[14]

A strength of our study is the simultaneous examination of two distinct fields, allowing for a comparative evaluation between them. Nevertheless, the study has certain limitations. First, data were retrieved from a single database, which may have resulted in the omission of relevant publications not indexed therein. Additionally, bibliometric analyses inherently rely on quantitative metrics, which may not fully capture the qualitative impact or clinical significance of individual studies. Furthermore, variations in citation practices across disciplines and time periods could introduce bias in citation-based comparisons.

Conclusion

The present bibliometric analysis demonstrates that MARPE research has experienced rapid growth in recent years, whereas SARPE research represents a more established but relatively stable body of literature. Citation and keyword analyses indicate that MARPE is characterized by mechanically and digitally oriented investigations, while SARPE focuses predominantly on surgical procedures and stability. The distribution of countries and authors highlights different geographical centers, and economic analyses reveal a positive correlation between citation counts and national income levels.

Conflict of interest

The authors declare no conflicts of interest.

Ethics

This bibliometric study used publicly available bibliographic metadata and did not involve human participants, animals, tissues, or identifiable personal data; Institutional Review Board approval was not required.

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Data and code availability

The processed bibliometric datasets and code used to generate figures/tables are available from the corresponding author upon reasonable request.

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