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Global Research Trends in Transoral Robotic Surgery (TORS): A Comprehensive Bibliometric Analysis of the Literature from 2015 to 2025

Ulrich Hay
Marienhospital Stuttgart
Ines Hecht
Marienhospital Stuttgart https://orcid.org/0009-0001-2900-0587
Florian Kister
Klinikum Saarbrücken https://orcid.org/0000-0002-3500-1172
Adrian Hoenle
adrian.l.hoenle@gmail.com
Klinikum Stuttgart https://orcid.org/0000-0002-6608-0782

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Global Research Trends in Transoral Robotic Surgery (TORS): A Comprehensive Bibliometric Analysis of the Literature from 2015 to 2025

Ulrich Hay[1], Ines Hecht[1], Florian Kister[2] and Adrian Hoenle[3,4]

1 Department of Otorhinolaryngology, Head and Neck Surgery, Marienhospital Stuttgart, Germany
2 Division of Oral and Maxillofacial Surgery, Klinikum Saarbrücken, Germany
3 Department of Otorhinolaryngology, Head and Neck Surgery, Klinikum Stuttgart, Germany
4 Department of Otorhinolaryngology, Head and Neck Surgery, Brandenburg Medical School, Neuruppin, Germany

Corresponding author: Dr. Adrian Hoenle, B.Sc., Department of Otorhinolaryngology, Head and Neck Surgery, Klinikum Stuttgart, Kriegsbergstrasse 60, 70174 Stuttgart, Germany. E-mail: a.hoenle@klinikum-stuttgart.de

Abstract

Purpose: Transoral robotic surgery (TORS) has grown substantially as a field over the past decade. Recent bibliometric studies have mapped the TORS literature, but none has incorporated an explicit post-hoc validation step to exclude publications captured by broad search strategies that are not topically specific to TORS or head and neck surgery. This study aimed to characterise temporal publication trends, identify leading contributors, and delineate journal distribution and growth in the TORS literature from 2015 to 2025, using a corpus explicitly screened for topical and journal-level relevance to head and neck robotic surgery.

Methods: Publications were retrieved from OpenAlex (2015–2025) using a broad Boolean search strategy and analysed using Bibliometrix (R) and RStudio. Because broad interdisciplinary search strings risk capturing publications from adjacent, non-head-and-neck robotics fields, an additional post-hoc relevance screening step was applied: records were classified using OpenAlex primary-topic labels and source-journal identity, and records whose topic or source journal was not specific to TORS or head and neck surgery were excluded. Outcome measures included annual publication volume, citation metrics, country- and institution-level output, author productivity, and journal distribution. Linear regression assessed overall and journal-level temporal growth trajectories.

Results: Of 9,501 records initially identified, 3,362 publications remained after relevance screening. Annual output showed a statistically robust linear growth trend (+21.5 articles/year; $R^2 = 0.94$, $p < 0.001$) and a compound annual growth rate (CAGR) of 6.6%. The United States and China led total citation volume, while Canada (CPP = 20.86), Switzerland (37.38, n = 26), Germany (17.25), and China (16.46) demonstrated the highest citation impact per publication. The University of Pennsylvania ranked first in institutional output (54 articles). The Journal of Robotic Surgery showed statistically significant positive growth ($\beta = +1.04$, $p = 0.015$).

Conclusion: After explicit relevance screening, TORS research shows sustained, statistically robust growth over the past decade. Citation impact per publication varies substantially by country, with Canada, Switzerland, and Germany showing the highest values among countries contributing at least five publications; this pattern should be interpreted cautiously given the absence of citation-window normalisation. These findings provide a validated evidence base for future research prioritisation in robotic head and neck surgery.

Keywords: transoral robotic surgery; TORS; bibliometric analysis; robotic surgery; scientometrics; head and neck surgery

Introduction

Transoral robotic surgery (TORS) has become one of the most significant technological advances in head and neck surgery of the past two decades. First described by Weinstein et al. using the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA), TORS received FDA approval in 2009 for benign and malignant oropharyngeal and supraglottic lesions [1-4]. Compared with open surgery and transoral laser microsurgery, TORS offers three-dimensional visualisation, enhanced instrument dexterity, tremor elimination, and avoidance of mandibulotomy, thereby reducing morbidity and improving functional outcomes [5-7].

The rising incidence of human papillomavirus (HPV)-associated oropharyngeal squamous cell carcinoma (OPSCC) has substantially amplified the clinical relevance of TORS, given the younger patient demographic and the primacy of functional preservation as a therapeutic goal [8]. Multiple prospective trials support TORS-based approaches as an oncologically comparable alternative to chemoradiotherapy with favourable swallowing outcomes [9, 10]. Beyond oropharyngeal oncology, TORS applications have expanded to obstructive sleep apnoea, hypopharyngeal and supraglottic pathology, transoral thyroidectomy, and skull base surgery [11-15].

Bibliometric analysis provides a validated, reproducible framework for evaluating large scientific corpora and identifying publication trends, key contributors, citation patterns, and emerging research frontiers [16, 17]. Prior bibliometric work in robotic surgery has confirmed the utility of this approach across related fields [18-22]. Two recent studies have specifically mapped the TORS literature: Zhang et al. examined global research trends and prospects in TORS from 2005 to 2024, and Farasani et al. analysed 938 Scopus-indexed TORS publications from 2005 to 2025 using Bibliometrix and VOSviewer, encompassing citation, collaboration, co-citation, and keyword-based analyses [26,27]. However, broad Boolean search strategies applied to interdisciplinary databases risk capturing substantial numbers of

publications from adjacent, non-head-and-neck robotics fields; neither of these prior studies reported an explicit post-hoc step to quantify or exclude such topically unrelated records, a gap that is addressed directly in the present analysis through explicit post-hoc relevance screening.

The present study therefore aims to: (1) characterise temporal publication and citation trends within a topically and journal-level validated TORS corpus; (2) identify leading countries, institutions, and authors; and (3) analyse journal distribution and growth trajectories. Together, these analyses provide an evidence base for future research prioritisation in robotic head and neck surgery.

Materials and Methods

Database Selection and Search Strategy

A systematic literature search was conducted in OpenAlex (https://openalex.org), selected for its broad disciplinary coverage, open access, and suitability for programmatic data retrieval [23, 24]. The search string applied to titles, abstracts, and keywords was: (Oropharynx OR Oropharyngeal OR Tonsil OR Head and Neck OR Otolaryngology OR HNO OR ENT OR Otorhinolaryngology) AND (Robot* OR TORS). Records were restricted to peer-reviewed journal articles and reviews published between 1 January 2015 and 31 December 2025, indexed with a journal-type source and an English-language record. Conference proceedings, book series, repository records, editorials, and non-peer-reviewed documents were excluded. This base filtering step retained 6,349 of 9,501 initially identified records.

Post-hoc Relevance Screening

Because the broad Boolean search strategy is, by design, sensitive but not specific, general robotic-surgery and engineering terms can capture publications from entirely unrelated fields, an additional relevance screening step was applied to the base-filtered corpus. Each record's

OpenAlex primary-topic classification was assigned to one of two categories: (a) topically relevant to TORS or head and neck surgery (including surgical, robotic, reconstructive, radiotherapeutic, and otolaryngology-specific topic labels), or (b) unrelated to this field (including, but not limited to, agricultural robotics, industrial manufacturing, general urological or hepatobiliary disease, and non-medical engineering domains). In addition, a small number of source journals were excluded at the journal level irrespective of individual-article topic label, where the journal's disciplinary scope was structurally unrelated to head and neck surgery despite individual articles carrying generic surgical topic labels (The Journal of Urology, HPB, a lepidopterology journal identified as an indexing artefact, a general robotics conference proceedings series, and three general robotics/sensor engineering journals whose indexed TORS-related content could not be confirmed as head-and-neck-specific on manual topic inspection). This two-step relevance screening reduced the base-filtered corpus of 6,349 records to a final analytic corpus of 3,362 records. The complete screening process is illustrated in Fig. 1.

Data Processing and Statistical Analysis

$$CAGR = \left(\frac{N_end}{N_start}\right)^{\frac{1}{t_end - t_start}} - 1$$

Retrieved metadata were exported in CSV format. Data harmonisation and article-level relevance classification were performed in RStudio (v4.3.2) using Bibliometrix (v4.1.4) [11]. Publication trends and citation metrics were computed on the final relevance-screened corpus. The compound annual growth rate (CAGR) was calculated as . Linear regression assessed the overall publication trend and the temporal growth trajectories of individual journals (annual slope β and p-value). Country-level citation metrics were computed using the corresponding author's country of affiliation; countries contributing fewer than five publications were excluded from country-level comparison to avoid unstable estimates from small samples. Records without information on the corresponding author's country were excluded from

country-level analyses. International co-authorship networks were visualised using VOSviewer (v1.6.20) [25].

Ethical Considerations

This study used only publicly available, aggregated publication metadata; no individual patient data, clinical records, or biological material were accessed. Ethical approval was not required.

Results

Corpus Composition

Of 9,501 records initially identified from OpenAlex, 6,349 remained after document-type, source-type, language, and date filtering. Post-hoc relevance screening at the topic and journal level excluded a further 2,987 records, yielding a final analytic corpus of 3,362 publications (Fig. 1). This represents a substantially smaller and more topically homogeneous corpus than would result from the unscreened search string alone, reflecting the exclusion of publications from adjacent, non-head-and-neck robotics and engineering fields.

Publication Volume and Temporal Trends

Annual output in the relevance-screened corpus rose from 219 articles in 2015 to 414 in 2025, with a statistically robust linear trend (+21.5 articles/year; $R^2 = 0.94$, $p < 0.001$) and a CAGR of 6.6% (Table 1; Fig. 2). The largest year-on-year increments occurred between 2016–2017 (+53 articles; +25.6%) and 2023–2024 (+54 articles; +14.8%), with declines in 2015–2016 (−12 articles; −5.5%) and 2018 (−24 articles; −9.2%). Mean citations per article declined from 19.73 (2015) to 1.41 (2025), reflecting citation lag in more recent publications.

Table 1 Annual publication output and citation metrics of the relevance-screened TORS corpus (2015–2025).

Year	No. of Articles	Mean Citations/Article	Abs. Difference	Growth (%)	Cumulative (n)
2015	219	19.73	—	—	219
2016	207	16.40	−12	−5.5	426
2017	260	19.56	+53	+25.6	686
2018	236	17.35	−24	−9.2	922
2019	272	17.81	+36	+15.3	1,194
2020	317	17.49	+45	+16.5	1,511
2021	332	11.60	+15	+4.7	1,843
2022	323	13.00	−9	−2.7	2,166
2023	364	9.64	+41	+12.7	2,530
2024	418	4.25	+54	+14.8	2,948
2025	414	1.41	−4	−1.0	3,362

Note. Linear trend: +21.5 articles/year ($R^2 = 0.94$, $p < 0.001$). CAGR: compound annual growth rate = 6.6%.

Geographic Distribution and Citation Impact

The United States and China were the dominant contributors by total citation volume (10,564 and 7,718 citations, respectively; 28.6% and 20.9% of citations among countries contributing at least five publications; Table 2). Citation impact per publication (CPP) was highest for Switzerland (37.38; n = 26), Canada (20.86; n = 78), Germany (17.25; n = 108), and China (16.46; n = 469). Given the small sample size for Switzerland, this estimate should be interpreted with caution. India (CPP = 4.99) demonstrated high volume but comparatively lower average impact.

Table 2 Citation impact by country of the corresponding author (top 10 countries by total citations).

Country	Total Citations (TC)	Citations per Publication (CPP)	Share of Total Citations (%)
United States	10,564	13.39	28.6
China	7,718	16.46	20.9
United Kingdom	2,135	13.77	5.8
Germany	1,863	17.25	5.0
South Korea	1,850	14.02	5.0
Italy	1,770	13.62	4.8
Canada	1,627	20.86	4.4
Switzerland	972	37.38	2.6
France	910	15.17	2.5
India	768	4.99	2.1

Note. Countries contributing fewer than five publications were excluded. TC = Total Citations; CPP = Citations per Publication, computed using the corresponding author's country. Records without country information (n = 520) were excluded; percentages refer to total citations among records with identified country. CPP values are not normalised for publication year or field-specific citation practices.

Institutional Contributions and Author Productivity

The University of Pennsylvania led institutional output with 54 publications (1.6% of the corpus), followed by The University of Texas MD Anderson Cancer Center (47; 1.4%) and Yonsei University (45; 1.3%). Among individual authors, Umamaheswar Duvvuri ranked as the most prolific contributor (36 articles; fractionalised count 6.73), followed by John N. Lukens (30 articles; fractionalised count 2.57) and F. Christopher Holsinger (29 articles; fractionalised count 6.56). Full institutional and author rankings are provided in Table 3.

Table 3a Top 10 contributing institutions in the relevance-screened corpus.

Institution	No. of Articles	Share of Total (%)
University of Pennsylvania	54	1.6
The University of Texas MD Anderson Cancer Center	47	1.4
Yonsei University	45	1.3
Stanford University	44	1.3
University of Toronto	36	1.1
Johns Hopkins University	34	1.0
Icahn School of Medicine at Mount Sinai	33	1.0
University of Pittsburgh Medical Center	30	0.9
Chinese Academy of Sciences	29	0.9
Harvard University	28	0.8

Note. Percentages reflect share of the total corpus (n = 3,362). An article may be attributed to more than one institution.

Table 3b Top 10 most productive authors in the relevance-screened corpus (fractionalised count adjusts for number of co-authors per paper).

Author	Articles (Total)	Articles (Fractionalised)
Umamaheswar Duvvuri	36	6.73
John N. Lukens	30	2.57
F. Christopher Holsinger	29	6.56
Alexander Lin	26	2.19
Gregory S. Weinstein	25	2.11
John R. de Almeida	24	3.02
Bert W. O'Malley	22	1.75
Jason G. Newman	22	1.76
Giuseppe Meccariello	22	2.53
Vinidh Paleri	22	3.42

Note. Fractionalised article count adjusts for number of co-authors per paper.

Journal Distribution and Growth Trends

Among the ten highest-volume journals in the relevance-screened corpus, the International Journal of Radiation Oncology, Biology and Physics (108 articles), Journal of Robotic Surgery (90 articles), and Head & Neck (81 articles) predominated (Table 4). The Journal of Robotic Surgery showed a statistically significant positive growth trajectory ($\beta = +1.04$, $p = 0.015$). Scientific Reports ($\beta = +0.52$, $p = 0.012$) and Journal of Clinical Medicine ($\beta = +0.60$, $p = 0.002$) also showed statistically significant growth, consistent with a broader trend toward

publication in general-scope, open-access venues rather than a specific engineering-discipline expansion.

Table 4 Top 10 journals by article volume and annual growth trend.

Journal	Total Articles	Growth Slope (β)	p-value
International Journal of Radiation Oncology, Biology and Physics	108	−1.02	0.030*
Journal of Robotic Surgery	90	+1.04	0.015*
Head & Neck	81	−0.43	0.279
Oral Oncology	54	+0.30	0.272
Journal of Clinical Oncology	38	+0.26	0.090
The Laryngoscope	29	+0.01	0.924
Otolaryngologic Clinics of North America	26	−0.10	0.837
Otolaryngology–Head and Neck Surgery	23	+0.06	0.760
Scientific Reports	23	+0.52	0.012*
Journal of Clinical Medicine	22	+0.60	0.002*

*Note. β = average annual increase in articles per journal, linear regression. * $p < 0.05$.*

International Collaboration Networks

VOSviewer network analysis was recomputed on the relevance-screened corpus. A citation-based country network map (Fig. 3) and the international co-authorship network (Fig. 4) both show the United States and China as the two largest nodes, consistent with their dominant contribution to total citations and corpus volume respectively (Table 2). In the co-authorship network, six colour-coded clusters are visually distinguishable: (1) a United States-anchored cluster including India, Sweden, Portugal, Bangladesh, Denmark, Switzerland, Brazil, and Norway; (2) a cluster comprising South Korea, Italy, and Egypt; (3) a Germany/United Kingdom-anchored cluster including Australia, Greece, Austria, Israel, and Ireland; (4) a Canada-anchored cluster including Colombia, Argentina, and Chile; (5) a France-anchored cluster including Spain and Mexico; and (6) a China-anchored cluster including Japan, Taiwan, Singapore, Malaysia, Thailand, Iran, Poland, and Pakistan. This differs from the four-cluster structure reported for the unscreened corpus, most notably in the separation of a distinct Canada-centred cluster and in Germany's grouping with the United Kingdom and

Australia rather than with other Central European countries. As no underlying VOSviewer network export file was retained, this description is based on visual inspection of the rendered map; node assignments for smaller, more peripherally connected countries are correspondingly less certain than for the major hub countries named above. A bibliographic coupling density map (Fig. 5) similarly shows the United States and China as the principal centres of density, with Germany, France, and Italy forming a secondary, lower-density concentration.

Discussion

This study presents a bibliometric analysis of the global TORS literature from 2015 to 2025, using a corpus explicitly screened for topical and journal-level relevance to head and neck robotic surgery. Three principal findings warrant discussion: the sustained growth trajectory, the variation in citation impact across countries, and the composition of the underlying corpus itself.

Corpus Validity

A substantial proportion of records identified by the initial broad Boolean search string (2,987 of 6,349 base-filtered records, 47%) were excluded on relevance grounds, spanning topics with no plausible connection to head and neck surgery, such as agricultural robotics and industrial manufacturing, as well as journals with a structurally different disciplinary scope, such as The Journal of Urology. This finding indicates that broad interdisciplinary search strings in bibliometric studies of surgical robotics require explicit post-hoc relevance validation; without it, downstream country-, institution-, and journal-level analyses risk substantial distortion from topically unrelated publications. The corpus-composition analysis underlying this screening step is summarised in the Methods above. Neither of the two prior TORS-specific bibliometric studies [26,27] reported a comparable relevance-validation step;

given the scale of exclusion observed here, this methodological addition may be of relevance to future bibliometric work on surgical robotics subfields more broadly.

Sustained Growth Trajectory

The statistically robust linear growth trend ($R^2 = 0.94$; CAGR 6.6%) in the relevance-screened corpus reflects the progressive institutionalisation of TORS as a mainstream surgical modality. The acceleration observed between 2016 and 2017 and again between 2023 and 2024 is temporally associated with the broader adoption of TORS-based treatment deintensification strategies for HPV-positive OPSCC; this temporal association is observational and does not establish causation, as multiple factors concurrently drive publication growth in an expanding field [9, 10].

Variation in Citation Impact Across Countries

Citation impact per publication varied substantially across the ten countries with the highest total citation counts (all contributing at least five publications), with Switzerland, Canada, Germany, and China showing the highest values. Canada and Switzerland are not European nations in the case of Canada, and this distinction is noted explicitly given that citation-impact patterns are sometimes discussed in terms of European versus North American research systems; the present data show high per-publication impact in both North American (Canada) and European (Switzerland, Germany) settings, without a clear continental pattern. The small sample size underlying the Swiss estimate ($n = 26$) warrants caution in interpretation. These CPP values are not normalised for publication year or field-specific citation practices, and more recent publications are systematically disadvantaged by citation lag; this limits direct cross-country comparison and is discussed further below.

Limitations

Several limitations merit explicit consideration. This analysis is restricted to OpenAlex; Other databases, used in earlier exploratory work on this topic, could not be incorporated into the

relevance-screened analysis because article-level raw metadata were not available, and this may result in a somewhat different corpus composition than a combined-database search would yield. The relevance-screening step itself relied on OpenAlex's automated primary-topic classification and a manually curated journal-exclusion list; this is not equivalent to full manual review of each record's abstract, and residual misclassification at the margins cannot be excluded. Citation data for 2024–2025 substantially underestimate long-term impact due to citation lag. CPP values are not normalised for publication year or field-specific citation practices, limiting direct cross-country comparisons. Bibliometric methods quantify output but cannot directly assess methodological rigour or clinical significance. The co-authorship cluster description (Fig. 4) is based on visual inspection of the rendered VOSviewer map rather than the underlying network export file, which was not retained; assignment of smaller, peripheral countries to a cluster is correspondingly less certain than for the major hub countries.

Conclusion

This bibliometric analysis of 3,362 relevance-screened TORS publications (2015–2025) demonstrates sustained growth (CAGR 6.6%; +21.5 articles/year) following explicit exclusion of topically and journal-level unrelated publications identified in the initial broad search corpus. Citation impact per publication varies by country, with Canada, Switzerland, Germany, and China showing the highest values among countries contributing at least five publications; these patterns should be interpreted cautiously given the absence of citation-window normalisation and, for Switzerland, a small underlying sample. The corpus-validation approach applied here may be of methodological relevance to future bibliometric studies of surgical robotics, where broad Boolean search strategies risk conflating clinically distinct subfields.

Declarations

Funding: No funding was received for conducting this study.

Competing interests: The authors have no competing interests to declare that are relevant to the content of this article.

Ethics approval: This bibliometric study used only publicly available, aggregated publication metadata. No individual patient data, clinical records, or biological material were accessed. Ethical approval was not required.

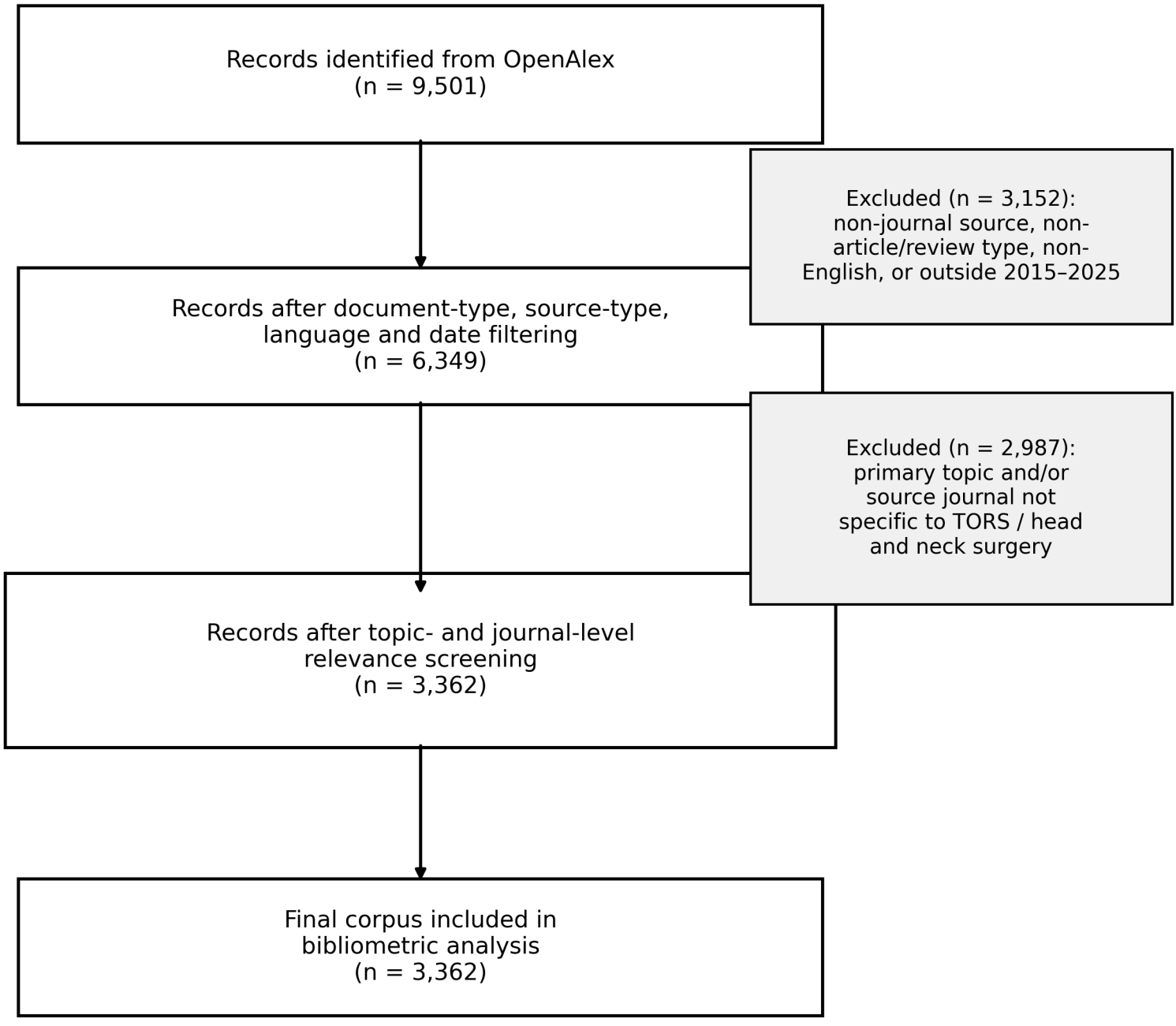
Data availability: Bibliometric data supporting the findings of this study are available from the corresponding author upon reasonable request.

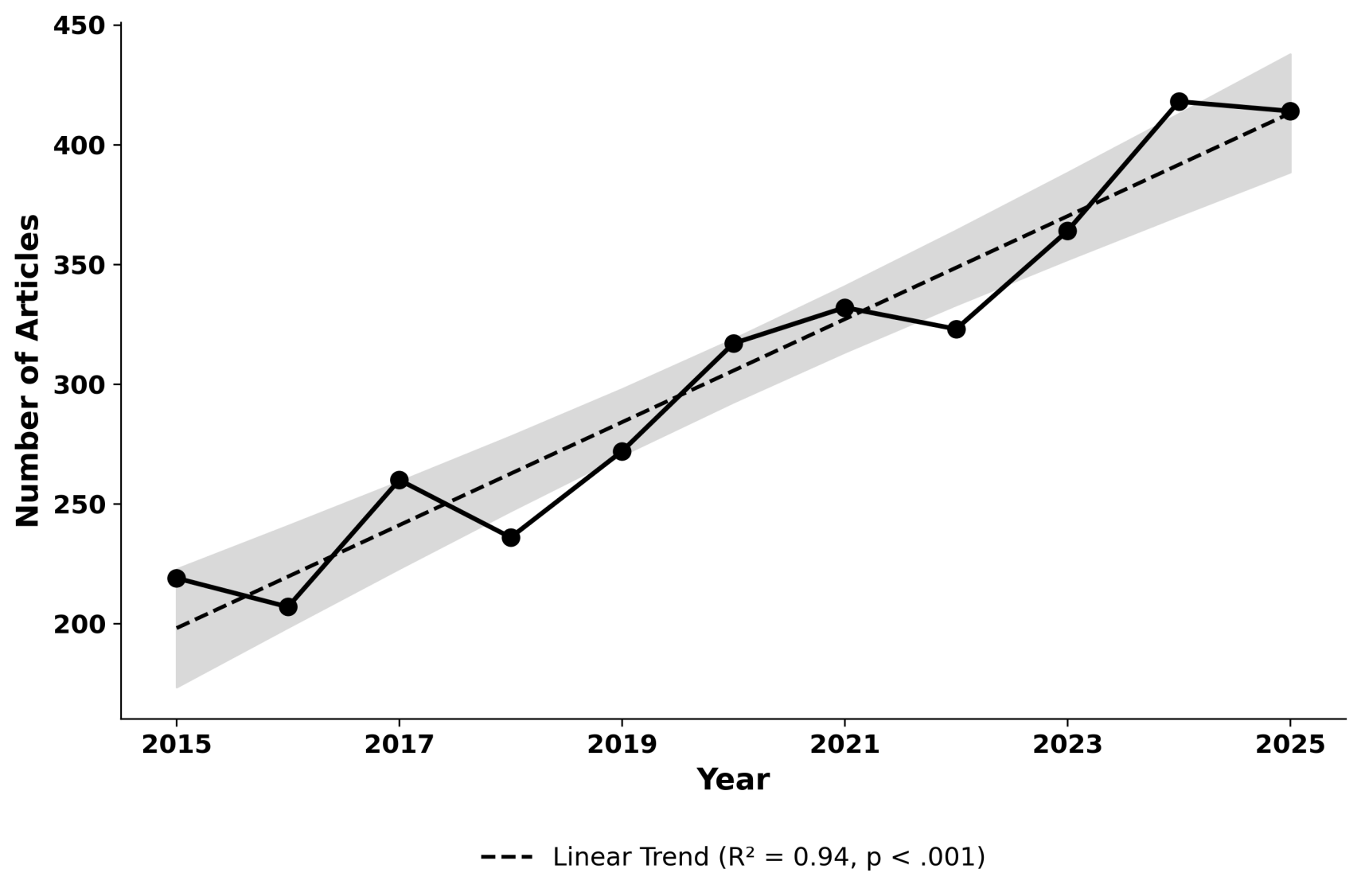
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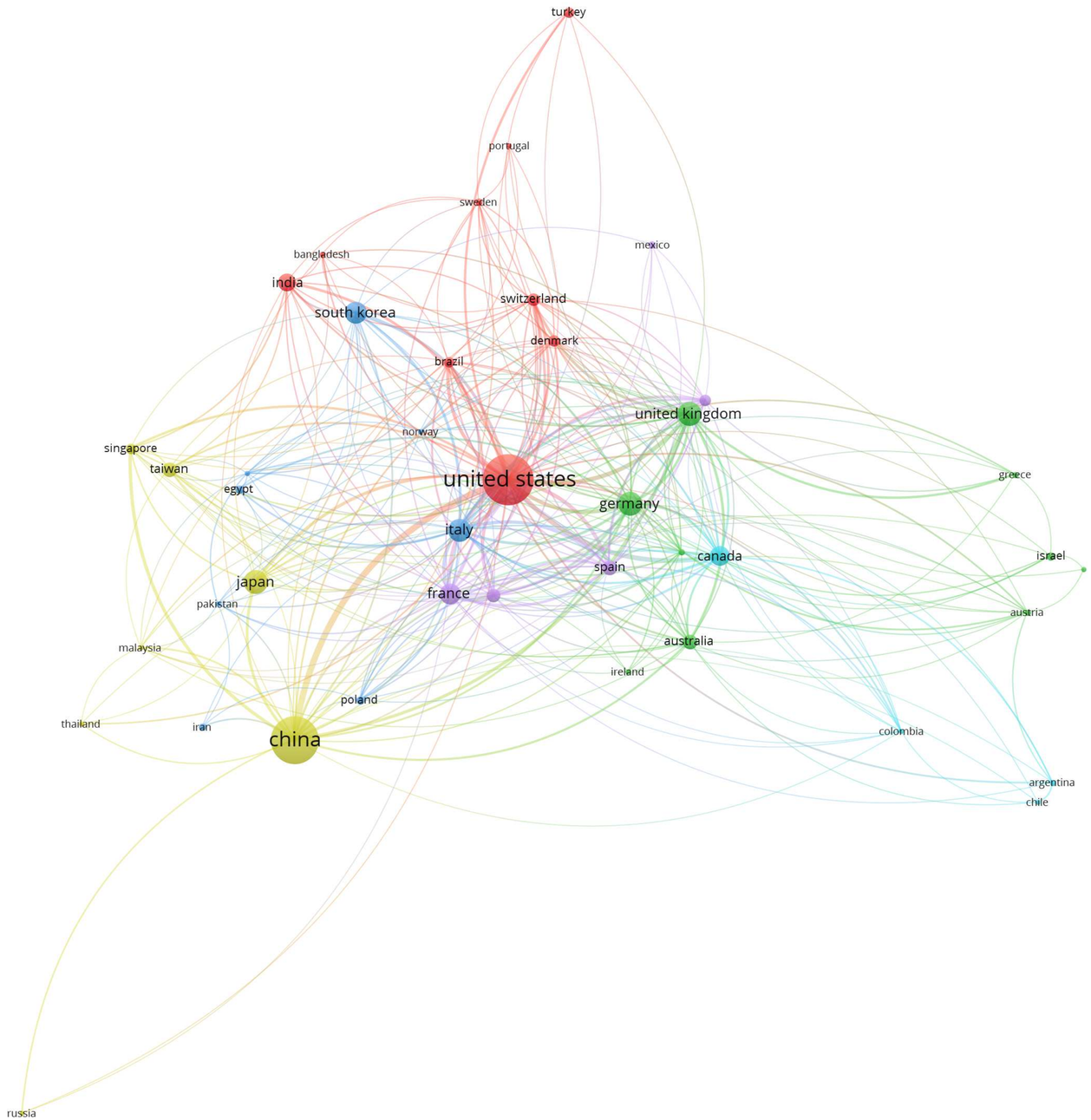
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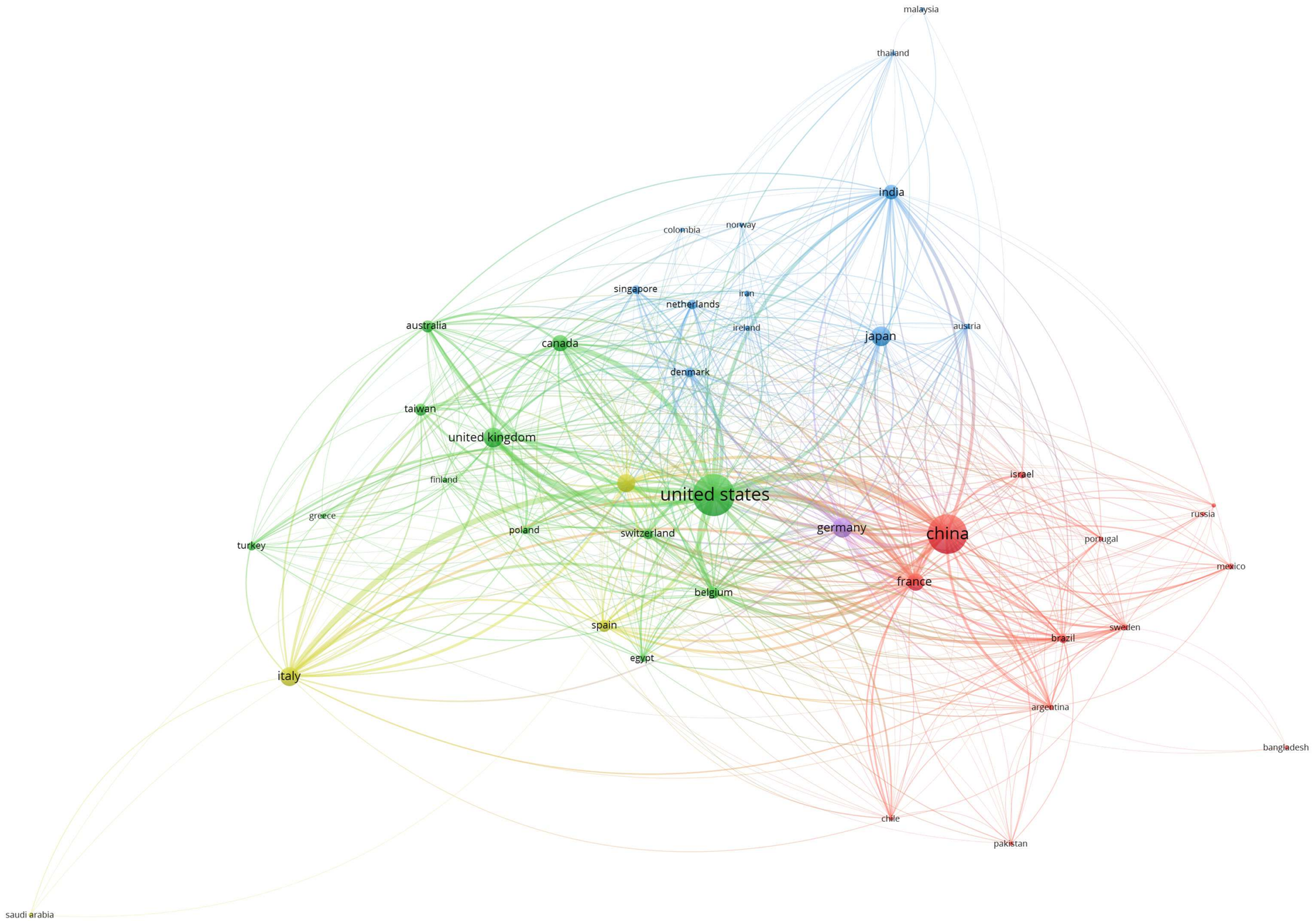
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Records identified from OpenAlex
(n = 9,501)
Excluded (n = 3,152):
non-journal source, non-
article/review type, non-
English, or outside 2015–2025
Records after document-type, source-type,
language and date filtering
(n = 6,349)
Excluded (n = 2,987):
primary topic and/or
source journal not
specific to TORS / head
and neck surgery
Records after topic- and journal-level
relevance screening
(n = 3,362)
Final corpus included in
bibliometric analysis
(n = 3,362)

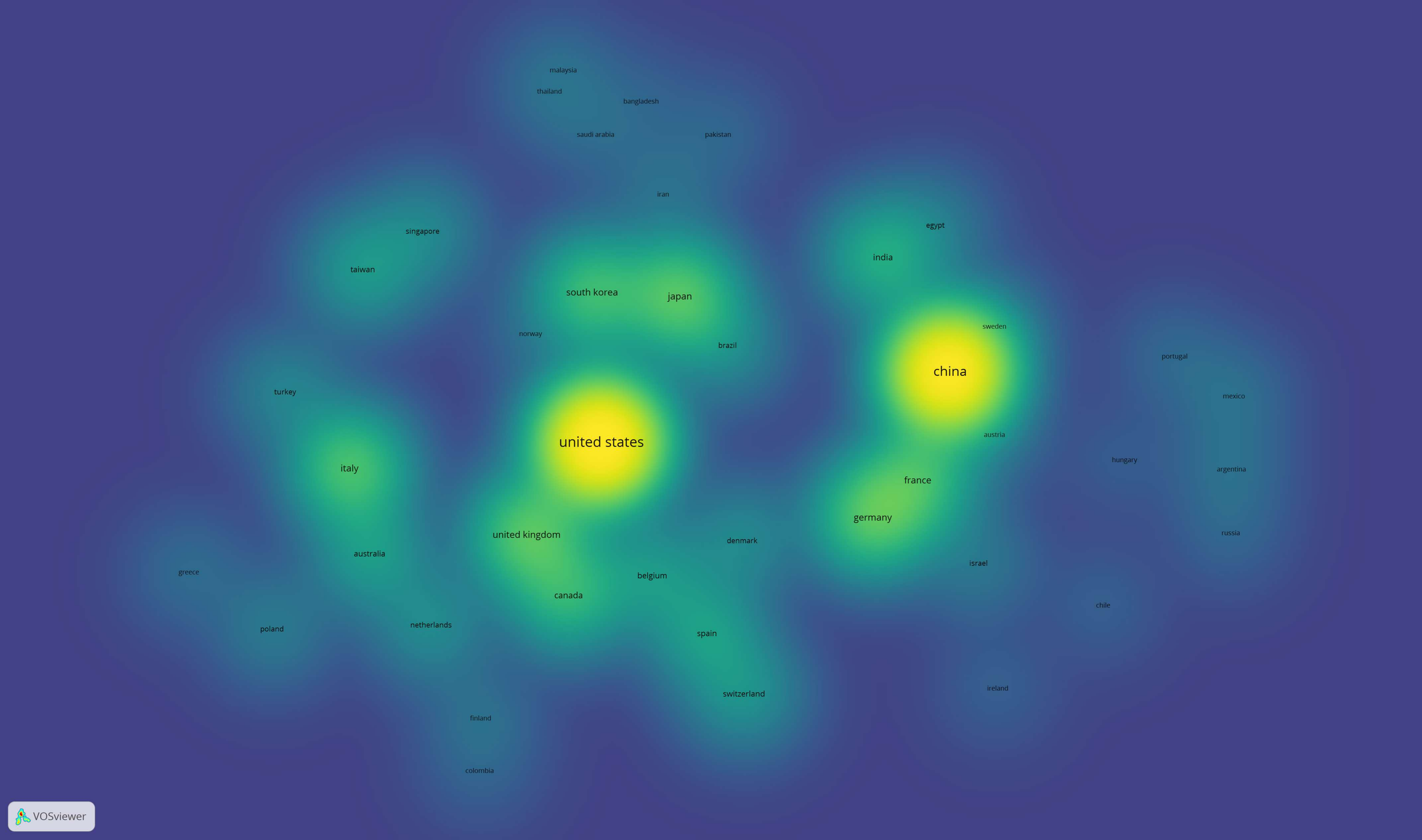

450
400
350
300
250
200
Number of Articles
2015
2017
2019
2021
2023
2025
Year
Linear Trend (R² = 0.94, p < .001)


turkey
portugal
sweden
mexico
bangladesh
india
switzerland
south korea
denmark
brazil
united kingdom
norway
singapore
taiwan
egypt
united states
greece
germany
italy
canada
israel
spain
japan
france
pakistan
austria
malaysia
australia
ireland
poland
thailand
iran
china
colombia
argentina
chile
russia

VOSviewer


malaysia
thailand
india
colombia
norway
singapore
iran
netherlands
australia
ireland
japan
austria
canada
denmark
taiwan
united kingdom
finland
united states
israel
russia
greece
poland
switzerland
germany
china
portugal
turkey
mexico
france
belgium
spain
sweden
brazil
egypt
italy
argentina
bangladesh
chile
pakistan
saudi arabia

VOSviewer


malaysia
thailand
bangladesh
saudi arabia
pakistan
iran
singapore
egypt
india
taiwan
south korea
japan
sweden
norway
brazil
portugal
china
turkey
mexico
austria
united states
hungary
italy
argentina
france
germany
united kingdom
russia
denmark
australia
israel
greece
belgium
canada
chile
poland
netherlands
spain
ireland
switzerland
finland
colombia

VOSviewer