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A Bibliometric and Visual Analysis of Tongue Squamous Cell Carcinoma : Current Knowledge Structure and Future Research Trends

Yuanzhi Zhu[1],Tao Liang [1], Yao Ding[1], Yi Huang[1], Shizi Wang[1], Xiaoqiang Mo [1,2*].

[1.] Youjiang Medical University for Nationalities, Baise 533000, Guangxi, China.
[2.] Medical College of Guangxi University, Nanning, 530004, China.
*Corresponding author: Xiaoqiang Mo, Medical College of Guangxi University, Nanning, 530004, China.
Emails: 29109799@qq.com

Abstract: Background: The incidence and mortality of tongue squamous cell carcinoma (TSCC) have steadily increased over the past few decades, while survival rates have not significantly improved. This has led to numerous studies and publications. However, to date, no systematic bibliometric analysis or visualization of these publications has been conducted.
Objective: This study aims to provide a clear and intuitive overview of the current knowledge structure and potential future research trends in TSCC through bibliometric and visual analysis of relevant publications.
Methods: Bibliographic data from TSCC-related publications between 2001 and 2021 were extracted from the Web of Science Core Collection. The data were visualized and analyzed using Microsoft Excel, VOSviewer, CiteSpace, bibliometrix (R package), SCImago Graphica Beta, and Pajek software.
Results: A total of 9,734 publications on TSCC were identified. The number of publications has shown a consistent increase, with the United States leading in terms of productivity, citation impact, centrality, and sigma values(centrality refers to its importance in the research network, and sigma values reflect its significant impact on the field). Sun Yat-sen University (China) is the most productive institution. *Oral Oncology* is the most influential journal, while *SALO T* is the most productive author. Keyword analysis indicates a decline in research on *neck dissection*, *human papillomavirus*, and *diagnosis*, while topics such as *apoptosis* and *quality of life* remain prominent. Emerging keywords include *depth of invasion*, *biomarkers*, and *resistance*. Co-citation analysis reveals a shift in research focus from traditional areas like *E-cadherin*, *metastasis*, and *epidemiology* to more recent topics such as *depth of invasion*, *transoral robotic surgery*, *lymphatic spread*, *young patients*, and *tumor budding*.
Conclusions: This is the first comprehensive bibliometric study of TSCC research, highlighting current trends and future directions. Clinical research dominates the field now, while emerging sub-fields include *depth of invasion*, *biomarkers*, *transoral robotic surgery*, *young patients*, and *tumor budding*, indicating potential future research areas. we provide insights into emerging research trends, helping to inform future research directions and strategies for TSCC prevention and treatment.
Keywords: tongue cancer, bibliometric analysis, visual analysis

Introduction

Oral squamous cell carcinoma (OSCC) ranks as the 18th most common cancer worldwide, with an estimated 377,713 new cases and 177,757 deaths in 2021, posing a serious threat to human health [1]. TSCC, the most common and aggressive subtype of OSCC, accounts for about 33% of all OSCC cases [2-4]. The incidence of TSCC is increasing, with a noticeable trend toward younger patients. While the overall mortality rate of OSCC has slightly decreased in recent years, TSCC mortality continues to rise by 2% annually due to its high recurrence rate and propensity for lymphatic and distant metastasis [4]. In contrast, mortality for other types of OSCC has been steadily decreasing by approximately 1% each year [4]. Key risk factors for TSCC include tobacco, alcohol, viral infections, and betel quid, with HPV (human papillomavirus) being a major focus of recent studies. HPV has been linked to the rise in TSCC cases, particularly among younger and female populations [4, 6-8]. Despite advances in diagnosis and treatment for many cancers, the five-year survival rate for TSCC patients has remained below 50% for nearly four decades [9-11]. This contrasts sharply with improved survival rates for other solid tumors. The ongoing challenge of improving TSCC outcomes underscores the urgent need for better diagnostic tools and treatments. Moreover, the growing burden of TSCC is expected to increase further due to an aging population and insufficient control of risk factors [11, 12].

Given the critical need for effective strategies in addressing TSCC, extensive research has been conducted. However, these studies have yet to be systematically organized, analyzed, and visualized. To address this, we retrieved publications on TSCC from the Web of Science Core Collection database (2001-2021) and applied bibliometric methods and visualization tools. This study aims to assess the research output of countries, institutions, and authors, while also mapping their collaborative relationships. By visualizing the knowledge landscape of TSCC research, we provide insights into emerging research trends, helping to inform future research directions and strategies for TSCC prevention and treatment.

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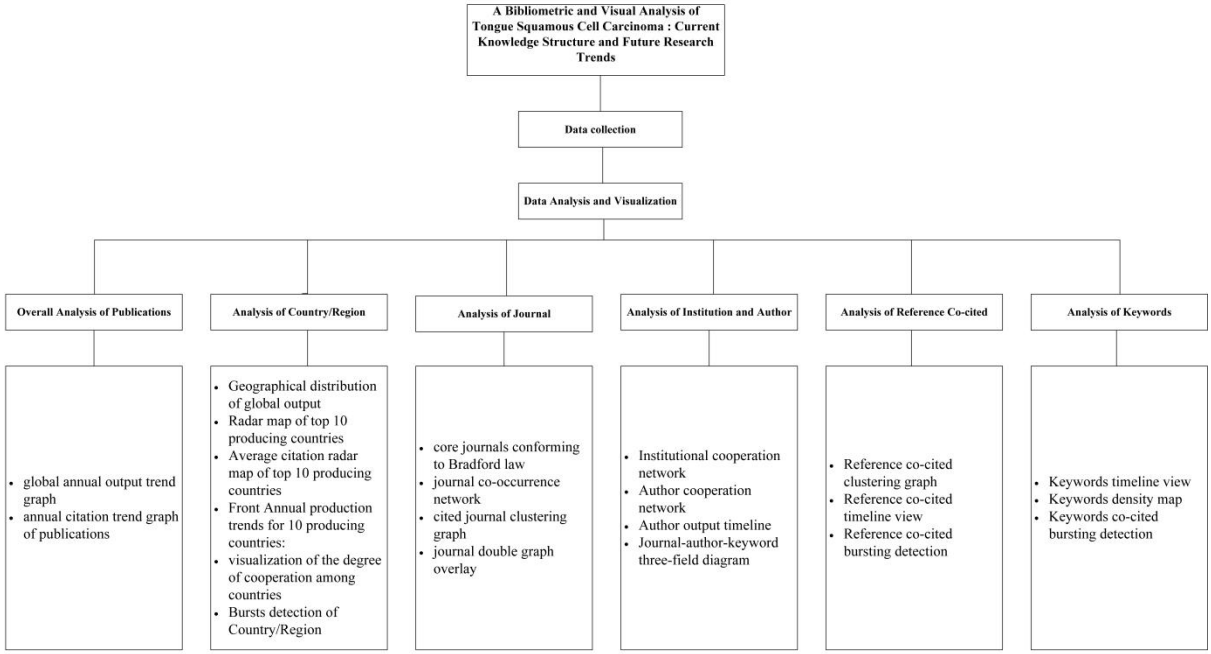
Materials and Methods



Data Collection

Publications related to TSCC were extracted from the web of science core collection database on December 1, 2021, and the search formula was as follows: TS = Tongue AND (Neoplasm or cancer or tumor or Neoplasia or Malignancy or Malignancies or Malignant), with a time span of 2001 Until 2021, publication types are limited to articles and reviews, but unlimited to language. Bibliographic information for these publications was collected and exported to a "plain text" document with "full record and cited references" as content. Finally, we imported the data into citespace for deduplication for further analysis. Furthermore, since this study did not include any animals or experiments, thus no ethical consent was required.

Data Analysis and Visualization

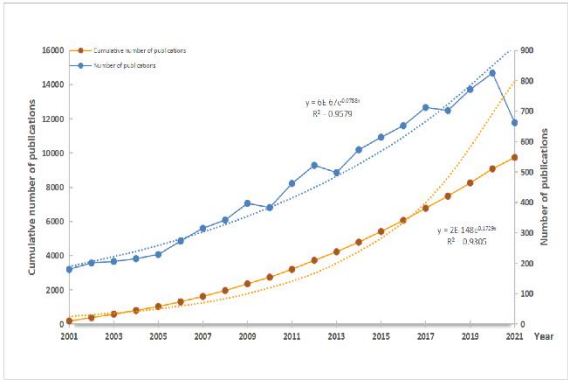
In this study, Microsoft Excel (version 2019MSO), VOSviewer (version 1.6.16),
CiteSpace (version 5.8.R3), R packages bibliometrix (version 3.1), SCImago Graphica Beta (version 1.0.15), Pajek (version 5.14) were used for bibliometric and visual analysis.
Microsoft Excel (version 2019MSO) for analyzing and plotting trend graphs, annual citation trends for publications and radar charts.
VOSviewer[13] is used to visualize complex co-citation networks, such as collaborations and temporal trends among countries, institutions, and individuals. The size of the nodes represents the number of publications; the thickness of the lines represents the strength of the links; and the colors of the nodes represent different clusters or times.
CiteSpace[14] is used for visual analysis of knowledge domains and emerging trends, including cluster analysis, journal double graph overlay, timeline graph, reference and keyword citation burst detection. The size of the circle represents the number of articles or citations. The color of the circle is the year of publication, the warmer the year, the higher the year. The thicker the line between the two circles, the greater the number of co-occurrences.
Bibliometrix[15] is used to perform comprehensive scientific mapping analysis of scientific literature, such as the core journal analysis of Bradford law in this paper, the author output timeline graph, and the three-field graph.

Results

Overall Analysis of Publications

Through data collection, we included a total of 9734 TSCC-related publications, including 8913 monographs and 821 reviews. The publication timeline and curve fitting analysis are shown in **Figure 1A**. The cumulative number of publications has increased exponentially, with the early years showing little growth and the more recent years exhibiting a steep rise. The overall trend of annual publications is relatively steady, suggesting that the development of TSCC research has been gradual without any sudden breakthroughs. And there are fluctuations in the annual publication count, suggesting that there may be adjustment in some aspects of this area.
WOS citation analysis showed that these publications were cited by 93,517 publications (excluding self-citations), with a citation frequency of 142,701, an average citation frequency of 14.66 per article, and an h-index of 138 (indicating that 138 publications were cited at least 138 times). As shown in **Figure 1B**, the annual citation frequency increases linearly. The combination of h-indexes indicates that publications on TSCC are of high quality and receiving increasing attention.

A



B

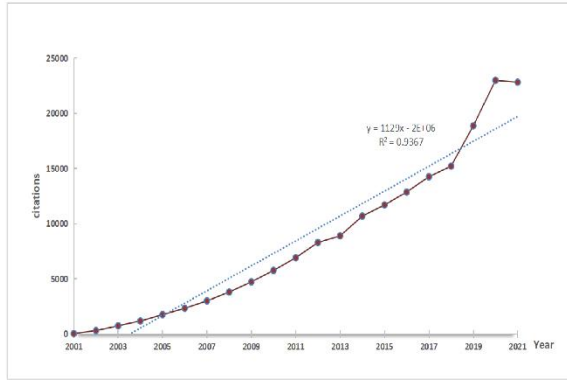


Figure 1 Overall analysis of publications: **(A) global annual output trend graph:** This graph shows how the number of publications on TSCC has changed each year, highlighting whether the research in this field is increasing, decreasing, or staying stable over time; **(B) annual citation trend graph of publications:** This graph illustrates how the number of times TSCC publications have been cited each year, helping to show how the impact or attention to this research has grown or changed.

Analysis of Country/Region

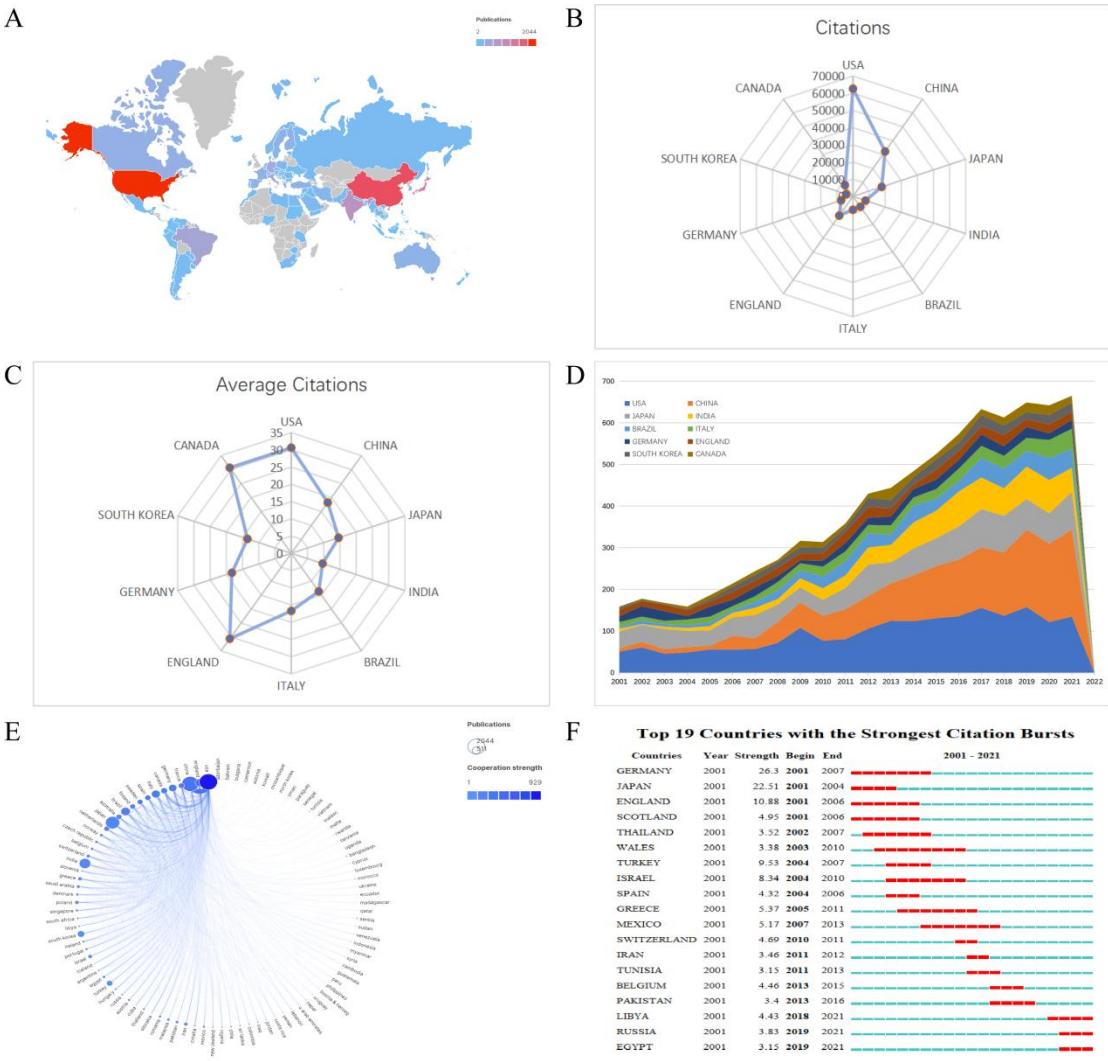
Major 104 countries published publications on TSCC between 2001 and 2021. As shown in **Figure 2A**, **Figure 2B**, and **Table 1**, the United States has the highest global productivity and citation frequency, followed by China and Japan. They published a total of 5045 articles, accounting for 51.8% of the world. It is worth noting that Canada has the highest average citation rate (**Figure 2C**), followed by the United Kingdom, and the United States ranks third, but the United States has the highest centrality and sigma values (centrality refers to its importance in the research network, and sigma values reflect its significant impact on the field).

Overall, the United States is the leader in this field, but the number of publications has declined in the past 3 years while other countries are on the rise (**Figure 2D**). As shown in the figure, almost all countries have cooperation with the United States, with China and the United States most closely cooperating (**Figure 2E**). In addition, the burst detection found that countries such as Libya have increased their research on TSCC in recent years (**Figure 2F**).

Table 1. Top 10 countries in TSCC field.

Country/Region	Publications	citation	Average citation	Centrality	sigma	Half life
USA	2044	62624	30.63796477	70	0.36	12.5
CHINA	1777	32315	18.1851435	43	0.14	14.5
JAPAN	1224	17843	14.57761438	43	0.1	12.5
INDIA	807	7785	9.646840149	28	0.03	14.5
BRAZIL	541	7401	13.68022181	41	0.07	13.5
ITALY	463	7740	16.71706263	49	0.09	12.5
ENGLAND	450	13793	30.65111111	54	0.11	10.5
GERMANY	400	7318	18.295	51	0.13	10.5
SOUTH KOREA	315	4249	13.48888889	19	0.01	12.5
CANADA	263	8071	30.68821293	42	0.08	12.5

Figure 2 Country/Region distribution of TSCC studies: **(A) Geographical distribution of global output:** This map



shows where research on TSCC is being published worldwide. It highlights the countries that contribute the most to TSCC studies, giving a visual representation of global research distribution. **(B) Radar map of top 10 producing countries:** This radar chart displays the top 10 countries with the highest citation frequency for their TSCC research. It shows which countries' research is being cited the most, reflecting their influence in the field; **(C) Average citation radar map of top 10 producing countries：** This radar chart compares the average citation rates of the top 10 countries producing TSCC research; **(D) Front Annual production trends for 10 producing countries:** This graph tracks the number of TSCC publications from the top 10 countries over time, showing whether research output is increasing or decreasing in these countries; **(E) visualization of the degree of cooperation among countries:** This chart illustrates how countries collaborate on TSCC research. The closer and stronger the lines between two countries, the more they cooperate; **(F) Bursts detection of Country/Region:**This graph identifies countries or regions where TSCC research has experienced a sudden increase in publication activity.

Analysis of Journal

With 9734 publications published in 1774 journals, **Figure 3A** shows the core journals in the TSCC field that comply with Bradford law (a principle that shows how research is spread across journals, with a few journals publishing most of the articles on a topic, while many others publish fewer). **Table 2** shows the top 10 most popular journals, in which about 20% of publications are published. ORAL ONCOLOGY ranks first, with 419 TSCC-related articles published and cited 14,801 times, with an average of over 35 citations per article. It was followed by HEAD AND NECK-JOURNAL FOR THE SCIENCES AND SPECIALTIES OF THE HEAD AND NECK (343 publications, 9045 citations) and JOURNAL OF ORAL PATHOLOGY & MEDICINE (205 publications, 4678 citations). **Figure 3B** shows their mutual reference relationship. In addition, we analyzed 18,264 source journals for 9,734 publication references. They were grouped into 19 clusters (**Figure 3C**), with the most references from ORAL ONCOLOGY and the highest centrality. The double graph overlay (**Figure 3D**) shows several major citation paths, and the citing papers are mainly concentrated in the fields of MOLECULAR, BIOLOGY, GENENTICS, HEALTH, NURSING, MEDICINE, DERMATOLOGY, DENTISTRY, SURGERY, etc. The cited papers are concentrated in the fields of MOLECULAR, BIOLOGY, IMMUNOLOGY,

DENTISRY, DERMATOLOGY, SURGERY, MEDICUNE, MEDICAL, CLINICAL and so on. In addition, we also found that the internal citation paths of citing citations and cited documents are concentrated in some disciplines that are partial to medical clinical research.

Table 2. The Top 10 journals that published articles in TSCC field.

Journal	Publications	IF (2021)	Quartile in category (2021)	Centrality
ORAL ONCOLOGY	419	5.972	2	91
HEAD AND NECK-JOURNAL FOR THE SCIENCES AND SPECIALTIES OF THE HEAD AND NECK	343	3.821	2	90
JOURNAL OF ORAL PATHOLOGY & MEDICINE	205	3.539	3	81
INTERNATIONAL JOURNAL OF ORAL AND MAXILLOFACIAL SURGERY	163	2.986	3	86
JOURNAL OF ORAL AND MAXILLOFACIAL SURGERY	162	2.136	4	84
LARYNGOSCOPE	149	2.970	1	86
EUROPEAN ARCHIVES OF OTO-RHINO-LARYNGOLOGY	134	3.236	3	81
ONCOLOGY LETTERS	112	3.111	4	69
ORAL SURGERY ORAL MEDICINE ORAL PATHOLOGY ORAL RADIOLOGY	106	2.538	4	75
JOURNAL OF CRANIOFACIAL SURGERY	103	1.172	4	49

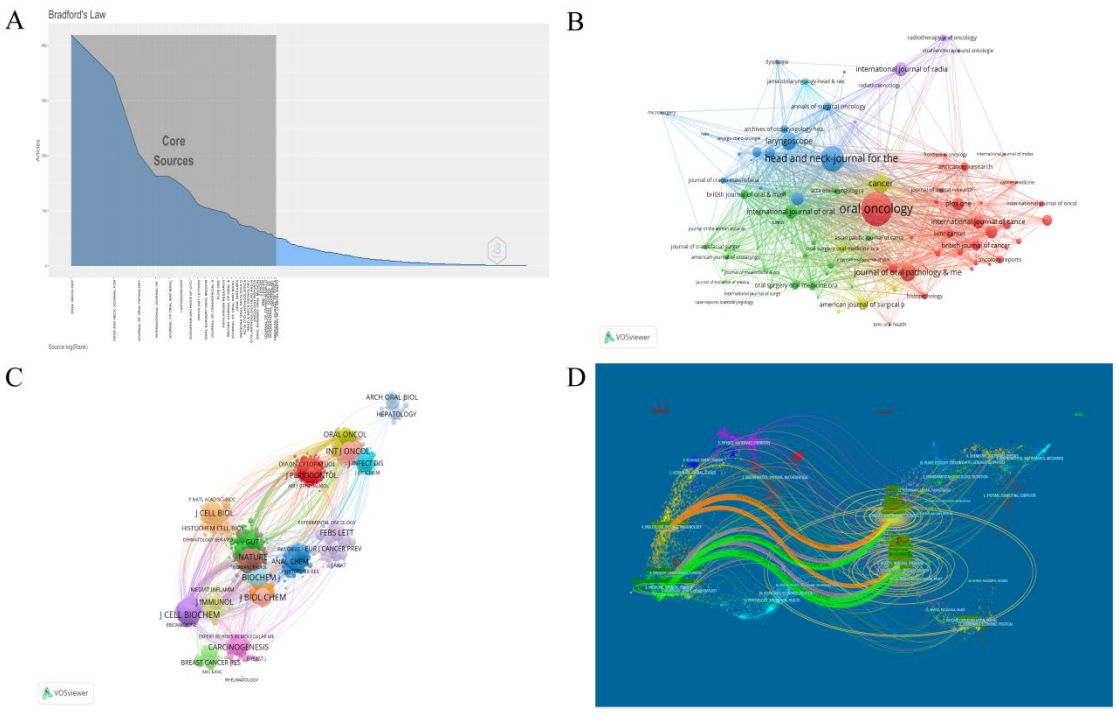


Figure 3. Journal analysis of TSCC research: **(A) core journals conforming to Bradford law:** This graph shows the core journals in TSCC research that follow Bradford's Law, which suggests that a small number of journals publish most of the research on a topic, while many other journals publish fewer articles. It highlights the key journals in the TSCC field where most of the research is concentrated; **(B) journal co-occurrence network:** This network graph illustrates the relationships between journals that often reference each other; **(C) cited journal clustering graph:** The graph highlights the main journals that researchers rely on for TSCC studies; **(D) journal double graph overlay:** The graph highlights the main research areas (such as Molecular Biology, Genetics, Medicine, Surgery, etc.) where TSCC-related articles are being cited most frequently.

Analysis of Institution and Author

9734 publications were published by 42893 authors from 7191 institutions (**Table 3**). The most productive institution was Sun Yat-sen University in China (243), followed by the Helsinki University in Finland (148) and São Paulo University in Canada (133) (**Figure 4A**). As shown in the figure (**Figure 4B**), there is strong cooperation between institutions and authors around the world, and this result matches the increasing trend of cooperation between countries and the number of publications, which may be because the TSCC is also increasingly harmful and the TSCC field is in a process of scientific accumulation. The three authors with the highest number of publications are SALO T (95) of the Helsinki University, Finland, KOWALSKI LP (69) of the Sao Paulo University, Brazil, and DALIANIS T (48) of the Karolinska Institute, Sweden. Their research in the field of TSCC is full of momentum, because the annual publication volume and influence are on an upward trend (**Figure 4C**). In addition, we also show the journals and keywords they focus on in the TSCC field (**Figure 4D**).

Table 3. The Top 10 authors and institutions that published articles in TSCC field.

Authors	Publications	citation	Average citation	institutions	Publications
SALO T	95	2627	27.65263158	sun yat sen univ	243
KOWALSKI LP	69	1841	26.68115942	univ helsinki	148
DALIANIS T	48	1535	31.97916667	univ sao paulo	133
UMEDA M	46	546	11.86956522	shanghai jiao tong univ	109
WANG Y	42	548	13.04761905	karolinska inst	98
LI J	40	590	14.75	univ oulu	98
TANAKA T	40	888	22.2	tokyo med & dent univ	97
NASMAN A	36	1070	29.72222222	univ texas md anderson canc ctr	95
CHATURVEDI P	35	1089	31.11428571	china med univ	90
YANAMOTO S	35	500	14.28571429	tata mem hosp	89

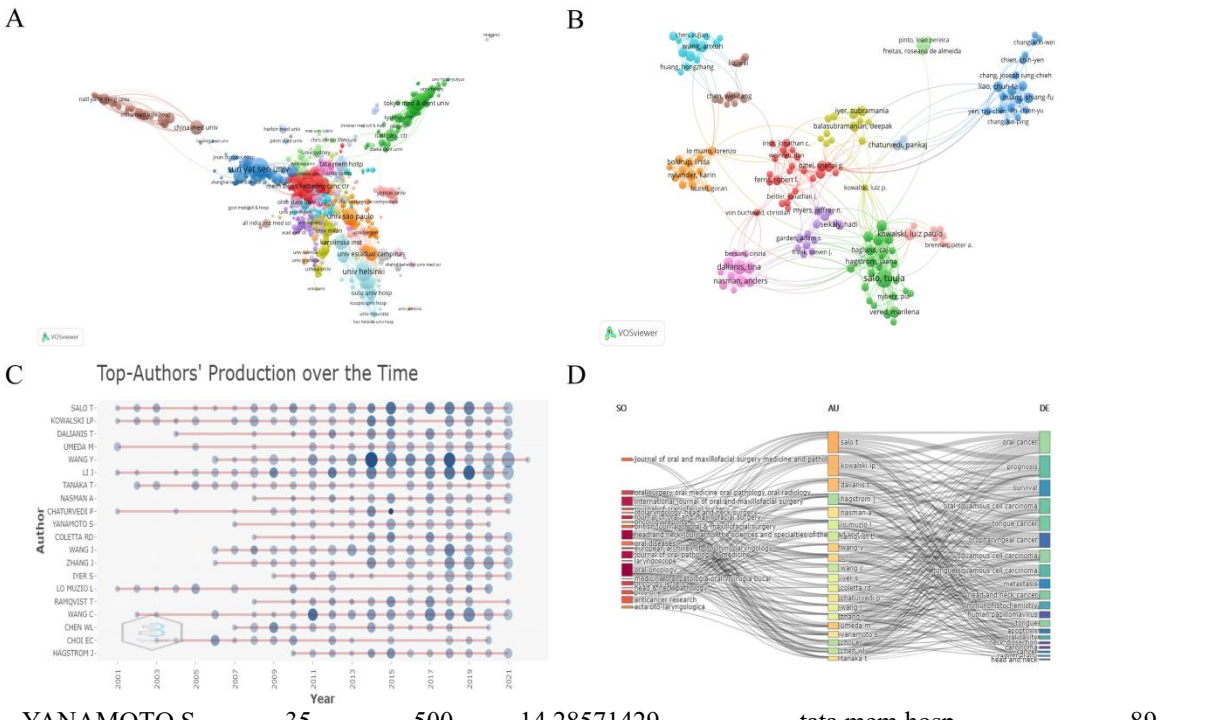


Figure 4 Institution/author analysis of TSCC research: **(A) Institutional cooperation network:** This diagram shows the collaboration between institutions around the world on TSCC research; **(B) Author cooperation network:** This diagram shows the collaboration between authors around the world on TSCC research; **(C) Author output timeline:** This graph shows the publication output over time of the authors in the TSCC field.; **(D) Journal-author-keyword three-field**

diagram: This diagram displays the journals, authors, and keywords most commonly associated with TSCC research.

Analysis of Reference Co-cited

A total of 171,614 references were cited in 9,734 publications, and we screened the top 10 most-cited references (**Table 4**), all of which focused on epidemiological investigations and clinical studies of TSCC. Then we used citespace to construct a reference co-cited network and clustered, and found a total of 18 clusters with a modularity Q of 0.7572 (Q > 0.3) and an average profile value S of 0.8918(S > 0.5), indicating that the clustering is reliable (**Figure 5A**). Its underlying network shows the disciplinary foundations of TSCC, and the clustering labels show frontier fields. In addition, we used a timeline view (**Figure 5B**) to visualize the evolution of each cluster and the associations between different clusters, which shows a shift in research focus from the fields of E-cadherin, Metastases, Epidemiological, Sentinel lymph node, etc. to Depth of invasion, Transoral robotic surgery, Lymphatic, Young patient, Tumor budding. Finally, we perform burst detection to capture references or keywords with a sharp increase in attention over a certain period of time. As shown in figure (**Figure 5C**), the literature with the greatest burst intensity and the most durable time was published by Yuen et al.

Table 4. The Top 10 cited references in TSCC research

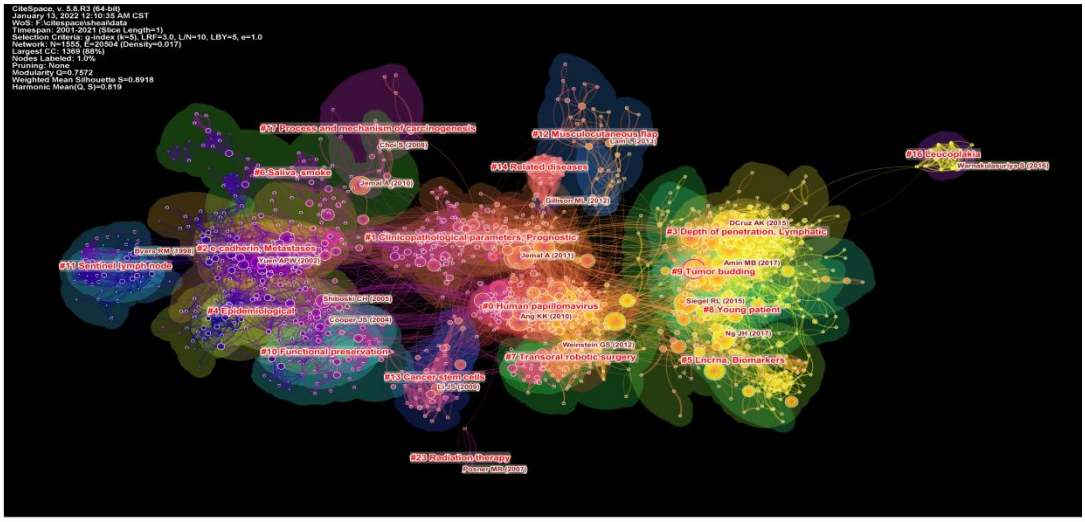
Title	Be-citation	Journal	IF	Year
Global epidemiology of oral and oropharyngeal cancer	277	Oral Oncol	5.972	2009
Human papillomavirus and survival of patients with oropharyngeal cancer	234	N Engl J Med	176.079	2010
Tongue and tonsil carcinoma: increasing trends in the U.S. population ages 20-44 years	203	Cancer	6.921	2005
Oral squamous cell carcinoma: histologic risk assessment, but not margin status, is strongly predictive of local disease-free and overall survival	196	Am J Surg Pathol	6.298	2005
Predictive Value of Tumor Thickness in Squamous Confined to the Tongue and Floor of the Mouth	184	Am J Surg	3.125	1986
Postoperative concurrent radiotherapy and chemotherapy for high-risk squamous-cell carcinoma of the head and neck	179	N Engl J Med	176.079	2004
Prognostic factors of clinically stage I and II oral tongue carcinoma-A comparative study of stage, thickness, shape, growth pattern, invasive front malignancy grading, Martinez-Gimeno score, and pathologic features	178	Head Neck	3.821	2002
Elective versus Therapeutic Neck Dissection in Node-Negative Oral Cancer	167	N Engl J Med	176.079	2015
Global cancer statistics, 2002	166	CA Cancer J Clin	286.130	2005
Human papillomavirus and rising oropharyngeal cancer incidence in the United States	163	J Clin Oncol	50.717	2011

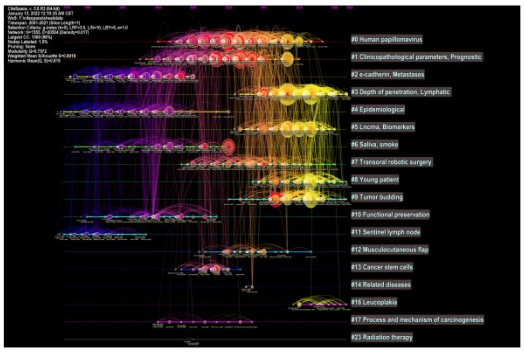
Figure 5 Reference co-cited analysis of TSCC research: **(A) Reference co-cited clustering graph:** This graph shows how different references are grouped based on how often they are cited together in TSCC research. The clusters represent related research areas, and the modularity Q and average profile value S indicate that the clustering is reliable. This helps us understand the main research topics and fields that form the foundation of TSCC studies; **(B) Reference co-cited timeline view:** This timeline visualization illustrates how the focus of TSCC research has changed over time. It helps track the changing trends and emerging areas of interest in TSCC research; **(C) Reference co-cited bursting detection:** This graph highlights references that have experienced a sudden surge in attention over a specific period, this method helps identify breakthrough papers that have recently gained importance in TSCC research.

Analysis of Keywords

A total of 23,260 keywords were extracted from 9,734 publications. Five categories were identified by cluster analysis. And the timeline view (**Figure 6A**) shows that research on TSCC's subfields is decreasing, such as Neck dissection, Human papillomavirus, and Diagnosis, while the fields such as Apoptosis, Quality of Life, and so on continue to be hot. The density map (**Figure 6B**) shows the frequency of keyword co-occurrence, revealing the current status and hotspots of the study, and it can be seen that Expression is the most important keyword, appearing 1023 times, followed by Survival, Metastasis, Radiotherapy and Prognosis. In addition, burst detection (**Figure 6C**) time sequencing found that Depth of

invasion and Biomark were the most emerging keywords of burst intensity in recent years.

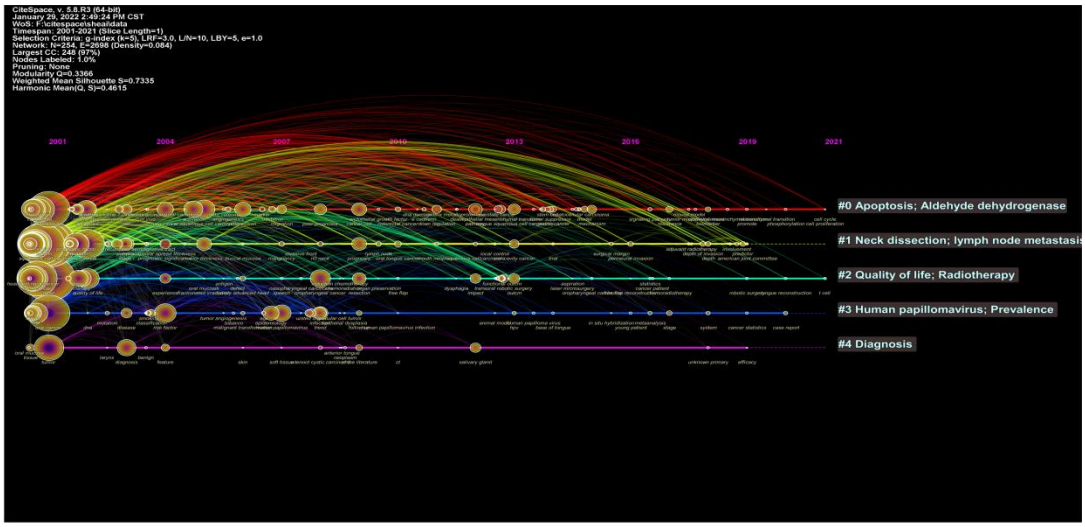


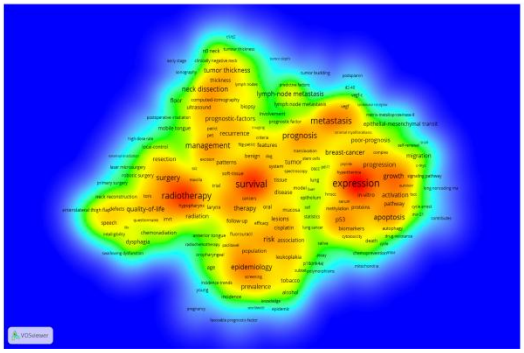


C

Top 25 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2001 - 2021
Yuen APW, 2002, HEAD NECK-J SCI SPEC, V24, P513, DOI 10.1002/hed.10094, DOI	2002	19.95	2003	2007	
Shibata CH, 2005, CANCER-AM CANCER SOC, V103, P1843, DOI 10.1002/cncr.20998, DOI	2005	22.29	2007	2010	
Parkin DM, 2005, CA-CANCER J CLIN, V55, P74, DOI 10.3322/canjclin.55.2.74, DOI	2005	19.49	2007	2010	
DSouza G, 2007, NEW ENGL J MED, V356, P1944, DOI 10.1056/NEJMoa065497, DOI	2007	21.75	2008	2012	
Fakhry C, 2008, JNCI-J NATL CANCER I, V100, P261, DOI 10.1093/jnci/djn011, DOI	2008	28.03	2009	2013	
Warnakulasuriya S, 2009, ORAL ONCOL, V45, P309, DOI 10.1016/j.oraloncology.2008.06.002, DOI	2009	28.69	2010	2014	
Ang KK, 2010, NEW ENGL J MED, V363, P24, DOI 10.1056/NEJMoa0912217, DOI	2010	38.75	2011	2015	
Marur S, 2010, LANCET ONCOL, V11, P781, DOI 10.1016/S1470-2045(10)70017-6, DOI	2010	23.13	2011	2015	
Jemal A, 2010, CA-CANCER J CLIN, V60, P277, DOI 10.3322/caac.20073, DOI	2010	19.05	2011	2015	
Jemal A, 2011, CA-CANCER J CLIN, V61, P134	2011	32.34	2012	2016	
Patel SC, 2011, J CLIN ONCOL, V29, P1488, DOI 10.1200/JCO.2010.31.7883, DOI	2011	22.62	2012	2016	
Leemans CR, 2011, NAT REV CANCER, V11, P9, DOI 10.1038/nrc2982, DOI	2011	22.62	2012	2016	
Chaturvedi AK, 2011, J CLIN ONCOL, V29, P4294, DOI 10.1200/JCO.2011.36.4596, DOI	2011	31.43	2013	2016	
Almangush A, 2014, HEAD NECK-J SCI SPEC, V36, P811, DOI 10.1002/hed.23380, DOI	2014	24.03	2015	2019	
Siegel RL, 2015, CA-CANCER J CLIN, V65, P5	2015	23.58	2015	2018	
DCruz AK, 2015, NEW ENGL J MED, V373, P521, DOI 10.1056/NEJMoa1506007, DOI	2015	41.13	2016	2021	
Ferlay J, 2015, INT J CANCER, V136, P0, DOI 10.1002/ijc.29210, DOI	2015	21.69	2016	2019	
Lawrence MS, 2015, NATURE, V517, P576, DOI 10.1038/nature14129, DOI	2015	19.78	2016	2021	
Amin MB, 2017, AJCC CANC STAGING MA, V8th, P0	2017	27.31	2017	2021	
Ebrahimi A, 2014, JAMA OTOLARYNGOL, V140, P1138, DOI 10.1001/jamaoto.2014.1548, DOI	2014	22.71	2017	2019	
Torre LA, 2015, CA-CANCER J CLIN, V65, P87, DOI 10.3322/caac.21262, DOI	2015	22.05	2017	2019	
Siegel RL, 2016, CA-CANCER J CLIN, V66, P7, DOI 10.3322/caac.21332, DOI	2016	20.35	2017	2021	
Lydiatt WM, 2017, CA-CANCER J CLIN, V67, P122, DOI 10.3322/caac.21389, DOI	2017	35.52	2018	2021	
Ng JH, 2017, HEAD NECK-J SCI SPEC, V39, P287, DOI 10.1002/hed.24589, DOI	2017	28.88	2018	2021	
Siegel RL, 2017, CA-CANCER J CLIN, V67, P7, DOI 10.3322/caac.21387, DOI	2017	19.82	2018	2021	





C

Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2001 - 2021
advanced head	2001	14.7	2001	2008	
radiation therapy	2001	13.45	2001	2007	
protein	2001	12.57	2001	2006	
gene	2001	11.9	2001	2005	
irradiation	2001	17.71	2002	2007	
dissection	2001	15.45	2002	2006	
prognostic significance	2001	14.29	2004	2014	
upper aerodigestive tract	2001	13.78	2004	2009	
stage i	2001	20.91	2005	2011	
prostate cancer	2001	15.53	2013	2017	
transoral robotic surgery	2001	15.29	2013	2017	
epithelial mesenchymal transition	2001	12.16	2015	2019	
of the literature	2001	14.95	2016	2018	
poor prognosis	2001	14.34	2016	2019	
colorectal cancer	2001	14.25	2016	2018	
metaanalysis	2001	12	2017	2018	
depth	2001	20.78	2018	2021	
depth of invasion	2001	15.77	2018	2021	
biomarker	2001	12.83	2018	2021	
tongue squamous cell carcinoma	2001	25.55	2019	2021	
resistance	2001	15.65	2019	2021	
american joint committee	2001	14.6	2019	2021	
migration	2001	14.08	2019	2021	
impact	2001	13.99	2019	2021	
predictor	2001	12.24	2019	2021	

Figure 6 Keywords analysis of TSCC research: **(A) Keywords timeline view:** This timeline shows how the focus of TSCC research keywords has changed over time; **(B) Keywords density map:** This map shows the frequency of co-

occurrence of keywords across TSCC publications; **(C) Keywords co-cited bursting detection:** This graph shows which keywords have gained a sudden surge in attention over recent years.

Discussion

9,734 TSCC-related publications indexed in WoSCC (time span 2009-2021), published in 1,774 academic journals by 42,893 authors from 7,191 institutions in 104 countries, citing 171,614 references literature, and extracted 23,260 keywords. This study sorts out this information and visually describes the overall research results of TSCC in recent years through bibliometrics and visual analysis.

In general, publications about TSCC are on the rise and have entered a relatively mature stage, but the internal subfields are still improving, and there may be adjustments in their composition. Combining the growth curve with Thomas Kuhn theory[16], it can be concluded that TSCC is in the stage of paradigm accumulation(the gradual building up of knowledge and understanding in a field as new discoveries and insights are added over time), but the low level of 5-year survival rate in the past 40 years has not improved, which indicates a scientific crisis, because the existing scientific paradigm does not effectively solve existing problems.

From the perspective of national and regional cooperation distribution. The number of publications is closely related to the economic level[17], and high productivity is basically concentrated in developed countries. The economies of China and India have also risen in recent years. However, the increase in their publications may be partly due to the fact that risk factors have not been effectively controlled, especially betel nut[18].

Journal analysis can be used to identify popular journals and the latest literature information for tracking or submission[19], and the results of the journal distribution in this study show that ORAL ONCOLOGY is the most popular journal in the TSCC research field, which is dedicated to publishing basic, translational or clinical research papers. However, we found that TSCC-related articles published in ORAL ONCOLOGY are biased towards clinical research. In addition, the citation paths of the journals' double-image overlay and the topics of interest in the top 10 journals are all concentrated in some subjects that are partial to medical clinical research, which means that the basic research in the TSCC research field is relatively weak.

The author's analysis can enable researchers to clearly see the changes in the core leaders of disciplines in this field, which is helpful for the introduction of talents in universities and think tank research[20]. Of the three most productive authors, SALO T and KOWALSKI LP have the most closely cooperation. In recent years, they are committed to the research of early TSCC, pathological grading and prognosis, while DALIANIS T is committed to the molecular chemical research related to the occurrence and prevention of TSCC.

Keyword analysis and co-cited reference analysis can show the evolution process of the TSCC knowledge field and discover emerging hotspots[21], and speculate on potential future research trends. Through the co-occurrence, clustering and burst analysis of keywords, we found that at present in the field of TSCC, most researchers prefer clinical research, such as Expression, Survival, Metastasis, prognosis, management, and these keywords are concentrated in neck dissection, human papilloma virus, diagnosis and other fields. These fields tend to mature and lose their popularity with gradual thoroughly research. For example, neck dissection is an operation to remove the lymph node metastasis of cancer in the neck, and its radical surgery was first proposed by Crile in 1906[22]. However, due to the need to improve complications such as large surgical trauma and shoulder dysfunction, it gradually derived surgical methods such as prolonged neck dissection, modified radical neck dissection, and selective neck dissection[23, 24]. These procedures are now widespread in clinical treatment and are described in detail in the American Society of Head and Neck and the American Society for Otolaryngology to update the classification of neck sweeps[25].

In the field of TSCC, research on human papillomavirus has mainly focused on epidemiological investigations, and its type 16 was identified as one of the major risk factors for TSCC (especially tongue base cancer) in 2007, and is considered to be the culprit driving the increased incidence, youthfulness, and feminization of TSCC in recent years[26-30]. This is followed by a focus on the p16 protein, a member of the INK4 class of cell cycle inhibitors whose specific binding to the cyclin-dependent kinases CDK4 and CDK6 blocks their interaction with D-cyclin, thereby preventing Phosphorylation of retinoblastoma (Rb) gene by CDK4/CDK6-CyclinD complex enables Rb gene to bind to free transcription factor E2F to form RB-E2F complex, thereby preventing cells from entering S phase from G1 phase and inhibiting cell growth, proliferation[31, 32]. Because of this mechanism, p16 is considered to be the brake pad in the progression of most cancers, including in TSCC, and its high expression often represents a good prognosis[33]. Its binding to HPV DNA is considered to be a marker for the presence of HPV[27]. Because, the E7 oncoprotein transcribed by hpv will competitively bind with the Rb protein, leading to the release of the E2F transcription factor, thereby resulting in the compensatory overexpression of the p16 protein[32, 34]. But there are other pathways (such as cellular senescence) that interfere with p16 regulation, so combined detection of HPV DNA is required to determine the presence of HPV[35].

The reference Co-cited analysis further verifies the conclusions of the keyword analysis in these fields. For example, the corresponding to the keyword HPV field is reference co-cited HPV clustering, and the corresponding to the keyword neck dissection field is reference co-cited Treatment, Sentinel lymph and Musculocutaneous flap clustering. In addition, we also have new findings. First of all, it is unquestionable that the risk factors for TSCC have been basically identified, but it's interesting to note that the cluster found that saliva is also considered one of the risk factors because of its cytotoxicity and its lethal synergy with cigarette smoke. Saliva can form a pro-oxidative environment after exposure to cigarette smoke[36], and convert low-activity free radicals into high-activity free radicals to promote the occurrence and development of cancer[37, 38]. Second, TSCC has also developed in the field of cancer stem cells. Common cancer stem cell markers such as CD44, OCT-2, ABCG2, SOX2, NANOG, and OCT4 are often used in TSCC stem cell research[39-

41], However, currently only Bmi1, CD133, p75, and ALDH have been confirmed by studies to be suitable for TSCC stem cells, and it is unclear whether the rest also define TSCC cancer stem cells[42-44]. However, having clear and unambiguous markers is the cornerstone of basic research and screening of anti-cancer stem cell drugs. Third, as a marker of epithelial mesenchymal transformation (EMT), e-cadherin has also flourished in the field of TSCC, which is mainly involved in cell-to-cell adhesion and plays an important role in maintaining cell polarity and integrity. Although its low expression is often used as an indicator of cancer cell invasion, delayed metastasis, and poor prognosis in TSCC studies[45], recent retrospective studies have shown that E-cadherin is not an important prognostic factor in TSCC, but is significantly correlated with tumor invasion patterns[46-48]. Inconsistent findings lead to caution in the use of E-cadherin as a prognostic marker[49], which may be the main reason for its heat loss in the TSCC field. Finally, we found that clinicopathological parameters (e.g, TNM staging, immunohistochemistry) remain the main force in prognostic assessment, and Bello's two reviews perfectly encapsulate this area[50, 51].

In addition, we identified depth of invasion, biomarkers, robotic surgery, young tumor patients, tumor budding as emerging subfields of TSCC and potential future research trends through keyword analysis and reference co-cited analysis. It is not difficult to find that these emerging sub-fields are inextricably linked with the above-mentioned fields of heat loss, and even some of them are derived fields. For example, invasion depth and tumor budding are associated with TSCC invasion and lymphatic metastasis (especially early occult lymphatic metastasis)[52, 53], and they have been shown to be reliable models for assessing prognosis and guiding treatment planning[54]. The depth of invasion refers to the vertical distance from the level of the basement membrane of the nearest adjacent normal mucosa to the deepest level of tumor invasion, which replaces the previous tumor thickness because of its better and more precise predictive value. Starting with the sixth edition of the AJCC Cancer Staging Manual, the depth of invasion has been incorporated into the TNM records and used for analysis. Previously, T categories were incremented at 2 cm intervals based on tumor thickness, but now at 5 mm intervals according to the depth of invasion[55]. In early TSCC, the depth of invasion can be used as an independent prognostic factor, dividing into high/low risk groups with a 4 mm boundary to predict regional lymph node metastasis[56], and can guide the choice of neck dissection[57]. Tumor budding refers to the appearance of a single cancer cell or a cluster of <5 cancer cells in the stroma at the invasive front[58], with <5 budding considered low risk and ≥5 budding considered high risk. Multiple studies have shown that tumor budding has a higher prognostic value than the classic WHO tumor grading system[59]. In view of this, some studies have suggested its inclusion in the current WHOTSCC histopathological grading system[60]. Robotic surgery is a very mature manifestation of surgical procedures. Studies have shown significant advantages over classical open surgery or endoscopic transoral laser surgery[61, 62]. It is worth emphasizing that the molecular mechanism of TSCC is not yet fully understood, and there are no specific targeted therapy drugs and reliable biomarkers for detection, while the corresponding solid tumor patients in other parts of the body are affected by biomarkers and Targeted drugs benefit. This underlines the need for substantial basic research for development, and our results demonstrate this trend, as biomarkers are also one of the emerging subfields and future research trends in TSCC. Although two large-scale meta-analyses have identified some promising TSCC biomarkers, such as cyclin D1, VEGF-A, HIF-1α, SOX2, E-cadherin, vimentin, MALAT1, TP53, and NOTCH1[63]. However, most biomarkers have only been studied once or twice in TSCC, and no very reliable conclusions can be drawn, which also means that further verification of existing biomarkers may be a good research direction for TSCC.

Limited

This study also has certain limitations, as data were only retrieved and extracted from the core database, and although the publications from WOSCC are sufficiently comprehensive, omissions are inevitable. In addition, some newly published high-quality literature may be underestimated due to the continuous updating of the database.

Conclusions

As far as we know, this is the first comprehensive bibliometric and visual analysis of recent publications in the TSCC field, and our findings suggest that the TSCC field is in a stage of scientific paradigm accumulation (the gradual building up of knowledge and understanding in a field as new discoveries and insights are added over time). The United States is the leader in the field, and the most productive institution is Sun Yat-Sen University, and ORAL NCOLOGY and SALO T are the most influential and productive journals and authors, respectively. At present, this field focuses more on clinical research and less on basic research. Invasion depth, biomarkers, robotic surgery, young tumor patients, and tumor budding are emerging subfields of TSCC and potential future research trends. It is worth noting that basic research in this field is still relatively small, such as the development of biomarkers and the discovery of therapeutic targets, which requires more research to fill these gaps. In conclusion, we provide a more intuitive perspective to analyze and reflect the basic knowledge structure and emerging hotspots in the TSCC field, which will greatly save researchers' time, especially for new entrants.

In summary, this study highlights the dynamic nature of TSCC research, with increasing global collaboration, shifting research foci, and emerging areas of scientific interest. These insights can guide future research directions and inform clinical practices in TSCC diagnosis and treatment.

For example: First, the growing focus on biomarkers and depth of invasion suggests that future research could explore the development of more precise diagnostic tools, allowing for earlier and more accurate detection of TSCC, particularly in its early stages. Then, the increasing emphasis on transoral robotic surgery (TORS) in recent studies highlights the potential for improving surgical techniques and patient outcomes by integrating minimally invasive procedures into routine TSCC treatment protocols, and so on.

Outlook and Future Directions

Our current study summarizes TSCC research from 2001 to 2021. In the future, new papers and data related to TSCC will emerge. A subsequent study that visualizes the current status and trends of TSCC research will help understand the development trends of TSCC research and provide researchers with insights into future research directions and emerging hotspots.

Data Availability Statement

The original contributions presented in the study are included in the article/ Supplementary Material. Further inquiries can be directed to the corresponding author.

Author Contributions

Yuanzhi Zhu performed the majority of the writing and data acquisition; Tao Liang and Yao Ding performed data acquisition; Yi Huang and Shizi Wang performed the Data interpretation and Article design; Xiaoqiang Mo performed the manuscript modification and verification. All authors read and approved the final manuscript.

Conflict of Interest

There is no conflict of interest associated with any of the senior author or other coauthors contributing their efforts in this manuscript.

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