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Dental implants surface morphology: Bibliometric analysis of current trends in literature

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Abstract

Background and Aims: Dental implants have become essential in restorative dentistry, with surface morphology playing a critical role in enhancing osseointegration, bone regeneration, and long-term stability. Advancements in materials science and surface engineering, particularly micro-rough and nano-textured designs, have revolutionized implant technology to address challenges such as peri-implantitis and implant failure.

Methods: This study presents a bibliometric analysis of research trends in dental implant surface morphology from 1999 to 2024, utilizing data extracted from the Web of Science Core Collection. This analysis yielded 2,814 documents, with an annual growth rate of 2.65%. Research output has significantly increased since 2010, driven by technological advancements and a multidisciplinary approach that integrates dentistry, materials science, and bioengineering.

Results: The analysis identified leading journals, including Clinical Oral Implants Research and Dental Materials, as major platforms for high-impact studies. Influential contributors include institutions such as the University of Bern and the University of Gothenburg. Geographically, the USA, China, Germany, and Switzerland lead in publication volume, reflecting their robust implant manufacturing industries and research infrastructure. Keyword analysis reveals recurring themes such as "osseointegration," "surface roughness," and "titanium," emphasizing the importance of surface properties in improving implant performance. Emerging trends include nanotechnology, bioactive coatings, and additive manufacturing, highlighting innovative approaches to enhance implant integration.

Conclusion: This study underscores the importance of global collaboration, with 28.93% of publications involving international co-authorship.

Keywords: Dental implants, Osseointegration, Surface roughness, Bibliometrics.

Introduction

Dental implants have revolutionized modern dentistry by providing a reliable solution for tooth replacement that closely mimics both the function and aesthetics of natural teeth. As the global demand for implant treatments continues to rise, research aimed at optimizing their design and effectiveness has intensified.[1,2] Among the various factors influencing the success of dental implants, surface morphology has garnered significant attention due to its critical role in enhancing osseointegration, reducing failure rates, and promoting long-term stability. The surface characteristics of dental implants determine their interaction with surrounding tissues, which directly influences biological responses and mechanical integration.[3,4]

The concept of modifying implant surfaces to improve biological performance has undergone transformative changes, driven by advancements in materials science and engineering. Early dental implants predominantly featured smooth surfaces, which posed challenges in achieving strong bone-implant integration.[5-7] Over time, surface modifications -including roughening, coating, and texturing- have emerged as innovative strategies to address these challenges. The importance of surface morphology extends beyond osseointegration; it encompasses bioactivity, antimicrobial properties, and the prevention of

peri-implant diseases. Researchers have focused on optimizing surface features such as roughness, porosity, and chemical composition to align with the biological demands of implant sites.[8-10]

A bibliometric analysis of the literature in this domain provides a comprehensive understanding of the knowledge landscape and identifies influential studies, authors, and institutions that are shaping the field. By analyzing publication trends, citation networks, and research themes, it is possible to map the trajectory of innovation in dental implant surface morphology. This approach not only highlights areas of significant progress but also uncovers gaps that warrant further exploration. With the growing integration of multidisciplinary approaches -such as nanotechnology and bioengineering- dental implant research is poised to enter a new era of innovation.

Objectives

This study aims to provide a holistic overview of the current state of research on dental implant surface morphology.

Methods

Data Collection and Search Strategy

This analysis aimed to identify key trends, influential authors, institutions, journals, and countries contributing to the field of dental implant surface morphology. Relevant data were retrieved from the Web of Science Core Collection database. The search terms were meticulously selected to encompass publications related to "dental implants" and "surface morphology" (see Appendix 1). The search was conducted on 25 November 2024, and to ensure reproducibility, it excluded literature published in 2024 and later.

Only peer-reviewed articles were included in this analysis; other types of research -such as editorials, commentaries, non-peer-reviewed publications, and retracted works- were excluded.

Data Analysis

The collected data were analyzed using VOSviewer (Centre for Science and Technology Studies, Leiden University, The Netherlands) and the bibliometrix package in R (R Foundation for Statistical Computing, Vienna, Austria) via R Studio (RStudio, Inc., Boston, MA). Various metrics were evaluated, including publication counts, citation trends, co-authorship networks, and keyword co-occurrence. VOSviewer was utilized to create visual maps illustrating collaboration networks among authors, institutions, and countries, as well as to display keyword co-occurrences and density plots. R was employed for data visualization, producing word clouds of keywords, tree maps of keywords, country collaboration chord diagrams, and publication trends.

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki.

Results

Publication Trends

The bibliometric analysis indicated a steady increase in research activity related to dental implant surface morphology from 1999 to 2024. During this period, a total of 2,814 documents were published, highlighting the growing significance of this field. The annual growth rate was calculated at 2.65%, with a marked increase in publications observed after 2010. By 2024, the field reached its peak, with over 250 articles published annually. The dataset revealed an average document age of 8.07 years, reflecting a balanced mix of foundational research and recent advancements. Additionally, the average citation count per document was 29.42, underscoring the relevance and impact of these studies on both the scientific and clinical communities. Furthermore, the dataset included 72,202 references, illustrating the extensive research underpinning this field [Figure 1].

Most Influential Journals

Several journals have emerged as leaders in publishing high-quality research on implant surface morphology. Clinical Oral Implants Research was identified as the most influential journal, with 128 publications and a total of 6,540 citations. This was followed by Dental Materials and Acta Biomaterialia, which published 64 and 39 articles, respectively, accumulating 5,135 and 4,636 citations. Other notable journals include Biomaterials, with 34 articles and 4,103 citations, and the International Journal

of Oral Maxillofacial Implants, contributing 121 articles and 3,501 citations. These journals have played a pivotal role in advancing the field, focusing on critical topics such as osseointegration, surface roughness, and bioactive coatings. Among the most cited articles, those addressing nano-scale surface modifications and their impact on implant stability received particular attention [Table 1].

Leading Authors and Institutions

Adriano Piattelli and Takahiro Ogawa were identified as the leading authors in this field, with 34 and 33 publications, respectively. Piattelli's work garnered over 1,211 citations, while Ogawa's studies amassed 2,207 citations, reflecting their substantial contributions to the discipline. Other notable authors include F. Schwarz, who achieved 2,506 citations across 15 publications, and H.L. Wang, with 2,024 citations from 15 articles. The University of Bern in Switzerland ranked as the top institution with 57 publications and 5,597 citations, followed by the University of Gothenburg in Sweden with 35 publications and 3,786 citations. In Asia, Seoul National University in South Korea led with 45 publications and 2,408 citations. Strong collaboration among these institutions is evidenced by the global co-authorship networks [Tables 2-3; Figures 2-3].

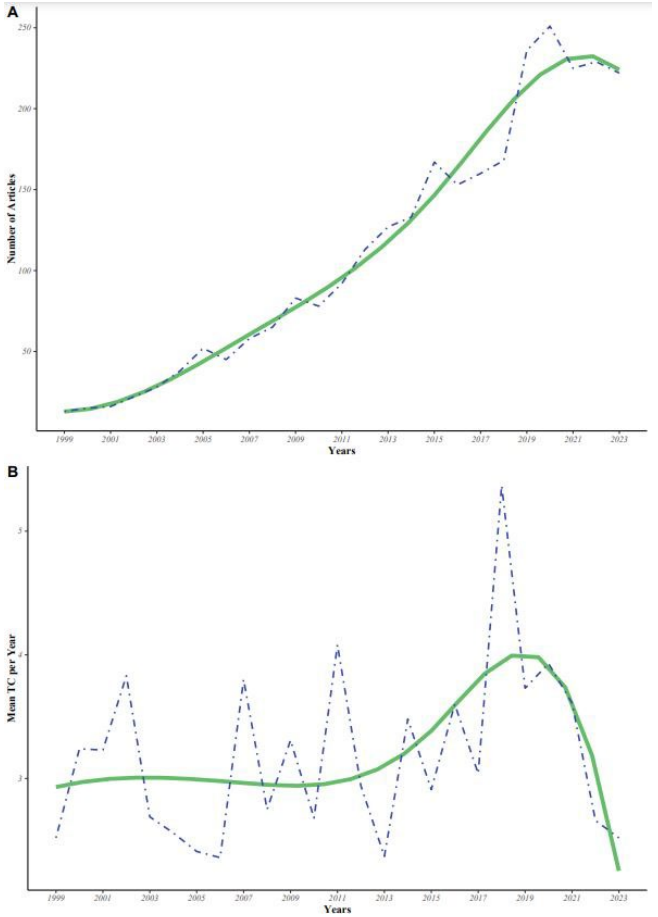

Figure 1. Publication trends regarding research trends in implant surface morphology (TC = total citation).

Table 1. Top 20 journals in the Implant Surface Morphology

#	Name	NOD	NOC	HI	GI	MI
1	Clinical Oral Implants Research	128	6540	45	75	1.73
2	Dental Materials	64	5135	36	64	1.64
3	Acta Biomaterialia	39	4636	28	39	1.56
4	Biomaterials	34	4103	31	34	1.19
5	International Journal of Oral & Maxillofacial Implants	121	3501	33	54	1.27
6	Journal of Periodontology	45	2825	28	45	1.12
7	Journal of Clinical Periodontology	16	2808	13	16	0.50
8	Clinical Implant Dentistry and Related Research	59	2260	26	46	1.30
9	Materials Science & Engineering: C	49	1958	30	43	2.14
10	Journal of Materials Science-Materials in Medicine	50	1911	21	43	0.88
11	Journal of Biomedical Materials Research Part A	51	1857	25	42	1.14
12	Journal of The Mechanical Behavior of Biomedical Materials	45	1750	21	41	1.24
13	Journal of Biomedical Materials Research Part B-Applied Biomaterials	44	1707	23	41	1.10
14	Applied Surface Science	49	1591	23	39	0.96
15	Surface & Coatings Technology	57	1534	23	37	1.15
16	Journal of Prosthetic Dentistry	34	1324	21	34	0.84
17	Materials	87	1097	18	26	1.29
18	Materials Science and Engineering C-Materials for Biological Applications	21	995	16	21	2.00
19	International Journal of Molecular Sciences	38	903	17	29	1.55
20	Biomed Research International	20	801	12	20	1.09

NOD: number of documents; NOC: number of citations; HI: h-index; GI: g-index; MI: m-index.

Table 2. Top 20 authors in the field of Implant Surface Morphology

#	Name	NOC	NOD	HI	GI	MI
1	Schwarz, F	15	2506	13	15	0.59
2	Ogawa, T	33	2207	25	33	1.25
3	Wang, Hl	15	2024	14	15	0.74
4	Buser, D	13	1469	12	13	0.48
5	Sculean, A	13	1345	9	13	0.41
6	Cochran DL	11	1336	10	11	0.40
7	Piattelli, A	34	1211	21	34	0.84
8	Ueno, T	11	1180	9	11	0.56
9	Coelho, Pg	22	960	14	22	0.82
10	Yamada, M	12	924	11	12	0.69
11	Elias, CN	18	900	10	18	0.43
12	Wang, L	15	781	10	15	0.53
13	Ivanovski, S	13	744	12	13	0.86
14	Jansen, Ja	18	681	14	18	0.64
15	Gil, FJ	17	672	13	17	0.57
16	Gulati, K	13	671	12	13	1.33
17	Romanos, Ge	11	646	8	11	0.36
18	Rocha, La	10	578	10	10	0.67
19	Mathew, Mt	14	575	12	14	0.92
20	Barao, Var	17	547	12	17	1.33

NOD: number of documents; NOC: number of citations; HI: h-index; GI: g-index; MI: m-index.

Table 3. Top 40 keywords in the field of Implant Surface Morphology

#	Name	Occurrence	#	Name	Occurrence
1	Implants	901	21	Growth	103
2	Surface	434	22	Alloys	102
3	In-Vitro	400	23	Attachment	101
4	Titanium	352	24	Expression	99
5	Bone	319	25	Wettability	94
6	Osseointegration	315	26	In-Vivo	92
7	Titanium Implants	238	27	Alloy	89
8	Adhesion	223	28	Interface	86
9	Behavior	212	29	Integration	81
10	Differentiation	201	30	Stability	80
11	Roughness	182	31	Survival	74
12	Proliferation	157	32	Surface-Roughness	72
13	Mechanical-Properties	145	33	Fabrication	69
14	Topography	144	34	Biomaterials	68
15	Coatings	136	35	Microstructure	67
16	Hydroxyapatite	127	36	Surface Modification	65
17	Cells	126	37	Strength	64
18	Biocompatibility	119	38	Deposition	62
19	Morphology	108	39	Bone-Formation	59
20	Peri-Implantitis	104	40	Corrosion Behavior	58

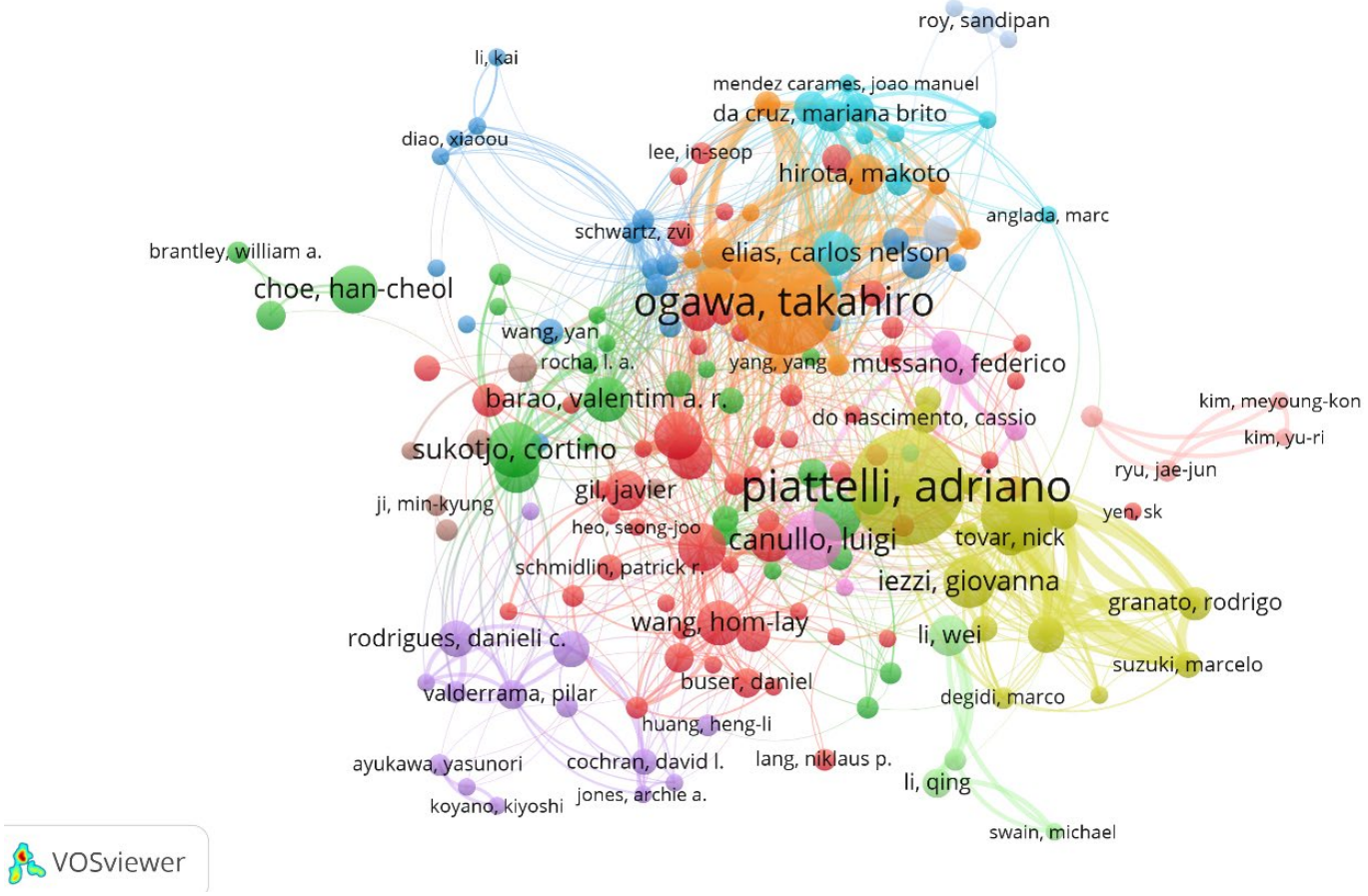

Figure 2. Authors' citation collaboration network.

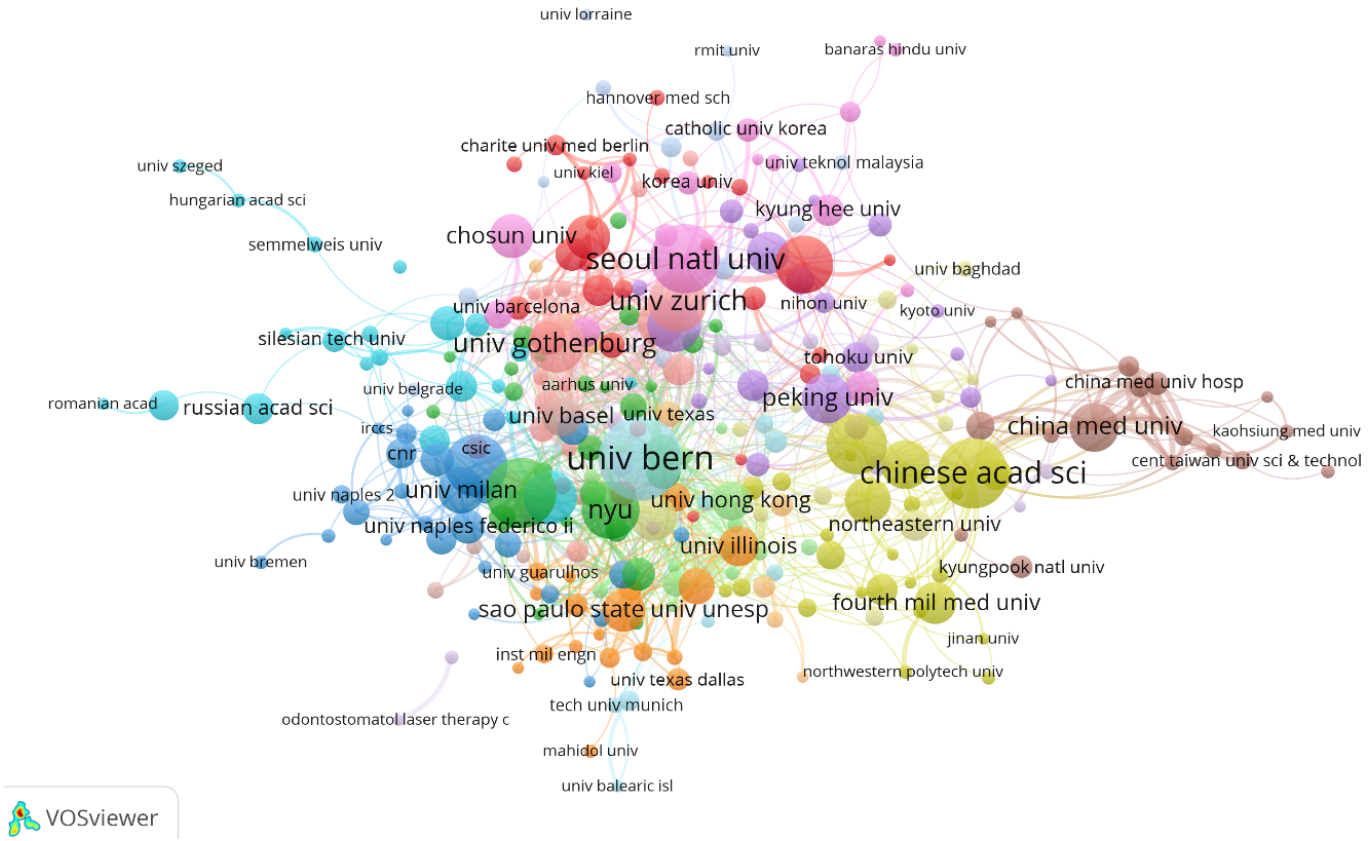

Figure 3. Organizations' co-authorship collaboration network.

Keyword Analysis and Emerging Trends

The keyword analysis revealed that the terms "implants" (901 occurrences), "titanium" (352), "osseointegration" (315), and "surface" (434) were the most frequently mentioned. Other notable keywords included "roughness" (182 occurrences) and "bioactivity" (119), indicating a focus on optimizing surface properties to enhance osseointegration and improve clinical outcomes. Emerging trends identified in the analysis encompassed "surface roughness," "nanotechnology," and "bioactive coatings," reflecting a growing interest in advanced materials and surface engineering techniques. The tree map visualization illustrated significant research interest in areas such as "peri-implantitis" (104 occurrences) and "mechanical properties" (145), which address critical clinical challenges. Additionally, the word cloud emphasized the prevalence of terms related to biological responses, material science, and clinical applications [Table 3; Figures 4-5].

Geographic Distribution of Research

The geographic distribution of research indicated that the United States, China, and Italy were the leading contributors, with 444, 455, and 282 publications, respectively. The United States also led in citation impact, accumulating a total of 19,868 citations, followed by China with 11,107 citations and Italy with 9,481 citations. Other notable contributors included Germany, which published 224 articles and received 11,116 citations, and Brazil, with 246 publications and 8,179 citations. International collaborations accounted for 28.93% of total publications, highlighting strong research ties between Europe, North America, and Asia. Switzerland and Sweden emerged as significant contributors relative to their size, illustrating the global nature of research in implant surface morphology [Figure 6; Table 4].

Table 4. Top 20 countries and institutions in the field of Implant Surface Morphology

#	Country	NOD	NOC	Institution	COI	NOD	NOC
1	USA	444	19868	University of Bern	Switzerland	57	5597
2	Germany	224	11116	University of Gothenburg	Sweden	35	3786
3	China	455	11107	University of California Los Angeles	USA	33	3419
4	Italy	282	9481	University of Zurich	Switzerland	37	3200
5	Switzerland	134	9337	Seoul National University	South Korea	45	2408
6	Brazil	246	8179	University of Michigan	USA	27	2150
7	South Korea	194	6572	Chinese Academy of Sciences	China	46	1996
8	Sweden	88	6245	New York University	USA	36	1399
9	Spain	179	5975	University of Gabriele d'Annunzio	Italy	40	1308
10	Japan	194	5058	University of Sao Paulo	Brazil	46	1273
11	France	68	4591	Peking University	China	30	1194
12	Australia	68	4048	Shanghai Jiao Tong University	China	29	1124
13	England	94	3412	Yonsei University	South Korea	36	936
14	Belgium	38	2819	Sichuan University	China	38	849
15	Netherlands	62	2520	University of Minho	Portugal	33	785
16	Canada	54	2215	King Saud University	Saudi Arabia	27	704
17	India	116	2098	University of Milan	Italy	27	682
18	Portugal	74	1905	International University of Catalonia	Spain	26	624
19	Taiwan	75	1824	China Medical University	China	29	548
20	Turkey	70	1798	Zhejiang University	China	27	381

NOD: number of documents; NOC: number of citations; COI: country of institute.

Figure 4. Keywords' word cloud mapping.

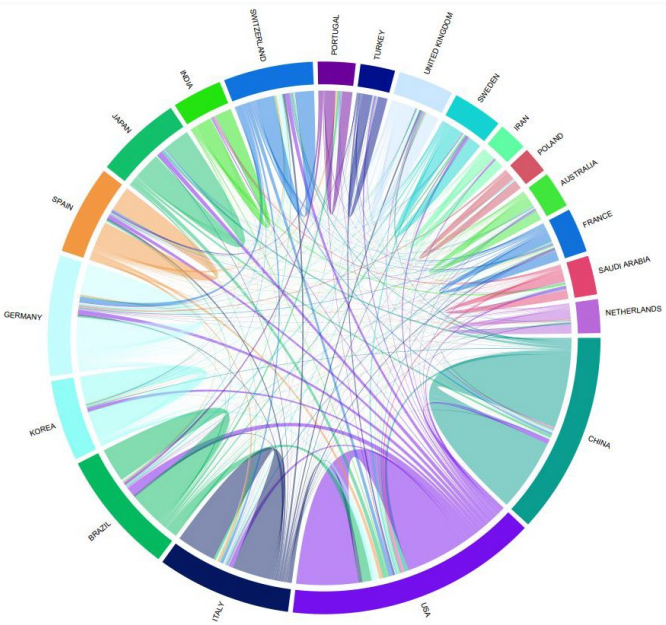

Figure 6. Countries' collaboration network

Figure 5. Keywords' tree map and percentage of occurrence.

Discussion

The bibliometric analysis of dental implant surface morphology reveals significant growth and development within this research field over the past two decades. The increasing number of publications, coupled with a rise in international collaborations and advancements in surface engineering, underscores the importance of this domain. As the demand for dental implants escalates -driven by aging populations and improved access to dental care- research focused on optimizing implant surfaces has become increasingly critical. The findings indicate a consistent emphasis on key themes such as

osseointegration, surface roughness, and material innovations, which reflect the central challenges and opportunities in implantology.

The steady increase in publications, particularly after 2010, signals technological advancements and a growing recognition of the essential role that surface morphology plays in the success of implants. Research output has been significantly propelled by innovations in materials science, including the development of nanostructured surfaces, bioactive coatings, and advanced fabrication techniques.[11,12] These surface modifications are designed to enhance biological responses, improve osseointegration, and mitigate complications such as peri-implantitis. For example, the transition from smooth to micro-rough and nano-textured surfaces has been demonstrated to significantly enhance implant stability and bone integration.[13-15] Furthermore, the sustained growth in publications reflects the multidisciplinary nature of this field, which integrates expertise from dentistry, medicine, materials science, biology, and engineering.[16,17]

The geographic distribution of research in dental implant surface morphology reveals notable trends and patterns in global contributions. The United States, for instance, has demonstrated a strong emphasis on advanced materials and nanotechnology, leading to significant innovations in the field. In Europe, countries such as Switzerland and Sweden have focused on clinical applications and long-term performance studies, reflecting their strengths in translational research. China's substantial contributions, particularly in recent years, indicate an increasing investment in the dental materials industry and a commitment to international collaborations.

The prominence of the United States, Germany, and Switzerland in dental implant research can be attributed to their leadership in implant manufacturing and the presence of renowned companies within these nations. These companies invest heavily in advancing implant technologies, including surface modifications, and collaborate closely with leading academic institutions. This synergy fosters high research output and innovation, particularly in surface technologies such as SLActive surfaces and advanced coatings that enhance osseointegration. The robust industrial presence not only drives technological advancements but also creates a feedback loop between manufacturers and researchers, accelerating the development of cutting-edge solutions in dental implantology.

A critical aspect highlighted in recent literature is the influence of implant surface morphology on cellular interactions that drive osseointegration and tissue integration. Modifications such as micro-roughening and nano-structuring significantly enhance the adhesion and proliferation of osteoblasts, contributing to faster and more robust bone integration.[18-20] Additionally, surface hydrophilicity plays a vital role in regulating protein adsorption and cellular attachment, both essential for the early stages of osseointegration. Advances in surface engineering techniques, such as laser treatment and acid etching, have been shown to create favorable topographies that mimic the natural extracellular matrix, further improving implant success rates. These findings underscore the importance of continued research into surface characteristics to optimize the biological and mechanical performance of dental implants.[21,22]

Emerging trends in the literature reveal promising opportunities for future research. The focus on nanotechnology, bioactive coatings, and additive manufacturing highlights a growing interest in innovative approaches to surface modification.[23,24] These technologies offer the potential to tailor implant surfaces to specific clinical needs, thereby enhancing their biological performance and durability. For example, bioactive coatings that release antimicrobial agents could address one of the most pressing challenges in implantology: peri-implantitis. However, while these innovations hold great promise, their long-term clinical effectiveness and safety must be thoroughly evaluated.[15,25] Future research should prioritize rigorous preclinical and clinical trials to establish evidence-based guidelines for their use. Additionally, addressing cost and scalability challenges will be essential for translating these technologies into widespread clinical practice.

Conclusions

The bibliometric analysis highlights the dynamic and evolving nature of research in dental implant surface

morphology. The consistent growth in publications, strong international collaborations, and emerging trends underscore the field's potential to address critical clinical challenges and enhance patient outcomes. However, to fully realize this potential, future research must prioritize the translation of laboratory innovations into clinical applications. It is essential to foster equitable contributions from underrepresented regions and address long-term performance and safety concerns associated with dental implants. By building upon the progress achieved thus far, researchers and clinicians can collaborate effectively to develop next-generation dental implants that offer improved performance, longevity, and patient satisfaction.

Acknowledgment

None.

Competing interests

The authors declare that they have no competing interests.

Abbreviations

Total Citations: TC; Number of Documents: NOD; Number of Citations: NOC; h-index: HI; g-index: GI; m-index: MI; Country of Institute: COI.

Authors' contributions

The author read and approved the final manuscript. He takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Role of the funding source

None.

Availability of data and materials

The data used in this study are available from the corresponding author on request.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

By submitting this document, the authors declare their consent for the final accepted version of the manuscript to be considered for publication.

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