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ORIGINAL ARTICLE

A Data Mining Analysis on Niobium in Dentistry: Promising Alloys for Dental Materials

Karla Lorene de França Leite[1], Millene de Oliveira Dias[1], Fernanda Oliveira Miranda Tavares[1], Kenderson Santos Silva[1], Ana Beatriz Chevitarese[1], Mariana Leonel Martins[1], Danielle Masterson[2], Livia Rodrigues de Menezes[3], Andrea Fonseca Gonçalves[1], Lucianne Cople Maia[1]

[1]Department of Pediatric Dentistry and Orthodontics, School of Dentistry, Federal University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil.
[2]Central Library of the Health Science Center, Federal University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil.
[3]Institute of Macromolecules Professor Eloisa Mano, Federal University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil.

Corresponding author: Karla Lorene de França Leite **E-mail:** karla.l.f.leite@gmail.com

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ABSTRACT

Objective: To investigate the trends of research on niobium (Nb) in dentistry to determine its use in dental materials. **Material and Methods:** Electronic searches were carried out in six databases. Studies that evaluated niobium alloys in dentistry in vitro, in situ, and in vivo (humans and animals) were included. Data on publication year, authors, country, journal, study design, application area, niobium alloy, study approach, assay type and results (positive, negative and null compared to controls) were grouped and analyzed in VantagePoint™ and Excel. Descriptive analyses of frequency, cross-tables and co-occurrence matrices were performed. **Results:** After screening, 315 studies published between 1977 and 2021 were included, with an increase in publications between 2011 and 2021 (n=209; 66.3%). "Doi, H" was the top author (n=9; 2.8%), and Brazil was the most productive country (n=70; 22.2%). "Dental Materials" was the major contributing journal (n=24; 7.6%), and most studies were carried out in vitro (n=266; 84.4%), under implant surfaces (n=162; 51.4%), followed by dental prostheses (n=77; 24.4%) and restorative materials (n=27; 8.6%). The most common niobium was a ternary alloy (n=147; 46.7%), which was mainly tested in vitro via structural characterization or material improvement (n=131; 41.6%). Mechanical assays (n=114; 36.2%) were the most prevalent. Positive effects of niobium were found in 264 articles (83.8%), and negative effects were found in 13 articles (4.1%). **Conclusion:** The number of studies on niobium has increased over time, resulting in improvements in the mechanical properties of materials used in dental practice.

Keywords: Niobium; Dentistry; Dental Materials; Bibliometrics.

Introduction

Niobium (Nb), atomic number 41, which has traditionally been used in manufacturing high-hardness materials, alloys and steels, is gaining increasing attention as a new metallic biomaterial for applications such as denture bases [1,2], dental implants [3,4], orthodontic appliances [5,6], endodontics [7,8] and dental materials [9,10]. Its use is associated with good mechanical properties, corrosion resistance, low cytotoxicity and poor biochemical compatibility, and it plays an important role in accepting niobium alloys as a substitute for other alloys in dentistry [1,3,5,7,9].

The development of new materials with different functionalities in dentistry has been increasing over the years. Considering the large number of applications of niobium due to its biocompatibility, high degree of mechanical strength and corrosion resistance, it would be meaningful to perform a bibliometric review of the history and trends of this chemical element to support researchers about what is necessary to advance in terms of new studies to provide scientific evidence about the clinical applicability of niobium. Thus, the purpose of the present study was to investigate the current state of research on niobium in dentistry to trace the use of this metal in dental materials.

Material and Methods

Eligibility Criteria

Published *in vitro*, *in situ* and *in vivo* studies were included. To be eligible, the studies should be performed in humans, animals and with any dental material (prosthetic device, orthodontic and restorative material, among others), treated with dental substances or materials containing niobium and/or having niobium in the composition compared with any other niobium-free dental material.

Exclusion criteria included studies that utilized niobium for purposes unrelated to dentistry and articles unavailable on digital platforms or case reports, literature reviews, editorials, and research letters and other studies that did not comply with the inclusion criteria.

Literature Search Strategy

One examiner, guided by a librarian, independently performed the searches for MeSH terms, free terms and Boolean operators (OR, AND), following the syntax rules of each database for the same data (Table 1). The following electronic databases were searched: MEDLINE via PubMed, Scopus and Embase/Elsevier, Web of Science/Clarivate Analytics, Cochrane Library, and Lilacs via VHL. Searches were performed up to August 2021 in a comprehensive manner, without any restrictions regarding the year or language of publication.

Table 1. Search strategy according to the different databases.

Database	Search	Date
PubMed [n=871]	(Niobium[Mesh] OR Niobium[all fields] OR Nb[all fields] OR NB2O5[all fields] OR Ti-6Al-7Nb[all fields] OR Ti-39Nb[all fields] OR Ti 38Nb 6Ta[all fields] OR Ti-35Nb-7Zr-5Ta[all fields] OR Ti-12.5Zr-3Nb-2.5Sn[all fields] OR Ti-35Nb-7Zr-5Ta[all fields] OR Ti-10Ta-2Nb-2Zr[all fields] OR Ti-28Nb-2Zr-8Sn[all fields] OR Ti-24Nb-4Zr-8Sn[all fields] OR Ti-25Nb-xHf[all fields] OR Ti-13Nb-13Zr[all fields] OR Ti-35.5Nb-5.7Ta[all fields] OR Ti-45Nb[all fields] OR Ti-24Nb-4Zr-8Sn[all fields] OR Ti6A17Nb[all fields] OR "Zr97.5Nb1.5VM"[all fields] OR "Ti-19.1Nb-8.8Zr"[all fields] OR Zr97.5Nb1.5Ta1.0[all fields] OR Zr97.5 Nb1.5VM1.0[all fields] OR TiNb[all fields] OR Ti-7Nb-6Al[all fields] OR TiAlNb[all fields] OR Ti-35Nb-xHf[all fields]) AND (Dentistry[Mesh] OR Dentistry[all fields] OR Dental Materials[Mesh] OR Dental Material*[all fields] OR Tooth[Mesh] OR Tooth[all fields] OR Dental Prostheses[all fields])	25.08.22
Scopus [n=524]	(INDEXTERMS(Niobium) OR ALL(Niobium OR Nb OR NB2O5 OR Ti-6Al-7Nb OR Ti-39Nb OR Ti 38Nb 6Ta OR Ti-35Nb-7Zr-5Ta OR Ti-12.5Zr-3Nb-2.5Sn OR Ti-35Nb-7Zr-5Ta OR Ti-10Ta-2Nb-2Zr OR Ti-28Nb-2Zr-8Sn OR Ti-24Nb-4Zr-8Sn OR Ti-25Nb-xHf OR Ti-13Nb-13Zr OR Ti-35.5Nb-5.7Ta	25.08.22

	OR Ti-45Nb OR Ti-24Nb-4Zr-8Sn OR Ti6A17Nb OR "Zr97.5Nb1.5VM" OR "Ti-19.1Nb-8.8Zr" OR Zr97.5Nb1.5Ta1.0 OR Zr97.5 Nb1.5VM1.0 OR TiNb OR Ti-7Nb-6Al OR TiAlNb OR Ti-35Nb-xHf)) AND (INDEXTERMS(Dentistry OR Dental Materials OR tooth) OR ALL(Dentistry OR Dental Material* OR Tooth OR Dental Prostheses))	
Cochrane Library [n=156]	#1 MeSH descriptor: [Niobium] explode all trees #2 (Niobium OR Nb OR NB2O5 OR Ti-6Al-7Nb OR Ti-39Nb OR Ti 38Nb 6Ta OR Ti-35Nb-7Zr-5Ta OR Ti-12.5Zr-3Nb-2.5Sn OR Ti-35Nb-7Zr-5Ta OR Ti-10Ta-2Nb-2Zr OR Ti-28Nb-2Zr-8Sn OR Ti-24Nb-4Zr-8Sn OR Ti-25Nb-xHf OR Ti-13Nb-13Zr OR Ti-35.5Nb-5.7Ta OR Ti-45Nb OR Ti-24Nb-4Zr-8Sn OR Ti6A17Nb OR "Zr97.5Nb1.5VM" OR "Ti-19.1Nb-8.8Zr" OR Zr97.5Nb1.5Ta1.0 OR Zr97.5 Nb1.5VM1.0 OR TiNb OR Ti-7Nb-6Al OR TiAlNb OR Ti-35Nb-xHf) #3 #1 OR #2 #4 MeSH descriptor: [Dentistry] explode all trees #5 MeSH descriptor: [Dental Materials] explode all trees #6 MeSH descriptor: [Tooth] explode all trees #7 (Dentistry OR Dental Material* OR Tooth OR Dental Prostheses) #8 #4 OR #5 OR #6 OR #7 #9 #3 AND #8	25.08.22
Web of Science (Core Collection) [n=456]	#1 TS=(Niobium OR Nb OR NB2O5 OR Ti-6Al-7Nb OR Ti-39Nb OR Ti 38Nb 6Ta OR Ti-35Nb-7Zr-5Ta OR Ti-12.5Zr-3Nb-2.5Sn OR Ti-35Nb-7Zr-5Ta OR Ti-10Ta-2Nb-2Zr OR Ti-28Nb-2Zr-8Sn OR Ti-24Nb-4Zr-8Sn OR Ti-25Nb-xHf OR Ti-13Nb-13Zr OR Ti-35.5Nb-5.7Ta OR Ti-45Nb OR Ti-24Nb-4Zr-8Sn OR Ti6A17Nb OR "Zr97.5Nb1.5VM" OR "Ti-19.1Nb-8.8Zr" OR Zr97.5Nb1.5Ta1.0 OR Zr97.5 Nb1.5VM1.0 OR TiNb OR Ti-7Nb-6Al OR TiAlNb OR Ti-35Nb-xHf) #2 TS=(Dentistry OR Dental Material* OR Tooth OR Dental Prostheses) #3 #1 AND #2	25.08.22
Embase [n=185]	('niobium'/exp OR niobium:af OR nb:af OR nb2o5:af OR 'ti 6al 7nb':af OR 'ti 39nb':af OR 'ti 38nb 6ta':af OR 'ti 12.5zr 3nb 2.5sn':af OR 'ti 35nb 7zr 5ta':af OR 'ti 10ta 2nb 2zr':af OR 'ti 28nb 2zr 8sn':af OR 'ti 25nb xhf':af OR 'ti 13nb 13zr':af OR 'ti 35.5nb 5.7ta':af OR 'ti 45nb':af OR 'ti 24nb 4zr 8sn':af OR ti6a17nb:af OR 'zr97.5nb1.5vm':af OR 'ti-19.1nb-8.8zr':af OR zr97.5nb1.5ta1.0:af OR 'zr97.5 nb1.5vm1.0':af OR tinb:af OR 'ti 7nb 6al':af OR tialnb:af OR 'ti 35nb xhf':af) AND ('dentistry'/exp OR 'dental material'/exp OR 'tooth'/exp OR dentistry:af OR 'dental material*':af OR tooth:af OR 'dental prostheses':af)	25.08.22
Lilacs (VHL) [n=31]	((mh: (niobium) OR niobium OR nb OR nb2o5 OR ti-6al-7nb OR ti-39nb OR "Ti 38Nb 6Ta" OR ti-35nb-7zr-5ta OR ti-12.5zr-3nb-2.5sn OR ti-35nb-7zr-5ta OR ti-10ta-2nb-2zr OR ti-28nb-2zr-8sn OR ti-24nb-4zr-8sn OR ti-25nb-xhf OR ti-13nb-13zr OR ti-35.5nb-5.7ta OR ti-45nb OR ti-24nb-4zr-8sn OR ti6a17nb OR "Zr97.5Nb1.5VM" OR "Ti-19.1Nb-8.8Zr" OR zr97.5nb1.5ta1.0 OR "Zr97.5 Nb1.5VM1.0" OR tinb OR ti-7nb-6al OR tialnb OR ti-35nb-xhf)) AND ((mh: (dentistry OR "Dental Materials" OR tooth) OR dentistry OR "Dental Material" OR "Dental Materials" OR tooth OR "Dental Prostheses")) AND (db:("LILACS"))	25.08.22

Selection Procedures

All the articles retrieved from the electronic databases of the search strategy were exported to reference manager software (Rayyan™), and duplicate articles were removed. Then, in the same software, the title and abstract of the remaining articles were read by two independent reviewers to select potentially eligible articles based on the eligibility criteria. If there was any disagreement between these two reviewers and no consensus was reached, a third reviewer was contacted to decide whether the study in question would be selected for full reading. Studies published in languages other than the ones of the authors of the present study were translated using the Google™ Translate Tool at https://translate.google.com.

Data Extraction

The reviewers, manually and independently, extracted the main study characteristics and, other two reviewers, organized the data on the VantagePoint™ software (Search Technology, Inc., Florida, USA) in the following categories: (1) year of publication; (2) authors; (3) journal title; (4) country; (5) study design; (6) keywords; (7) application area (tooth/restorative material/prothesis/implants/orthodontic appliances/radiographic filter/endodontic cements); (8) niobium alloy (free Nb/binary alloy/ternary alloy/quaternary alloy/quintenary alloy); (9) study approach (treatment/prevention/structural characterization or material improvement/treatment + structural characterization or material improvement/prevention + structural characterization or material improvement); (10) assay type

(mechanical/chemical/biological/mechanical + chemical/mechanical + biological/chemical + biological/mechanical + chemical + biological) and (11) application result (positive, null or negative in relation to negative control, placebo or other intervention).

Regarding the study approach, the treatment and prevention variables were only considered for *in vivo* studies when osseointegration, the expression pattern of inflammatory cytokines and biocompatibility tests were evaluated. When the *in vivo* studies evaluated structural characterization or material improvement, the study approach considered surface wear resistance, orthodontic tooth movement, physicochemical properties and bond strength. On the other hand, if the study was only *in vitro*, the variable named for the approach would be the structural characterization or material improvement.

To identify the effect and applicability of niobium on dental tissue or on organisms, data on the mechanical (hardness and flexibility, among others), chemical (corrosion resistance and degradation, among others) and biological (cytotoxicity and osseointegration, among others) properties of these dental materials were extracted.

A study was classified as positive when the group containing niobium had a better effect than the negative control, placebo, or other group that might be the gold standard; null when niobium had a similar effect as the negative control, placebo, or other group that might be the gold standard; and negative when niobium had a worse effect than the negative control, placebo, or another group that might be the gold standard.

Data Analyses

Data analyses were carried out in VantagePoint™ (Search Technology, Inc., Florida, USA) and Microsoft Office Excel 2010 (Microsoft™, USA). The values of frequency (absolute and relative) were calculated for all variables.

The studies' authors were classified according to the number of published articles (five or more), the top authors were represented on a donut chart, and the correlation between them, highlighting the partnership in publications, was demonstrated through a cross-correlation map, in which the thicker the line connecting these authors was, the greater the correlation between them. The absence of a line connecting one author to another indicates a lack of collaboration between them.

The study's country of origin was defined by the address provided in the manuscript, considering the corresponding author. The keywords cited in 15 or more articles, excluding the words from the search strategy, were sorted and mentioned in a word cloud. Data on the 2022 impact factors of the journals were collected from the Journal Citation Reports from Clarivate Analytics™.

The bubble chart represents the trends of the alloy type according to the year (represented by decade); thus, the larger the bubble is, the greater the number of published studies, in which different colored bubbles represent different clusters, and the size of the bubble is proportional to its frequency of occurrence.

Results

A search of the global literature resulted in the identification of 2223 articles, 1020 of which were duplicates. Thus, 1203 titles and abstracts were evaluated according to the eligibility criteria, and of these, 315 studies were selected for the final analyses (Figure 1). Among the excluded articles, 768 were excluded due to incorrect outcomes, 18 due to publication type and 102 because of study design.

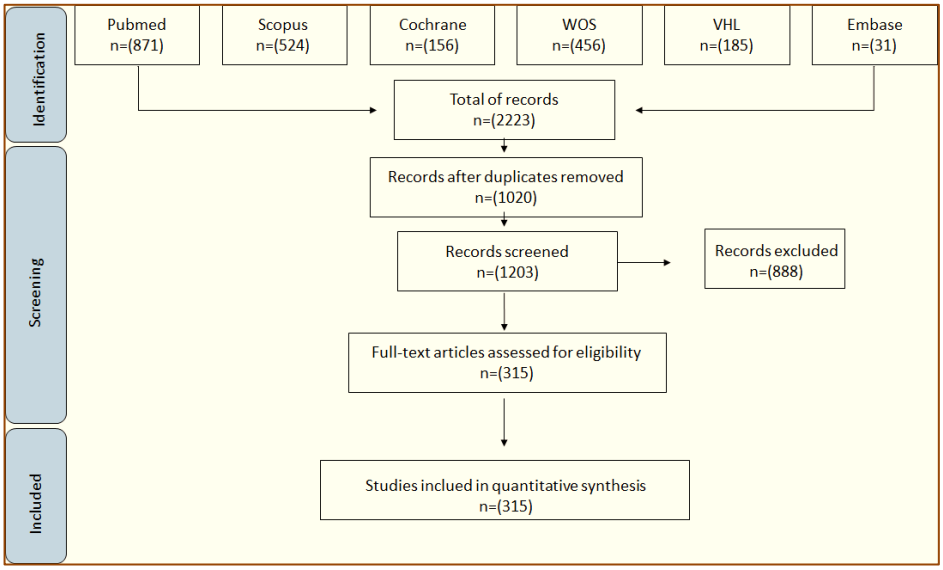

Figure 1. Flowchart of search results in databases.

Year of Publication, Authors, Journals and Countries

The studies were published between 1977 and 2021, with the largest number of publications occurring between 2011 and 2021 (n=209; 66.3%). An increase in the proportion of in vitro studies on implants and dental prostheses has been observed over the years. In turn, only restorative material was presented in studies from 2001 to 2021. Until the 2000s, no published studies on quaternary and quintenary alloys were published, showing that studies on these alloys are recent (Figures 2 a; b; c).

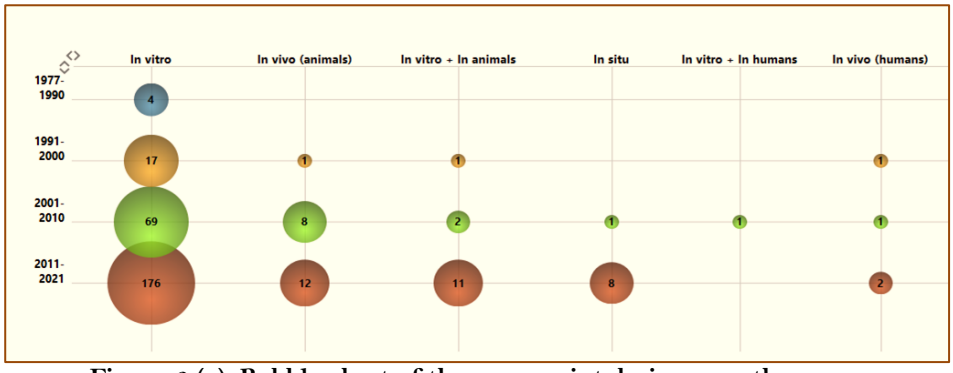

Figure 2 (a). Bubble chart of the manuscript design over the years.

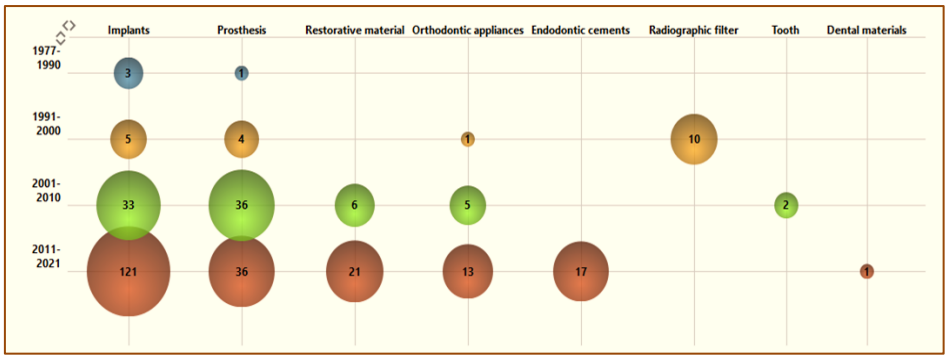

Figure 2 (b). Bubble chart of the application area where niobium was employed over the years.

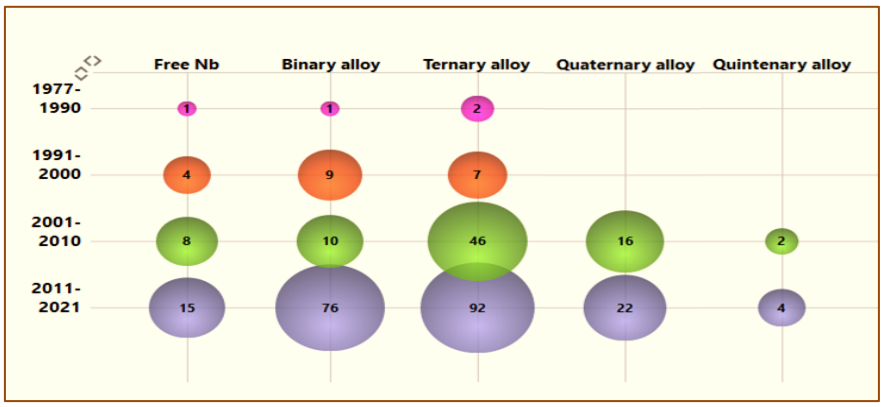

Figure 2 (c). Bubble plot of the niobium alloy over time.

The top authors with 5 or more published studies are shown in Figure 3. Doi, H. is the author with the most publications, followed by Yoneyama, T and Hanawa, T (Figure 4). Brazilian authors (n=6) were the majority within the top 10 authors with the most publications. The correlation between these top 10 authors shows that, in general, they have a strong partnership with each other.

The journal with the largest number of publications was Dental Materials (n=24; 7.6%), followed by the Journal of Materials Science (n=10; 3.2%) and the Journal of the Mechanical Behavior of Biomedical Materials (n=7; 2.2%) (Figure 3).

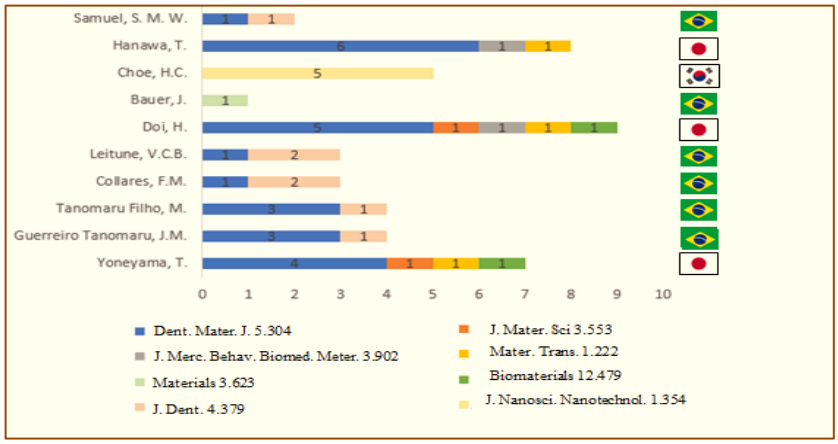

Figure 3. Frequency of studies according to the top authors' publications and the top journals in which they were published.

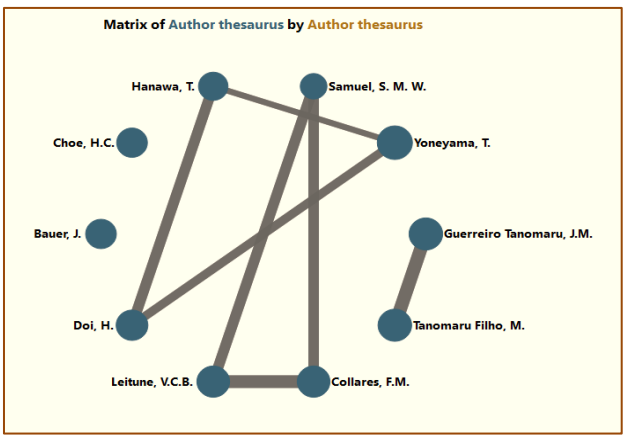

Figure 4. The correlation between the top 10 authors.

Brazil (n=70; 22.2%), Japan (n=62; 19.7%) and China (n=39; 12.4%) were the countries that published the most papers on the topic. Among the identified countries, 13 presented 5 or more studies carried out in their territory (Figure 5).

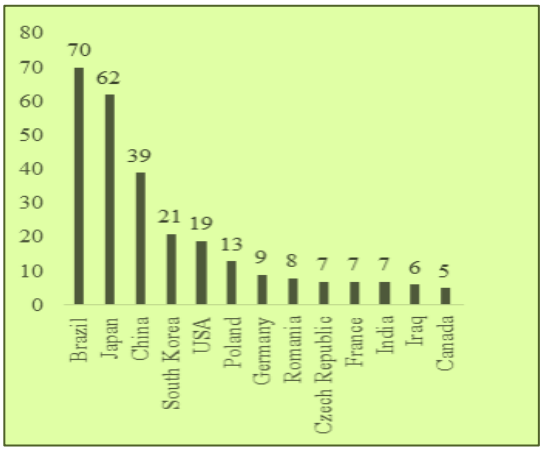

Figure 5. The countries with the largest number of publications.

Study Design, Keywords, Application Area

Most studies were in vitro (n=266; 84.4%), followed by studies in animals (n=21; 6.7%) and in vitro + studies in animals (n=14; 4.4%). Four studies were carried out in vivo (humans), showing a lack of these trials using niobium alloy (Figure 2 a).

Analysis of the most mentioned keywords revealed a diversity pattern because the most cited keywords were related to topics ranging from "titanium"/"materials testing"/"humans" and outcome assessment aspects such as "surface properties"/"corrosion"/"biocompatible materials" (Figure 6).

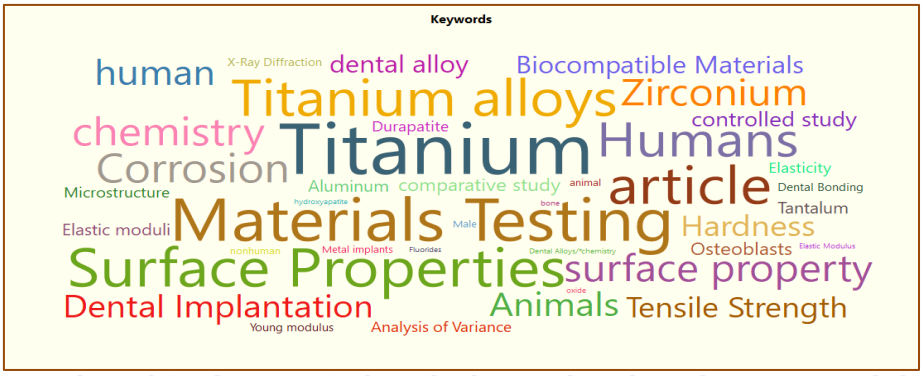

Figure 6. The word cloud for the most cited words, disregarding those that were included in the search key.

The most studied application areas were implants (n=162; 51.4%), followed by dental prostheses (n=77; 24.4%) and restorative materials (n=27; 8.6%). Few studies have evaluated tooth (n=2; 0.6%) and dental alginate (n=1; 0.3%). The details of the studies on restorative materials are described in the supplementary file.

Niobium Alloy, Study Approach, Assay Type and Result

Ternary alloys (n=147; 46.7%) were more prevalent among the included studies, mainly in vitro studies that evaluated structural characterization or material improvement (n=131; 41.6%). The second most prevalent alloy was binary alloys (n=96; 30.5%), followed by quaternary alloys (n=38; 12.1%) (Table 2).

Table 2. Niobium alloy used according to the application area and approach in the studies evaluated.

Variables	Niobium Alloy					
	Free Nb N	Binary N	Ternary N	Quaternary N	Quintenary N	Totals N
Application Area						
Implants	4	39	92	25	2	162
Restorative Material	12	12	-	2	1	27
Prosthesis	2	12	51	9	3	77
Orthodontic Appliances	-	14	3	2	-	19
Radiographic Filter	4	6	-	-	-	10
Endodontic Cements	3	13	1	-	-	17
Tooth	2	-	-	-	-	2
Totals	28	96	147	38	6	315
Study Approach						
Prevention	2	11	10	3	-	26
Prevention + Characterization*	-	2	6	1	-	9
Treatment	-	-	-	1	1	2
Characterization*	26	83	131	33	5	147
Totals	28	96	147	38	6	315

*Structural characterization or material improvement; (-)No studies were found.

The Ti-Nb-Zr (n=44; 14%), Ti-Nb (n=36; 11.4%), Ti-Nb-Zr-Ta (n=21; 6.7%) and Co-Cr-Nb-Mo-Zr (n=5; 1.6%) alloys were the most studied experimental groups according to the type of niobium alloy in the studies evaluated (Table 3).

Table 3. The most studied experimental groups according to the type of niobium alloy in the studies evaluated.

Binary Alloy	N	Ternary Alloy	N	Quaternary Alloy	N	Quintenary Alloy	N
Nb-Ta	2	Ni-Cr-Nb	4	Ni-Cr-Mo-Nb	2	Ti- Nb-Zr-Ta-Si	2
Nb-Al	6	Ni-Ti-Nb	2	Ti-Nb-Ta-Sn	1	Co-Cr-Nb-Mo-Zr	5
Nb-O	35	Ti- Nb-Zr	44	Ti-Nb-Zr-Mo	1		
Zr-Nb	9	Ti-Nb-Cu	3	Ti-Nb-Zr-Ta	21		
Ti-Nb	36	Ti-Nb-Sn	3	Ti-Nb-Zr-Sn	12		
Nb-Mo	2	Ti-Nb-Ta	12	Ti-Nb-Al-Zr	1		
Nb-Ag	1	Nb-Zr-Mo	1				
Zr-Nb	4	Ti-Al-Nb	78				

Mechanical assays (n=114; 36.2%) accounted for the majority of the assay type, and the combination of the three assays (mechanical + chemical + biological) was evaluated with positive results (n=16; 100%). Table 4 shows the main characteristics of each variable according to the results. Overall, positive results were found in 264 articles (83.8%), null results were found in 38 articles (12.1%), and negative results were found in 13 articles (4.1%).

Table 4. Results of the main variables for the niobium alloys.

Variables	Results			
	Negative N	Null N	Positive N	Totals N
Study Design				
in vitro	10	33	223	266
in vitro + in animals	1	1	12	14

in animals	-	3	18	21
in situ	1	2	6	9
in vitro + *in vivo* (humans)	-	-	1	1
in vivo (humans)	-	-	4	4
Totals	12	39	264	315
Application Area				
Implants	5	15	142	162
Restorative Material	2	11	59	72
Prosthesis	1	9	31	41
Orthodontic Appliances	3	2	14	19
Radiographic Filter	1	-	9	10
Endodontic Cements	-	1	8	9
Tooth	-	1	1	2
Totals	12	39	264	315
Niobium Alloys				
Free Nb	1	4	23	28
Binary Alloy	5	12	79	96
Ternary Alloy	6	19	122	147
Quaternary Alloy	-	3	35	38
Quintenary Alloy	-	1	5	6
Totals	12	39	264	315
Assay Type				
Mechanical	5	22	114	141
Chemical	2	6	25	33
Biological	1	5	40	46
Mechanical + Chemical	4	2	27	33
Mechanical + Biological	-	3	29	32
Chemical + Biological	-	1	13	14
Mechanical + Chemical + Biological	-	-	16	16
Totals	12	39	264	315

(-)No studies were found.

Discussion

Due to the absence of published articles on dental substances or materials containing niobium applied in dentistry, we found that it would be interesting to perform a data mining analysis by compiling all the articles that applied niobium alloys for prevention, treatment or structural characterization/materials improvement since 1977 until 2021. With the global upsurge in research on niobium alloys, extensive collaborations and publications have been noted among authors, institutions, and countries or regions. Research hotspots include dental implants, types of prostheses, restorative material, and properties of the materials or the techniques they were applied.

Dental Materials and the Journal of Materials Science were the two largest contributors to the research on niobium. They are also regarded as highly impactful journals in dentistry and for advancing materials science and chemical engineering research in other metric analyses [11]. The keywords might reflect the research focus, and in this analysis, "titanium", known for several attractive characteristics, such as biocompatibility, excellent corrosion resistance and high mechanical resistance, appeared as the keyword for Nb-related research with high frequency and impact and often served as a control material for niobium.

Most of the articles on niobium included in vitro studies, and few papers performed clinical assessments. Publications before 2010 mainly focused on the mechanical strength and microstructure, with researchers exploring the properties and potentials of Nb [12,13]. Since 2011, wear behavior, optical properties, and clinical survival analysis have become the emphasis of studies [14,15]. The most recent clinical data reported that combinations of metals in alloys incorporated into niobium can enhance its properties [16,17]. In the future,

studies with longer observation periods, which will provide valuable data on the long-term performance of niobium and clinical recommendations, should be conducted.

In the available literature, niobium products have attracted the attention of researchers. The long-term use of implants may lead to implant loosening and related complications, such as component failure and implant inflammation [18]. Titanium and its alloys have excellent mechanical and anti-corrosion properties as well as good biocompatibility, and they are regarded as the most suitable materials for biomedical applications. Nonetheless, this material undergoes electrochemical corrosion and represents a major challenge for metallic biomaterials [19]. Surface coatings have been successfully used to protect these materials; among these coatings, niobium is considered an additional element that has appropriate properties [20].

Cobalt-base alloys (Co-Cr-Mo) are widely employed in dentistry, but the release of these ions can influence cell viability and cause metal allergy and pigment metallic lesions in the oral cavity [21]. New elements are added to improve the composition of these alloys. Niobium is a highly passive metal due to its Nb_2O_5 protective oxide that covers its surface, and although there is no information available to date documenting its mutagenic potential, there are studies suggesting that some niobium compounds may have hypoallergenic and harmless properties [22].

Niobium alloys are promising for dental materials since the incorporation of this element has been of great interest due to its structural versatility and useful applications. Most dental devices are made of Ti alloys but do not have the same color as teeth, so they are inferior to ceramics and polymers in terms of aesthetic properties. However, in a previous study, Ti-29Nb-13Ta-4.6Zr was coated with a white Ti oxide layer by heat treatment to improve its aesthetic properties [17]. Moreover, the incorporation of niobium in dental adhesives has been a strategy for improving the radiopacity and physicochemical properties of polymers [23]. Tailoring the structure of these materials could contribute to their application in therapeutic strategies for dental restorations.

The present study revealed that niobium exhibits favorable mechanical, chemical, and biological properties; however, it is important to note that this conclusion lacks a comprehensive assessment of bias and the strength of evidence in the selected studies. In addition to having biological therapeutic effects, the niobium incorporated in bioactive glasses influences the structure and processability of the glass and confers additional functional properties [24]. In the literature, in terms of restoration, previous studies have evaluated the composition of the experimental powder modified by niobium and observed the formation of a polysalt matrix with good mechanical properties [25].

Niobium has become a promising material for dental restorative treatment and an essential dental research focus. This bibliometric analysis of niobium shows its research status and prospects for dental professionals and researchers, who are able to assist in the direction and development of future studies in this area.

Conclusion

The number of studies on niobium has increased over the years. Although this study suggested a positive impact of niobium on enhancing the mechanical properties of dental materials such as implants, dental prostheses, and restorative materials, it is essential to highlight that this conclusion lacks a comprehensive assessment of bias and the strength of evidence in the selected studies included in the review. However, more clinical trials are needed to confirm these effects since most studies have been carried out in in vitro models.

Authors' Contributions

KLFL	https://orcid.org/0000-0002-0113-6810	Conceptualization, Methodology, Investigation, Data Curation, Writing - Original Draft and Funding Acquisition.
MOD	https://orcid.org/0000-0003-0163-0146	Methodology, Data Curation, and Writing - Original Draft.
FOMT	https://orcid.org/0000-0001-9746-1708	Methodology, Investigation, Data Curation, and Writing - Original Draft.
KSS	https://orcid.org/0000-0001-8017-813X	Methodology, Data Curation, and Writing - Original Draft.
ABC	https://orcid.org/0000-0003-2140-7179	Conceptualization, Formal Analysis, and Writing - Original Draft.
MLM	https://orcid.org/0000-0001-6777-3225	Conceptualization, Data Curation, and Writing - Original Draft.
DM	https://orcid.org/0000-0001-7108-1117	Methodology and Writing - Original Draft.
LRM	https://orcid.org/0000-0003-1172-1199	Conceptualization, Methodology, Investigation, and Writing - Original Draft.
AFG	https://orcid.org/0000-0001-6467-7078	Conceptualization, Methodology, Formal Analysis, Data Curation, and Writing - Original Draft.
LCM	https://orcid.org/0000-0003-1026-9401	Conceptualization, Methodology, Formal Analysis, Investigation, Data Curation and Writing - Original Draft.

All authors declare that they contributed to a critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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