Methodological approaches for investigating links between dental and chronic diseases with claims data: A scoping study

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Abstract

Objectives: The purpose of this study was to provide an overview of methodological approaches to assess the relationship between dental diseases and other noncommunicable diseases on the basis of claims data.
Methods: Based on the methodological framework of Arksey and O'Malley, a scoping study was conducted. By searching electronic databases (PubMed, Web of Science, and LILACS), appropriate articles were identified. After extracting relevant information and entering it into a data-charting form, the study characteristics and the methodological approaches were summarized descriptively.
Results: Fifty-one articles were identified for inclusion in the analysis. Most of the selected studies (78 percent) originated from Taiwan and employed a cohort design. The majority of studies considered dental diseases, particularly periodontal disease (PD) measures, but no common standard was identified for the definition of PD. Unmeasured confounding, misclassification, and surveillance bias were reported to be the main limitations of the claims data analyses.
Conclusions: Claims data provide a very useful information source to further delineate the relationship between PDs and other noncommunicable diseases. If diagnostic codes are available, they seem to be the most suitable tool to assess PD in claims-based studies. In databases that do not contain dental diagnostic codes, e.g., databases in Germany and the United States, the identification of PD is a particular challenge. The inclusion of dental diagnostic codes in all claims databases is strongly recommended. Due to the public health relevance of PD, there is a need for more comprehensive documentation of dental parameters within claims data.

Introduction

To date, there is a large amount of empirical evidence indicating associations between dental parameters and other noncommunicable diseases. In particular, periodontal diseases (PD) are associated with diabetes, cardiovascular, and cerebrovascular diseases[1] – illnesses with a high disease burden.[2] There are indications that both general practitioners and other specialists and dentists do not sufficiently communicate this topic with their patients, and their respective collaboration with each other is limited and would benefit improvement.[3,4] One reason for this lack of communication might be a lack of insight into the causal pathways and uncertainty regarding the level of evidence of causal inference. Claims data can be a tool to analyze these associations. Claim codes are routinely collected for billing purposes and offer a large longitudinal data set for researchers.[5] The large sample size is particularly suitable for investigating conditions where the prevalence in a population is limited. A further main advantage of claims data is that they are free of

selection and recall bias. In many countries, claims data, in which dental records are included, are widely used in pharmacoepidemiology and health service research.[6,7] Nevertheless, the utility of claims data for analyzing associations between dental diseases and other noncommunicable diseases remains unclear.[5] A systematic review of the existing systematic reviews (umbrella review)[1] identified only three studies,[8–10] including each one claims-based study.

Considering this information, it seems useful to examine how dental diseases, particularly in relation to analyzing links with other noncommunicable diseases, are represented in claims data. This is important to better understand the suitability and added value of using such data for health service research. One specific concern appears to be that, other than for nondental diseases,[11] no validated or standardized framework is being used to accurately report and measure dental outcomes on the basis of claims data.

Accordingly, the aim of this study was to identify the methodological approaches of claims data analyses that investigate the relationships between highly prevalent dental diseases and other chronic diseases. Of particular interest are issues concerning the operationalization of dental diseases, particularly if no diagnostic codes are available. Scoping studies provide a suitable approach to analyze the range of research activity in a certain field,[12] especially when standard research procedures are lacking. The findings of this scoping study are intended to inform future data collection and analyses that aim to use claims data to examine interdependencies between dental diseases and other noncommunicable diseases.

Methods

This scoping study was conducted following the methodological framework of Arksey and O'Malley,[13] which comprises five stages.

In stage 1, the research questions guiding this scoping review were identified. In detail, they were as follows: (a) Until now, how many claims data analyses have been conducted investigating the relationships between dental and other chronic diseases? (b) What kind of study designs are being utilized? (c) How are dental diseases, including exposure and outcome, being operationalized? (d) What kind of limitations are reported when using administrative databases? A special focus on diabetes, cardiovascular, and chronic respiratory diseases, as they are chronic systemic conditions among others, that cause the most death and disability in Germany, and on three dental diseases with the highest disease burden (PD, tooth loss, caries) in Germany was established.[2,14]

To identify relevant articles, three electronic databases (PubMed, Web of Science, and LILACS) were searched in stage 2. The database search was performed in May 2018. The search strategy included terms about diabetes, cardio- or cerebrovascular, and chronic respiratory diseases as well as PD, caries, and tooth loss in addition to generic of dental and chronic disease terms. Furthermore, the search strategy contained terms related to claims data and health insurance (see Supporting Information S1). This search strategy was based on the approach of a recent umbrella review,[1] which examined links between highly prevalent dental diseases and other noncommunicable diseases. Additionally, the reference lists of the articles that were subjected to a full-text assessment were screened.

Stage 3 involved the study selection. All records identified through the database searches were recorded via the literature management program Endnote™ (Version X8.2, produced by Clarivate Analytics, previously Thomson Reuters). All duplicates were removed. Subsequently, two reviewers (KB, IS) independently screened the titles and abstracts of the articles and excluded all studies that did not meet the inclusion criteria. Studies were included if (a) they were published in English; (b) they focused on dental diseases or treatments and chronic diseases; and c) they analyzed claims data. Reviews and commentaries were excluded. Following title/abstract screening, the full texts of the remaining studies were independently screened by the two researchers (KB, IS). Disagreements in the assessment were resolved through consensus between reviewers.

In stage 4, a data-charting form was developed and included (a) the characteristics of the studies (author, year, country, study design, aim, and dental/chronic disease) and (b) the details of the methodology (database, exposure, outcome, covariates, statistic, and limitations). All relevant information was extracted and compiled by the two reviewers (KB, IS).

Stage 5 involved a descriptive numerical summary of the characteristics of the studies and the methodological approaches extracted in stage 4.

Results

The flow diagram of the literature search/screening is shown in Figure 1. A total of 231 records were found through database searches. Twelve articles were excluded because they were published in a non-English language. After removing duplicates and applying the inclusion and additional exclusion criteria for the assessment of the articles, 51 records were included for information synthesis. The publication dates of the included articles ranged from 2010 to 2018. Table 1 shows the databases used by the various studies. A total of 78 percent (n = 40) of the records originated from Taiwan and were based on subsamples of the National Health Insurance Research Database (NHIRD). Furthermore, five records were from the United States, four were from Korea, and one each was from Denmark and Japan.

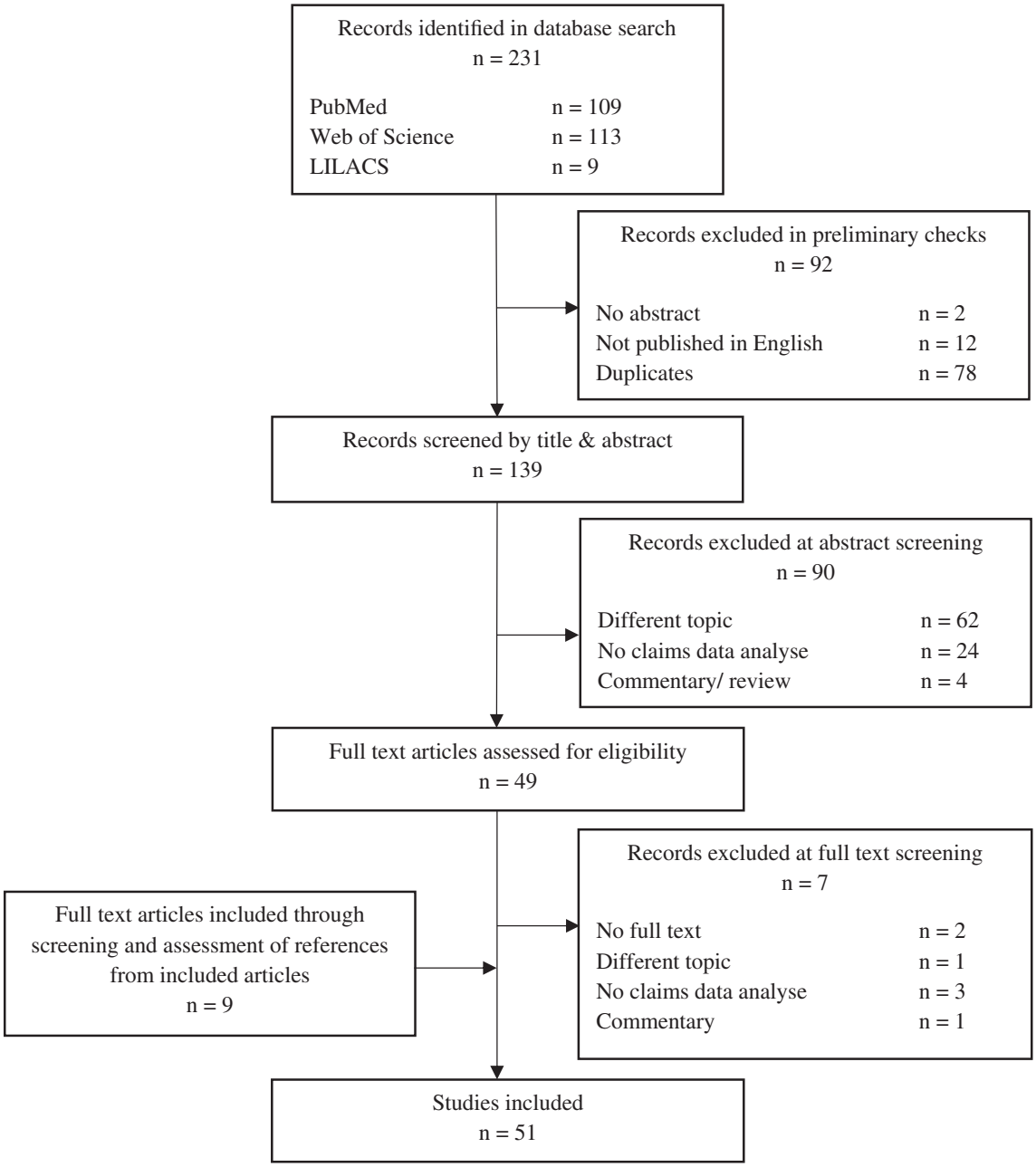

Figure 1 Flow chart of article selection.

All extracted study characteristics are presented in the Supporting Information (see supplement S2). A total of 74 percent (n = 38) of all included studies applied a cohort design.[15–46,55,58–60,62,63] In addition, seven studies reported a case–control design,[47,49–54] five studies reported a cross-sectional,[56,57,61,64,65] and one study a case-crossover design.[48] Two studies[61,64] reported a cohort design, but because the exposure and outcome variables were collected over the same time period and no time-related reference could be made, these studies were classified as cross-sectional designs. Additionally, in one study,[60] a cohort and a case–control design were utilized. Because the case–control study was carried out as a sensitivity analysis, the study was classified as a cohort design.

With respect to the aims of the studies, the following distinctions were found among the examined articles (see Supporting Information S2):

1. Thirty-one (61 percent) studies analyzed dental aspects as exposures and chronic diseases as outcomes.[15,17,18,20–25,27,30–38,44–53,62,63]

Table 1 Countries and Databases of All Records Included

Country	Database	*n*	Records
Taiwan	National Health Insurance Research Database (NHIRD) incl. different subsets like Longitudinal Health	40	15–54
n = 40 (78%)	Insurance Database 2000, 2005, 2010 and Registry of Catastrophic Illness Database (RCID)		
United States	Washington Dental Service (WDS) and Group Health Cooperative (GH)	3	55–57
n = 5 (10%)	United Concordia Companies, Inc (UCCI, Harrisburg PA) and Highmark, Inc (Pittsburgh PA)	1	58
	Truven Health MarketScan® Research Database	1	59
Denmark	Danish National Patient Register	1	60
n = 1 (2%)			
Korea	National Health Insurance Service-National Sample Cohort (NHIS-NSC)	1	61
n = 4 (8%)	National Health Insurance Service-Health Examinee Cohort (NHIS-HEC)	2	62,63
	Korean National Health Insurance Cohort Database (KNHICD)	1	64
Japan	Mie Prefecture	1	65
n = 1 (2%)			

2. Eight studies (16 percent) considered chronic diseases as exposures and dental outcomes.[16,28,29,40,43,54,55,60]
3. Seven (12 percent) studies investigated dental diseases or treatment effects during the course of a chronic disease.[19,26,39,41,42,58,59] The effects on the course of disease were measured as follows: (a) deterioration of the disease[26,41,42] or other chronic conditions,[19,39] (b) total all-cause or nondental medical costs,[58,59] (c) total all-cause or disease-related healthcare costs,[59] and (d) number of hospitalizations.[58]

Five studies could not be assigned to one of the areas listed above as they were based on a cross-sectional design.[56,57,61,64,65]

Table 2 shows the type of dental health measures used in the various studies. Regarding dental health problems, three main factors were identified: PD, root canal treatment and dental care utilization. Root canal treatment was investigated in only one article.[36] Eighty-six percent (n = 44) of all studies focused on PD or treatments. In 39 studies, dental diagnostic codes for PD were accessible. Most of these studies defined PD solely on the basis of the diagnosis (n = 20) or in combination with periodontal treatments (n = 17). In a few studies, the periodontal diagnosis was combined with antibiotic therapy, periodontal treatment, and/or dental scaling. Five studies used periodontal treatment alone for the identification of PD. In this regard, it must be taken into account that four of these

Table 2 Operationalization of Dental Diseases or Treatments

Topic	Operationalization	*n*	Records
Periodontal disease	Diagnosis of PD	20	15–18,24,25,27–29,38,40,44,45,49,50,52,60,62–64
(*n* = 44, 86%)	Diagnosis of PD AND periodontal treatment	17	22,26,30–34,37–39,41–43,49,50,54,61
	Periodontal treatment	5	46,56–59
	Diagnosis of PD AND antibiotic therapy OR periodontal treatment (other than DS) OR DS ≥3 times per year	3	23,35,47
	Diagnosis of PD AND antibiotic therapy OR DS ≥3 times per year	1	53
	Diagnosis of PD AND antibiotic therapy OR periodontal treatment other than DS	1	19
	(a) ≥ 1 diagnosis of PD AND receiving antibiotic therapy OR periodontal treatment simultaneously (b) dental visits with PD diagnosis ≥3 times AND concurrent DS within 1 year	1	18
Root canal treatment (*n* = 1, 2%)	Root canal treatment	1	36
Dental care utilization	Use of dental service	6	20,21,48,51,55,65
(*n* = 6, 25%)	(overall/a specific service)		
	Frequency of dental visits (overall/a specific service)	4	21,51,55,65

Articles can be allocated to several categories.
PD: periodontal disease; DS: dental scaling.

Table 3 Limitations Due to the Use of Claims Data

Limitations	*n* (%)	Records
Unmeasured confounding	44 (86)	15–23,26–32,34–50,52–60,64,65
No lifestyle factors	35	15,17–23,26–32,34,36–47,49,50,52,53,57,60,64
No/little laboratory/clinical parameters	17	16,18,19,23,35,36,40–44,48,52,53,58,59
No family history	16	21,27,28,31,32,34–38,40–42,45,49,65
No socioeconomic status	12	17,20,22,32,35,40,41,44,45,57,59,65
No environmental/occupational exposures	7	27,28,40,41,46,49,52
No number of teeth	4	35,46,55,57
No race/ethnicity	3	56,57,59
Nondocumented comorbidities (e.g., silent MI)	3	20,31,38
No data about use of medications	2	50,57
No genetic factors	2	35,44
No treatment information	2	44,54
Misclassification bias	34 (67)	16,18–23,26–28,31,33–35,38,40–43,45–53,56,57,59,60,62,63
No periodontal disease severity	15 (29)	18,24,25,35,37,39–42,45,53,55,61,62,65
Surveillance/detection bias	8 (16)	15,23,27,28,43,49,54,60
Generalizability of results	6 (12)	21,24,38,41,52,65
No dental diagnosis data	2 (4)	58,59

Articles can be allocated to several categories.
MI: Myocardial infarction.

five studies were from the United States, where no dental diagnostic codes were available in the claims database.[56–59] A total of 25 percent (n = 6) of the studies focused on dental care utilization. In all of these studies, a dichotomous variable was used for measuring the utilization of any or a specific dental service. Additionally, in some of these studies, the number of dental visits was used to describe the association between oral health and chronic disease.[21,51,55,65] Dental caries, as a common dental disease, was explicitly mentioned in only one of these studies measuring the frequency of dental visits for special dental conditions.[51]

A wide range of chronic diseases is considered in the studies (see Supporting Information S2). One of the most investigated chronic diseases was diabetes (n = 11).[19,37,39,55–59,63–65] In five of these studies, diabetes patients formed the study population.[19,39,57–59] Furthermore, in addition to cardiovascular events, other chronic diseases, such as ankylosing spondylitis, depression and hearing loss, were examined.

Table 3 shows the reported methodological limitations when using claims data. As claims data are routinely collected for billing and not for research purposes, several substantial limitations related to administrative databases were mentioned in the records. A frequently raised issue was unmeasured confounding (n = 44). Most commonly cited was missing information about lifestyle factors (n = 35), laboratory or clinical data (n = 17), as well as family history (n = 16). In particular, smoking was identified as a major risk factor for periodontitis and many noncommunicable diseases.[27,31,40,41,55,60] Chang et al.[15] considered smoking and alcohol consumption in their analyses by including chronic obstructive pulmonary diseases (COPD) and alcohol-related conditions as surrogate parameters. To establish smoking status, Egeberg et al.[60] used a previously developed algorithm combining drug prescriptions for smoking cessation, diagnoses of smoking, tobacco use or lung diseases, and treatments that support smoking cessation.[66] As a result, residual confounding due to an imperfect proxy or unmeasured confounding could not be ruled out.[15,21,36,44] To avoid these limitations, only one study combined primary and secondary data. In this case, lifestyle habits were collected by self-administered questionnaires.[65]

Some studies mentioned that clinical or laboratory data were needed to detect the precise PD severity.[23,43,52,53] Fifteen articles were identified in which the lack of PD severity was a named restriction. Eight studies attempted to specify the severity of PD using different indicators. These included classifications by the number of periodontitis-related dental visits[15,23,47,53] or their cumulative costs,[23,47,53] a combination of a periodontal diagnosis with different types of treatments,[22,37,38,43] as well as the presence of receipts for periodontal surgery[23,47] or antibiotics.[23] In regard to operationalizing the severity by different types of treatments, no consistent approach could be detected.

The second most frequently mentioned limitation was nondifferential misclassification bias (n = 34). To strengthen the validity of the PD diagnosis, in nine studies, PD was defined as having at least two or three diagnostic codes in the medical files.[27,28,41,44,45,49,50,52,62] Six studies recommended combining periodontal diagnostic codes and treatments to minimize miscoding errors.[19,31,32,34,42,58] Newton et al.[56] described periodontal care as an appropriate

proxy for PD because of a high sensitivity, even though the specificity was low. Patients with a dental or chronic disease who do not seek medical care or did not receive a diagnosis can be misclassified as controls.[22,26,34,35,48,50] Nevertheless, most of the studies concluded that the misclassification would underestimate the observed relationships. Eight articles indicated that the usage of claims data can lead to medical surveillance bias. Patients who underwent more medical visits have a higher probability of receiving a dental disease or other noncommunicable disease diagnosis.

Finally, six studies explicitly noted the unclear generalizability of their results to other populations. Most of these studies were conducted in Taiwan and based on the NHIRD; therefore, only a single ethnic population was included in the analysis. The authors stated that the results may not be representative of other ethnic groups.[21,24,38,41,52]

Discussion

This scoping study offers an overview of the different methodological approaches for investigating the relationships between dental diseases and other chronic diseases with claims data. To the best of our knowledge, this is the first review of this kind. Fifty-one studies were included in the present analysis, and their main focus was on PD. Although dental diagnostic codes were used to operationalize PD in 39 studies, no common standard was found for the definition of PD within the claims data. To allow for better comparisons between studies, an international standardized definition of dental diseases by claims data is recommended.

PD was mainly defined by diagnostic codes or in combination with periodontal treatments. In a few studies, the usage of diagnostic and treatment codes was recommended to reduce misclassification bias. When combining the documentation of diagnosis with the utilization of services to define a study population, one has to control how this combination might lead to unwanted selections within the population (e.g., severity of PD) and influence the chosen outcomes of the study. Accordingly, the operationalization of PD by dental diagnostic codes can only be classified as mostly feasible for claims-based studies. To validate the diagnosis of a patient, at least two recorded diagnostic codes are recommended.

Dental caries, as a common dental disease, were rarely included in the studies. However, the association between caries and diabetes is commonly discussed in the literature.[1] In general, dental diseases could be defined by International Classification of Diseases (ICD) codes, and in 39 studies, ICD codes were available for defining PDs. Therefore, it remains unclear why caries have not been investigated with claims data until now. The operationalization of other dental diseases by claims data requires further investigation.

In Germany, access to dental care data for research purposes started in 2009, which was much later than all other health-care sectors.[67] Similar to the United States, dental diagnostic codes are not available in Germany. This review demonstrates that in this case, periodontal treatments were used as a proxy with the restriction of possible misclassification errors. Moreover, unmeasured confounding and surveillance bias were highlighted as important limitations of claims data analyses. In particular, lifestyle factors such as smoking or alcohol consumption are difficult to operationalize. Indirect adjustment by using diagnostic codes for alcohol-related conditions or smoking-related diseases can lead to residual confounding. Only persons with high rates of alcohol consumption or smoking who seek treatment and visit a doctor can be detected by claims data. Consequently, as demonstrated by one study, lifestyle questionnaires can constitute a useful supplement to claims data analysis but require data linkage. In addition, clinical information is not routinely stored in claims databases. Clinical data not only provide an internal validation of a documented diagnosis but also an assessment of disease severity.[68] When information on severity was not available in the claims data, the study authors applied proxies related to the number of periodontitis-related visits or their cumulative costs, as well as the combination of periodontal diagnosis and different types of treatments, in particular. In addition to modifying ICD codes by including disease severity, linking claims data to individual patient records would also enhance these studies.

The type of study design was not part of the research question, but it was described as a relevant study characteristic of the included articles. In most of the studies in this review, a cohort design, which is known as the "gold standard" for observational studies, was used.[69] Claims data offer a longitudinal dataset that enables the depiction of a temporal relation and the guidance of a possible causal relationship. Despite the limitation of low evidence, cross-sectional studies were also included in this scoping review to provide an overview of the methods used to assess dental diseases in claims data.

Some caution should be applied when interpreting the findings from the present study. More than half of the studies included were conducted in Taiwan and used the same research database. Accordingly, similar methods were utilized. In addition, only three electronic databases (MedLine, Web of Science, and LILACS) were searched. It is possible that we missed relevant articles included in other databases. To reduce this risk, we checked the references of the included studies for additional publications. In addition, the search was limited to English articles. A total of 12 out of 231 identified studies were published in a

language other than English. The selection bias was considered to be low.

In conclusion, claims data provide a very useful and promising information source to further delineate the relationship between periodontal and noncommunicable diseases. The investigation of other dental diseases with claims data is lacking and needs to be studied. However, the absence of a standardized validated operationalization procedure for dental diseases in claims data is a significant restriction. If diagnostic codes are available, they seem to be most suitable to assess PD in claims-based studies. In this case, one particular challenge is the lack of diagnostic codes for dental diseases, especially for PD, in some countries such as Germany and the United States. We highly recommend the storage of dental diagnostic codes by all health insurance systems. To achieve this goal in Germany, as an example, statutory health insurances and health service researchers as well as other actors dealing with oral health prevention should try to convince the ministry of health to establish the transmission of dental diagnostic codes for billing purposes, as is common practice in disease reporting by other physician groups. In addition, dental codes in administrative data can be used in national surveillance systems to monitor the oral health of the population. Overall, there is a need for a more comprehensive and more standardized measurement of dental parameters within claims data.

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References

1. Seitz MW, Listl S, Bartols A, Schubert I, Blaschke K, Haux C, van der Zande MM. Current knowledge regarding links between highly prevalent dental and chronic diseases: an umbrella review. *Prev Chronic Dis*. 2018.
2. Institute for Health Metrics and Evaluation. Global Burden of Disease (GBD) 2016. Available from: http://www.healthdata.org/germany.
3. Holzinger F, Dahlendorf L, Heintze C. 'Parallel universes'? The interface between GPs and dentists in primary care: a qualitative study. *Fam Pract*. 2016;**33**(5):557-61.
4. Elangovan S, Hertzman-Miller R, Karimbux N, Giddon D. A framework for physician-dentist collaboration in diabetes and periodontitis. *Clin Diabetes*. 2014;**32**(4):188-92.
5. Strom BL. Overview of automated databases in Pharmacoepidemiology. In: Strom BL Kimmel SE , editors *Textbook of Pharmacoepidemiology*. Chichester, England: John Wiley & Sons, Ltd; 2006. p. 167-71.
6. Elseviers M, Wettermark B, Almarsdóttir AB, Andersen M, Benko R, Bennie M, Eriksson I, Godman B, Krska J, Poluzzi E, Taxis K, Vlahovic-Palcevski V, Vander Stichele R, editors. *Drug utilization research: methods and applications*. Chichester (West Sussex, UK), Hoboken (NJ): Wiley-Blackwell; 2016.
7. Leake JL, Werneck RI. The use of administrative databases to assess oral health care. *J Public Health Dent*. 2005;**65**(1):21-35.
8. Martin-Cabezas R, Seelam N, Petit C, Agossa K, Gaertner S, Tenenbaum H, Davideau JL, Huck O. Association between periodontitis and arterial hypertension: a systematic review and meta-analysis. *Am Heart J*. 2016;**180**:98-112.
9. Ungprasert P, Wijarnpreecha K, Wetter DA. Periodontitis and risk of psoriasis: a systematic review and meta-analysis. *J Eur Acad Dermatol Venereol*. 2017;**31**(5):857-62.
10. Zeng XT, Xia LY, Zhang YG, Li S, Leng WD, Kwong JS. Periodontal disease and incident Lung cancer risk: a meta-analysis of cohort studies. *J Periodontol*. 2016;**87**(10):1158-64.
11. Schubert I, Ihle P, Koster I. Interne Validierung von Diagnosen in GKV-Routinedaten: Konzeption mit Beispielen und Falldefinition. *Gesundheitswesen*. 2010;**72**(6):316-22.
12. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implement Sci*. 2010;**5**:69.
13. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol*. 2005;**8**(1):19-32.
14. Marcenes W, Kassebaum NJ, Bernabé E, Flaxman A, Naghavi M, Lopez A, Murray CJL. Global burden of oral conditions in 1990-2010:a systematic analysis. *J Dent Res*. 2013;**92**(7):592-7.
15. Chang JS, Tsai CR, Chen LT, Shan YS. Investigating the association between periodontal disease and risk of pancreatic cancer. *Pancreas*. 2016;**45**(1):134-41.
16. Chang WP, Chang WC, Wu MS, Pai JT, Guo YC, Chen KC, Liu ME, Chiu WT, Hung KS. Population-based 5-year follow-up study in Taiwan of osteoporosis and risk of periodontitis. *J Periodontol*. 2014;**85**(3):e24-30.
17. Chen CK, Wu YT, Chang YC. Association between chronic periodontitis and the risk of Alzheimer's disease: a retrospective, population-based, matched-cohort study. *Alzheimers Res Ther*. 2017;**9**(1):56.
18. Chen DY, Lin CH, Chen YM, Chen HH. Risk of atrial fibrillation or flutter associated with periodontitis: a Nationwide, population-based. *PLoS One*. 2016;**11**(10):e0165601.
19. Chen HH, Chen DY, Lin SY, Lai KL, Chen YM, Chou YJ, Chou P, Lin CH, Huang N. Periodontitis exposure within one year before anti-diabetic treatment and the risk of rheumatoid arthritis in diabetes mellitus patients: a population-based cohort study. *Rev Bras Reumatol*. 2014;**54**(2):124-30.

20. Chen SJ, Liu CJ, Chao TF, Wang KL, Chen TJ, Chou P, Wang FD, Lin SJ, Chiang CE. Dental scaling and atrial fibrillation: a nationwide cohort study. *Int J Cardiol*. 2013; **168**(3):2300-3.
21. Chen ZY, Chiang CH, Huang CC, Chung CM, Chan WL, Huang PH, Lin SJ, Chen JW, Leu HB. The Association of Tooth Scaling and Decreased Cardiovascular Disease: a Nationwide population-based study. *Am J Med*. 2012;**125** (6):568-75.
22. Chou SH, Tung YC, Lin YS, Wu LS, Lin CP, Liou EJW, Chang CJ, Kung S, Chu PH. Major adverse cardiovascular events in treated periodontitis: a population-based follow-up study from Taiwan. *PLoS One*. 2015;**10**(6):e0130807.
23. Chou YY, Lai KL, Chen DY, Lin CH, Chen H. Rheumatoid arthritis risk associated with periodontitis exposure: a Nationwide, population-based cohort study. *PLoS One*. 2015;**10**(10):e0139693.
24. Hsu CC, Hsu YC, Chen HJ, Lin CC, Chang KH, Lee CY, Chong LW, Kao CH. Association of periodontitis and subsequent depression: a nationwide population-based study. *Medicine (Baltimore)*. 2015;**94**(51):e2347.
25. Hu JM, Shen CJ, Chou YC, Hung CF, Tian YF, You SL, Chen CY, Hsu CH, Hsiao CW, Lin CY, Sun CA. Risk of colorectal cancer in patients with periodontal disease severity: a nationwide, population-based cohort study. *Int J Colorectal Dis*. 2018;**33**(3):349-52.
26. Huang ST, Lin CL, Yu TM, Wu MJ, Kao CH. Intensive periodontal treatment reduces risk of infection-related hospitalization in Hemodialysis population: a Nationwide population-based cohort study. *Medicine (Baltimore)*. 2015; **94**(34):e1436.
27. Keller JJ, Lin HC. The effects of chronic periodontitis and its treatment on the subsequent risk of psoriasis. *Br J Dermatol*. 2012;**167**(6):1338-44.
28. Keller JJ, Wu CS, Lin HC. Chronic rhinosinusitis increased the risk of chronic periodontitis: a population-based matched-cohort study. *Laryngoscope*. 2013;**123**(6):1323-7.
29. Lee CF, Lin MC, Lin CL, Yen CM, Lin KY, Chang YJ, Kao CH. Non-apnea sleep disorder increases the risk of periodontal disease: a retrospective population-based cohort study. *J Periodontol*. 2014;**85**(4):e65-71.
30. Lee CF, Lin CL, Lin MC, Lin SY, Sung FC, Kao CH. Surgical treatment for patients with periodontal disease reduces risk of end-stage renal disease: a nationwide population-based retrospective cohort study. *J Periodontol*. 2014;**85**(1):50-6.
31. Lee YL, Hu HY, Huang N, Hwang DK, Chou P, Chu D. Dental prophylaxis and periodontal treatment are protective factors to ischemic stroke. *Stroke*. 2013;**44**(4):1026-30.
32. Lee YL, Hu HY, Chou P, Chu D. Dental prophylaxis decreases the risk of acute myocardial infarction: a nationwide population-based study in Taiwan. *Clin Interv Aging*. 2015;**10**:175-82.
33. Lee YL, Hu HY, Huang LY, Chou P, Chu D. Periodontal disease associated with higher risk of dementia: population-based cohort study in Taiwan. *J Am Geriatr Soc*. 2017;**65**(9): 1975-80.
34. Lee YL, Hu HY, Yang NP, Chou P, Chu D. Dental prophylaxis decreases the risk of esophageal cancer in males; a nationwide population-based study in Taiwan. *PLoS One*. 2014;**9**(10):e109444.
35. Lee YT, Lee HC, Hu CJ, Huang LK, Chao SP, Lin CP, Su ECY, Lee YC, Chen CC. Periodontitis as a modifiable risk factor for dementia: a Nationwide population-based cohort study. *J Am Geriatr Soc*. 2017;**65**(2):301-5.
36. Lin PY, Chien KL, Chang HJ, Chi LY. Unfinished root canal treatments and the risk of cardiovascular disease. *J Endod*. 2015;**41**(12):1991-6.
37. Lin SY, Lin CL, Liu JH, Wang IK, Hsu WH, Chen CJ, Ting IW, Wu IT, Sung FC, Huang CC, Chang YJ. Association between periodontitis needing surgical treatment and subsequent diabetes risk: a population-based cohort study. *J Periodontol*. 2014;**85**(6):779-86.
38. Mau LP, Kuan YC, Tsai YWC, Lin JJ, Huynh-Ba G, Weng PW, Shieh YS, Cheng WC, Huang RY. Patients with chronic periodontitis present increased risk for osteoporosis: a population-based cohort study in Taiwan. *J Periodontal Res*. 2017;**52**(5):922-9.
39. Peng CH, Yang YS, Chan KC, Kornelius E, Chiou JY, Huang CN. Periodontal treatment and the risks of cardiovascular disease in patients with type 2 diabetes: a retrospective cohort study. *Intern Med*. 2017;**56**(9):1015-21.
40. Shen TC, Chang PY, Lin CL, Chen CH, Tu CY, Hsia TC, Shih CM, Hsu WH, Sung FC, Kao CH. Risk of periodontal diseases in patients with chronic obstructive pulmonary disease: a Nationwide population-based cohort study. *Medicine (Baltimore)*. 2015;**94**(46):e2047.
41. Shen TC, Chang PY, Lin CL, Chen CH, Tu CY, Hsia TC, Shih CM, Hsu WH, Sung FC, Kao CH. Periodontal treatment reduces risk of adverse respiratory events in patients with chronic obstructive pulmonary disease: a propensity-matched cohort study. *Medicine (Baltimore)*. 2016;**95**(20):e3735.
42. Shen TC, Chang PY, Lin CL, Wei CC, Tu CY, Hsia TC, Shih CM, Hsu WH, Sung FC, Kao CH. Impact of periodontal treatment on hospitalization for adverse respiratory events in asthmatic adults: a propensity-matched cohort study. *Eur J Intern Med*. 2017;**46**:56-60.
43. Su NY, Huang JY, Hu CJ, Yu HC, Chang YC. Increased risk of periodontitis in patients with psoriatic disease: a nationwide population-based retrospective cohort study. *PeerJ*. 2017;**5**:e4064.
44. Tzeng NS, Chung CH, Yeh CB, Huang RY, Yuh DY, Huang SY, Lu RB, Chang HA, Kao YC, Chiang WS, Chou YC, Chien WC. Are chronic periodontitis and gingivitis associated with dementia? A Nationwide, retrospective. *Matched-Cohort Study in Taiwan*. 2016;**47**(2):82-93.
45. Wen BW, Tsai CS, Lin CL, Chang YJ, Lee CF, Hsu CH, Kao CH. Cancer risk among gingivitis and periodontitis patients: a nationwide cohort study. *QJM*. 2014;**107**(4):283-90.

46. Lin TH, Lung CC, Su HP, Huang JY, Ko PC, Jan SR, Sun YH, Nfor ON, Tu HP, Chang CS, Jian ZH, Chiang YC, Liaw YP. Association between periodontal disease and osteoporosis by gender: a nationwide population-based cohort study. *Medicine (Baltimore)*. 2015;**94**(7):e553.
47. Chen HH, Huang N, Chen YM, Chen TJ, Chou P, Lee YL, Chou YJ, Lan JL, Lai KL, Lin CH, Chen DY. Association between a history of periodontitis and the risk of rheumatoid arthritis: a nationwide, population-based, case-control study. *Ann Rheum Dis*. 2013;**72**(7):1206-11.
48. Chen PC, Tung YC, Wu PW, Wu LS, Lin YS, Chang CJ, Kung S, Chu PH. Dental procedures and the risk of infective endocarditis. *Medicine (Baltimore)*. 2015;**94**(43):e1826.
49. Keller JJ, Kang JH, Lin HC. Association between ankylosing spondylitis and chronic periodontitis: a population-based study. *Arthritis Rheum*. 2013;**65**(1):167-73.
50. Keller JJ, Chung SD, Lin HC. A nationwide population-based study on the association between chronic periodontitis and erectile dysfunction. *J Clin Periodontol*. 2012;**39**(6):507-12.
51. Lu MC, Jheng CH, Tsai TY, Koo M, Lai NS. Increased dental visits in patients prior to diagnosis of primary Sjogren's syndrome: a population-based study in Taiwan. *Rheumatol Int*. 2014;**34**(11):1555-61.
52. Wu CS, Yang TH, Lin HC, Sheu JJ, Chu D. Sudden sensorineural hearing loss associated with chronic periodontitis: a population-based study. *Otol Neurotol*. 2013;**34**(8):1380-4.
53. Wu YD, Lin CH, Chao WC, Liao TL, Chen DY, Chen HH. Association between a history of periodontitis and the risk of systemic lupus erythematosus in Taiwan: a nationwide, population-based, case-control study. *PLoS One*. 2017;**12**(10):e0187075.
54. Hung SH, Tsai MC, Lin HC, Chung SD. Allergic rhinitis is associated with periodontitis: a population-based study. *J Periodontol*. 2016;**87**(7):749-55.
55. Chaudhari M, Hubbard R, Reid RJ, Inge R, Newton KM, Spangler L, Barlow WE. Evaluating components of dental care utilization among adults with diabetes and matched controls via hurdle models. *BMC Oral Health*. 2012;**12**:20.
56. Newton KM, Chaudhari M, Barlow WE, Inge RE, Theis MK, Spangler LA, Hujoel PP, Reid RJ. A population-based study of periodontal care among those with and without diabetes. *J Periodontol*. 2011;**82**(12):1650-6.
57. Spangler L, Reid RJ, Inge R, Newton KM, Hujoel P, Chaudhari M, Genco RJ, Barlow WE. Cross-sectional study of periodontal care and glycosylated Hemoglobin in an insured population. *Diabetes Care*. 2010;**33**(8):1753-8.
58. Jeffcoat MK, Jeffcoat RL, Gladowski PA, Bramson JB, Blum JJ. Impact of periodontal therapy on general health: evidence from insurance data for five systemic conditions. *Am J Prev Med*. 2014;**47**(2):166-74.
59. Nasseh K, Vujicic M, Glick M. The relationship between periodontal interventions and healthcare costs and utilization. Evidence from an integrated dental, medical, and pharmacy commercial claims database. *Health Econ*. 2017;**26**(4):519-27.
60. Egeberg A, Mallbris L, Gislason G, Hansen PR, Mrowietz U. Risk of periodontitis in patients with psoriasis and psoriatic arthritis. *J Eur Acad Dermatol Venereol*. 2017;**31**(2):288-93.
61. Lee JH, Choi JK, Kim SH, Cho KH, Kim YT, Choi SH, Jung UW. Association between periodontal flap surgery for periodontitis and vasculogenic erectile dysfunction in Koreans. *J Periodontal Implant Sci*. 2017;**47**(2):96-105.
62. Lee JH, Kweon HH, Choi JK, Kim YT, Choi SH. Association between periodontal disease and prostate cancer: results of a 12-year longitudinal cohort study in South Korea. *J Cancer*. 2017;**8**(15):2959-65.
63. Lee JH, Oh JY, Youk TM, Jeong SN, Kim YT, Choi SH. Association between periodontal disease and non-communicable diseases: a 12-year longitudinal health-examinee cohort study in South Korea. *Medicine (Baltimore)*. 2017;**96**(26):e7398.
64. Lee JH, Lee JS, Park JY, Choi JK, Kim DW, Kim YT, Choi SH. Association of lifestyle-related comorbidities with periodontitis: a Nationwide cohort study in Korea. *Medicine (Baltimore)*. 2015;**94**(37):e1567.
65. Saito M, Shimazaki Y, Nonoyama T, Tadokoro Y. Association between dental visits for periodontal treatment and type 2 diabetes mellitus in an elderly Japanese cohort. *J Clin Periodontol*. 2017;**44**(11):1133-9.
66. Egeberg A, Mallbris L, Gislason GH, Skov L, Hansen PR. Risk of multiple sclerosis in patients with psoriasis: a Danish Nationwide cohort study. *J Invest Dermatol*. 2016;**136**(1):93-8.
67. Schäfer T, Schneider A, Mieth I, Grobe TG, Schwartz FW. BARMER GEK Zahnreport 2011.
68. Schubert I, Hammer A, Köster I. Möglichkeiten zur Einschätzung des Schweregrades einer Erkrankung auf der Basis von Routinedaten am Beispiel des Schlaganfalls. *Z Evid Fortbild Qual Gesundhwes*. 2017;**126**:66-75.
69. Szklo M, Nieto FJ. *Epidemiology: beyond the basics*, 3rd ed. Burlington: Jones & Bartlett Learning; 2014.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1: Supporting Information

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