Journal of Dentistry 89 (2019) 103166

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Review article

Risk predictors of dental root caries: A systematic review

Jingyang Zhang, Katherine C.M. Leung, Divesh Sardana, May C.M. Wong, Edward C.M. Lo*

The University of Hong Kong, Hong Kong

ARTICLE INFO

Keywords:
Dental caries
Risk factors
Epidemiology
Preventive dentistry

ABSTRACT

Objectives: To identify the risk predictors of root caries and to describe their relationship with the incidence and increment of root caries.
Data: Observational longitudinal studies.
Sources: Four electronic databases (PubMed, MEDLINE, EMBASE, and Scopus) (From 1 January 1990 to 31 January 2019).
Study selection: Information on the factors associated with the incidence or increment of decayed and filled root surfaces (DF-root) and/or decayed root surfaces (D-root) were extracted by two reviewers independently. The factors were put into six categories, namely social-demographic background, general health, health behaviors, fluoride exposure, oral health habits and oral health condition. From the 440 potential papers identified, 19 papers reporting on 16 cohort studies were finally included. The total sample size was 7340 participants from different countries worldwide, with age ranging from 20 to 100 years. Positive correlations between new root caries and age, baseline root caries experience, gingival recession and use of tobacco were reported while negative correlations were found for socio-economic status, good oral hygiene and use of fluorides. Mixed findings were detected for the association between new root caries and the number of natural teeth.
Conclusion: This systematic review discovered a number of root caries risk predictors in different categories. People who are older, in lower socio-economic status or tobacco users, and those with more root caries experience, gingival recession and poor oral hygiene have higher risk of developing new root caries.
Clinical significance: This systematic review provides support that improvement of oral hygiene, prevention of gingival recession, and use of fluoride would be useful strategy for prevention of new root caries.

1. Introduction

In most countries around the world, the number and proportion of older adults is increasing [1]. With an increase in life expectancy and increase in number of natural teeth among the older adults, recently more attention has been paid on prevention of root caries [2]. It is estimated that one-third of the geriatric population is subjected to root caries [3]. The reported prevalence of root caries among the older adults varies from 10% in Canada [4] to 71% in the U.S.A. [5]. The latest national oral health survey conducted in China in 2015/16 reported that 62% of the adults 65 to 74 years old had root caries [6]. Meanwhile, the reported annual increments of root caries vary from 0.3 in Canada [7] to 4.4 in the U.S.A. [8]. The reported incidence of root caries also varies between studies, from a low incidence rate of 12% over 10 years [9] to as high as 77% over 3 years [7]. Since people are retaining more teeth and with the anticipated increase in root caries over time, the management of this dental disease in older adults will become an important dental public health issue because of the high need for prevention and treatment [10,11].

Root caries usually presents as a soft decayed lesion in the dentine of the root of a tooth. Often there is a cavity below the cementoenamel junction. Diagnosis of root caries is usually based on visual-tactile examination of the exposed root surfaces, including the color, texture and presence of cavitation [12,13]. Root caries results from the dissolution of minerals in dentine by the acids produced by bacteria and the enzymatic degradation of organic components in dentine. Since dentine have a much lower mineral content and a significant proportion of organic component when compared to enamel, the risk factors associated with the development of root caries and coronal caries may be different.

Root caries is a multifactorial disease that can be prevented [2]. Various risk factors on root caries have been found in a recent systematic review of cross-sectional studies [14]. There were a number of longitudinal cohort studies on root caries in different populations under different study settings but so far there is no systematic review on the risk predictors of new root caries. A high level of diversity in study

* Corresponding author at: Faculty of Dentistry, University of Hong Kong, 34 Hospital Road, Sai Ying Pun, Hong Kong.
E-mail address: edward-lo@hku.hk (E.C.M. Lo).

https://doi.org/10.1016/j.jdent.2019.07.004
Received 2 April 2019; Received in revised form 3 July 2019; Accepted 4 July 2019
0300-5712/

design and data analysis were found in the papers on observational studies published before the 1990s [15]. Moreover, root caries and coronal caries were often not reported separately in these earlier studies. Thus, there is a need to conduct a systematic review of the relatively recent longitudinal studies to summarize their study findings.

The aim of this systematic review was to identify the risk predictors of new root caries and to describe their relationship with the incidence and increment of new root caries. The study question was which baseline factors are associated with the development of new root caries, i.e. increase or decrease the risk of new root caries?

2. Materials and methods

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The proposal was registered a priori at the US National Institute for Health Research, International Prospective Register of Systematic Reviews (PROSPERO, registration number: CRD 42018091883).

The databases that were searched electronically included MEDLINE, EMBASE, PubMed and Scopus. Key words used in the search are presented in Appendix 1. These include “root caries”, “root decay”, “risk factor”, “risk predictor”, “adult” and “elder”. The inclusion criteria were as follows: 1) papers on longitudinal observational studies; 2) reporting on at least one risk predictor of root caries; and 3) the publication date was between 1 January 1990 and 31 January 2019. The exclusion criteria were: 1) studies on population with life-threatening disease; and 2) studies with follow-up rate less than 50%. No language restriction was set in the literature search. In addition, a manual search was conducted on the reference list of the selected papers and review articles. The papers were screened and relevant studies were identified by two reviewers (JZ and DS) independently. When there was disagreement, another researcher (MCMW) was consulted so as to achieve consensus.

Methodological quality (risk of bias) of the included papers was evaluated by adopting the modified Newcastle-Ottawa Scale for cohort studies (maximum 8 stars) (Appendix 2) [16]. If all the criteria of methodological quality were fulfilled in the domains, “stars” (*) were assigned to the corresponding paper. Papers with 7 or more stars were rated as high methodological quality, 4–6 stars as moderate quality, and studies with fewer than 4 stars were classified as low quality [17].

Information on the following aspects of the background of the included studies was extracted and presented in summary Tables 1) cohort location; 2) sample size; 3) sampling method; 4) factors studied; 5) diagnostic criteria for root caries; and 6) measures of root caries. Information on both the incidence and the increment of root caries was recorded in pre-defined piloted forms. The relationships between the studied factors and root caries revealed in the crude (unadjusted) and/or adjusted analysis performed in the studies were also noted. Risk predictors of root caries identified in the included studies were placed under six categories, namely: 1) socio-demographic background; 2) general health conditions; 3) general behaviors; 4) fluoride exposure; 5) oral health related habits; and 6) oral health condition (e.g. clinical parameters, oral microbiota and salivary parameters).

3. Results

A total of 868 potentially relevant records were identified through database searching and 440 were left after removal of duplicates (Fig. 1). After screening the titles and abstracts, 398 records were excluded due to the following reasons: cross-sectional studies (n = 107), clinical trials (n = 10), review articles (n = 29) and no data on root caries (n = 252). The remaining 42 papers, all published in English, were retrieved for full-text reading. Among them, 23 papers did not fulfill the inclusion criteria. Among the 19 papers included in the methodological quality assessment, 4 were classified as high quality, 13 as moderate quality and 2 as low (Appendix 3).

The 19 included papers, reporting on 16 cohort studies, were published between 1992 and 2018. The locations of the cohort studies were worldwide, including Australia, Brazil, U.S.A., Mexico, Finland, Sweden and China. The total sample size at baseline was 7340 participants and their age ranged from 20 to 100 years (Table 1). Random samples from the community were taken in 7 studies, while non-probability sampling was adopted in 8 studies and 1 study did not specify the sampling method adopted.

As for the root caries diagnostic criteria, 1 of the 16 included studies employed ICDAS II criteria [18], 3 studies followed the WHO criteria [10,19,20], 10 studies used visual-tactile examination with a reference cited while 2 studies did not specify the criteria.

Three studies reported both the incidence and the increment of root surface caries [7,21–23], while 6 studies only reported the incidence and 7 studies reported the increment. Seven studies only reported on DF-root (decayed and filled root), 4 studies only reported on D-root (untreated active root caries), while 5 studies reported on both DF-root and D-root.

4. Risk predictors of root caries

4.1. Socio-demographic factors

Ten studies had assessed the correlation between DF-root and socio-demographic factors (Table 2). Among the 7 studies that investigated the association between age and DF-root, 2 studies found a positive correlation in their crude analysis and 2 studies found this in their adjusted analysis after accounting for the influence of confounding factors. Among the 5 studies that investigated the association between gender and root caries, only 1 study found a higher male predilection in its crude data analysis while the other 4 studies did not find a statistically significant correlation. Regarding ethnicity and race, 1 study reported that Asians had the highest risk for developing new root caries compared with Caucasians, African-Americans and the Hispanics [8], while another study did not. One study reported that people who lived in rural areas had more new DF-root in its crude and adjusted analysis [24], while another study did not find a statistically significant relationship [12]. Among the 5 studies that included education level, only 1 reported a negative correlation with the incidence of DF-root in its adjusted analysis [25]. One study reported that people who had retired had higher incidence of DF-root [22,23]. As for household income, private dental insurance and marital status, no significant correlations were detected between them and new DF-root.

Gender, living areas and education level showed the same direction of association with D-root as that with DF-root (Appendix 4). There was no consistent finding regarding age. Among the 4 studies that investigated the association between age and root caries incidence, 1 study reported a positive correlation [26], while another reported the opposite [27]. Regarding ethnicity, 2 studies reported that African-Americans had a higher incidence or increment of root caries than the Whites [22,23,27]. Gilbert and co-workers reported that people with lower household income had higher risk of new D-root [27], while another study did not detect any statistically significant correlation [12].

4.2. General health factors

Six studies assessed the correlation between DF-root and general health factors (Table 2). Among the 3 studies assessing medication factors, 2 pointed out that taking medicine increased the incidence of DF-root [9,23]. Only 1 of the 4 studies reported that people with decreased self-care ability had a higher incidence of DF-root [23], while the others did not [8,21,25]. In the 2 studies on cognitive status, 1 reported people with Alzheimer disease had a lower incidence of DF-root in its adjusted analysis [25], while the other one did not [21]. In

Table 1
Summary of the included studies: cohort location, sampling, sample size, factors assessed, root caries diagnostic criteria, and root caries parameters reported.

Study and cohort location	Sample size **baseline / follow-up (duration)**	Sample	Potential predictors of root caries included							Diagnostic criteria	Reported measures
			Demographic characteristics	*Socio-economic status*	*General health conditions*	*General behaviors*	*Fluoride exposure*	*Oral health habits*	*Oral conditions*		
Hariyani 2018 Australia	913 /689 (2-year) /530 (5-year) /361 (11-year)	Community and random	Age: 60+ years	Living region, education level, household income		Tobacco use		Tooth brushing frequency, frequency of interdental cleaning, regular dental visit, reasons for dental visit	Numbers of root surface with gingival recession, gingivitis, DF-root at baseline	WHO 2007	Increment of D-root, DF-root
Bidinotto 2018 Brazil	388 /235 (4-year)	Community and random	Age: 60+ years Female: 49.4%	Living region, education level, household income, marital status		Tobacco use		Tooth brushing frequency, denture wearing, regular dental visit, reasons for dental visit	Oral hygiene, salivary flow	DePaola et al. 1989	Increment of DF-root
Hayes 2017 Ireland	334 /307(1-year) /280(2-year)	Self-selected (advertisement)	Age: 65+ years		Systemic diseases		Topical fluoride	Frequency of snacking	Oral hygiene, S. mutans count, LA count, salivary flow, salivary buffer capacity	ICDAS II	Increment of D-root
Sugihara 2014 Japan	141 /141 (5-year)	Convenience (company)	Age: 20+ years Female: 16.3%						DF-root at baseline, gingival recession, coronal caries at baseline	Not specified	Incidence of D-root
Sanchez-Garcia 2011 Mexico	698 /531 (1-year)	Selected (elderly homes)	Age: 60+ years	Education level, labor activity, marital status	Medicine intake, self-care ability, chronic disease, chemotherapy and/or radiotherapy, cognitive deterioration, depression	Tobacco use, coffee and tea consumption, salt consumption		Tooth brushing, mouthwash, oral health service use	DMFT, exposed root surfaces, RCI, loss of attachment, saliva flow rate, saliva buffer capacity, Lactobacilli count, S. mutans count	RCI	Incidence and incrementof DF-root
Senpuku 2010 Japan	183/183 (1-year)	Selected elderly homes	Female: 43.7%						S. mutans count	WHO 1997	Increment of DF-root, D-root
Ellefsen 2009 Denmark	106 /77 (1-year)	Patients referred from hospitals	Age: (Mean) 81.9 years Female: 65.1%	Education level	Self-rated health, instrumental activities of daily living, dementia				Number of coronal caries at baseline, number of teeth at baseline	NIDR, 1987*	Incidence of DF-root
Fure 2004 & 1998 Sweden	208 /148 (5-year) /102 (10-year)	Community and random	Age: 55-year; 65-year; 75-year Female: 46.6%			Medicine reducing saliva intake, tobacco use, carbohydrate consumption			Number of teeth, oral hygiene, saliva flow rate, saliva buffer capacity, Lactobacilli count, S. mutans count, S. sobrinus count	Banting 1980	Increment of DF-root
Takano 2003 Japan	544 /379 (1-year) /373 (2-year)	Self-selected (questionaire)			Body mass index			Interdental brushing	Prosthetic crown, Lactobacilli count, loss of attachment	WHO, 1997	Incidence of D-root
Thomson 2002 Australia	848 /528 (5-year)	Community and random	Age: 65-100 years Female: 42.4%		Medicine intake	Denture wearing			Number of DFS root at baseline	Not specified	Increment of D-root
Gilber 2001 United States	873 /723 (2-year)	Community and random	Age: 45+	Living region, education level, household income	Self-related general health	Tobacco use		Tooth brushing, interdental cleaning, regular dental visit	D-root at baseline, F-root at baseline, number of teeth, coronal caries, partial denture, loss of attachment	Miller et al., 1987	Increment of D-root, DF-root

(*continued on next page*)

Table 1 (*continued*)

Study and cohort location	Sample size **baseline / follow-up (duration)**	Sample	Potential predictors of root caries included							Diagnostic criteria	Reported measures
			Demographic characteristics	*Socio-economic status*	*General health conditions*	*General behaviors*	*Fluoride exposure*	*Oral health habits*	*Oral conditions*		
Powell 1998 United States	261 /201 (3-year)	Community and non-random	Age: 60+ years Female: 56%	Education level	Medication intake, self-care ability	Tobacco use			Coronal DMFS, bacteria count, salivary flow, saliva buffer capacity	NIDR*, 1997	Incidence of DF-root
Locker 1996 Canada	699 /492 (3-year)	Community and random	Age: 50+ years		Self-rated health	Tobacco use		Regular dental visit	Partial denture, DF-root at baseline, tooth brushing, number of teeth	NIDR* (1985-1986)	Increment and incidence of DF-root, D-root
Lawrence 1996 & 1995 United States	702 /452 (3-year) /363 (5-year)	Community and random	Age: 65+ years Race: White: Black = 54%: 46%	Retirement status	medication intake, self-care ability, calcium intake				Denture wearing, root fragments, gingival recession, presence of P. intermedia	Katz et al., 1984	Incidence of DF-root, increment of D-root
Scheinin 1994 & 1992 Finland	104 /100 (1-year) /96 (3-year)	Convenience (dental clinic)	Age: 47-79 years Female: 63%						Root DFS at baseline, S. mutans count, LA count, candida count, saliva buffer effect, oral hygiene	Katz et al., 1980	Incidence of DF-root
Joshi 1993 United States	130 /130 (9-month) /130 (2-year)	Convenience (volunteers)	Age: 45-82 years Female: 57.7%						Root DFS at baseline, oral hygiene, number of teeth	NIDR* (1985-1986)	Incidence of DF-root

DF-root: decayed or filled root surfaces; D-root: decayed root surfaces; F-root: filled root surfaces.

* NIDR: National Institutes of Dental Research, Epidemiology and Oral Disease Prevention Program.

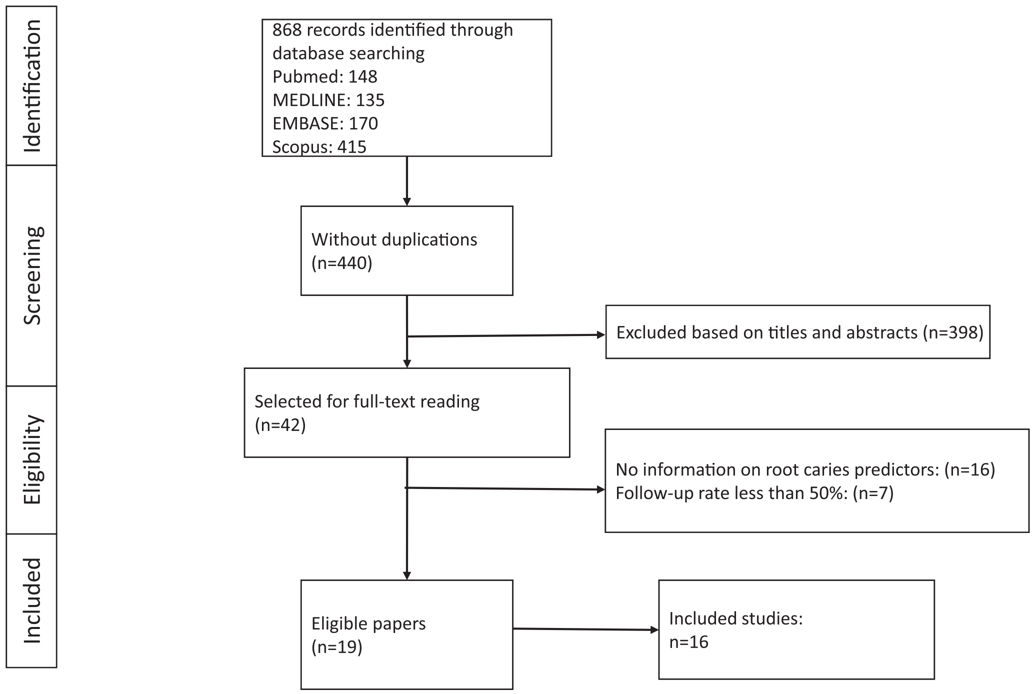

Fig. 1. Flowchart of the study selection process.

addition, Lawrence and co-workers studied calcium intake and found a negative correlation with the incidence of DF-root [23]. On the other hand, there was no significant correlations between DF-root and the other studied factors, including general systemic diseases, depression, chemotherapy and/or radiotherapy and self-rated general health.

Regarding D-root, the same direction of correlation with medicine intake as that with DF-root was detected (Appendix 4). Meanwhile, both studies which assessed self-rated general health reported a negative correlation with the increment of root caries [7,27]. Besides, body mass index showed no significant correlation with new root caries [20].

4.3. General health behavior

A positive correlation between the use of tobacco and new DF-root or D-root was reported in 5 of the 7 studies. One study reported a negative correlation between DF-root and the frequency of carbohydrate intake [9]. No significant correlations were found between new root caries and the consumption of coffee, tea and salt [21].

4.4. Fluoride exposure

Only 1 study assessed the correlation between use of fluoride and root caries [18]. Hayes and co-workers reported that people who avoided fluoride product had the highest risk of developing new DF-root, followed by people who used fluoride toothpaste daily, and the lowest risk was people who used additional fluoride product occasionally.

4.5. Oral health habits

Among the 3 studies that investigated tooth brushing frequency, only 1 reported a negative correlation with DF-root increment [24]. Regarding frequency of interdental cleaning, Hariyani and co-workers reported a negative correlation [12]. A positive correlation between the frequency of snacking and root caries was reported in 1 study [18], while another study did not [21]. Furthermore, Sanchez-Garcia et al. found that people who regularly used mouthwash had lower incidence of DF-root in both crude and adjusted analysis [21]. Among the 3 studies investigating dental visit frequency, only 1 study found that people who visited dentist within a year had a higher increment of DF-root [12].

In the studies using D-root in their analysis, same direction of correlation with the frequency of tooth brushing and interdental cleaning as that with DF-root was found. One study found people who had regular dental visits had lower incidence and increment of D-root in its crude analysis [7], while another study did not [27]. Besides, both of the above 2 studies reported that people who visited dentist for solving dental problems had higher incidence or increment of root caries, compared with those who went for regular dental check-up. On the other hand, no significant correlation between new root caries and recency of dental visit was reported in 1 study [12].

4.6. Oral clinical parameters

There were 12 studies which assessed the correlations between DF-root and various oral clinical parameters (Table 2). No consistent relationship between new DF-root and the number of teeth was detected because among the 4 studies including this factor, 2 reported a positive [25,28], one reported a negative [9,29], while one did not report a clear correlation [27]. Positive correlations between new root caries and baseline root caries experience were found in all 6 studies [7,21,23,28–30]. Three studies, in their adjusted analysis, found that having more root surfaces with recession or more gingival recession at baseline was associated with a higher incidence or increment of DF-root [12,21,23]. Regarding oral hygiene or plaque on root surfaces, 4 of the 5 studies found a positive correlation [9,18,28,30]. One study reported no significant correlation between gingivitis and DF-root increment [12] while 2 other studies found no significant correlation between attachment loss and new root caries [21,27]. Regarding denture wearing, 2 of the 3 studies reported a positive correlation [7,23] while 1 study did not [24].

Regarding the correlation with D-root, same direction of association as that of DF-root was found for the number of natural teeth, baseline root caries experience and gingival recession (Appendix 4). Besides, 2 studies found the amount of attachment loss had a positive correlation with the incidence of D-root [20,27]. Furthermore, 3 studies found a

Table 2
Associations between the studied factors, and the incidence and the increment of decayed or filled root (DF-root) surfaces.

Associated factors	Study	Crude analysis (Incidence)	Adjusted analysis (Incidence)	Crude analysis (Increment)	Adjusted analysis (Increment)
Socio-demographic factors **i. Age**					
	Hariyani 2018				X
	Bidinotto 2018			X	X
	Sanchez-Garcia 2011	X	X		
	Ellefsen 2009		At 1 year RR [95% CI] ≤80 years ref. > 80 years 7.69 [1.55, 38.15]		
	Fure 2004 & 1998			Fure 2004 DFRS % increment: Age group: 5-yr 60/65 2.1 ± 4.4 70/75 4.5 ± 6.8 80/85 6.0 ± 4.4 p-value: < 0.05 Age group: 10-yr 60/65 9.4 ± 15.3 70/75 13.8 ± 17.7 80/85 25.0 ± 21.3 p-value: < 0.05	Fure 1998 Linear regression analysis: (5-yr) Outcome: DMFRS % increment Beta: 0.23; partial corr: 0.40 p = 0.0001
	Gilbert 2001	At 2 years Incidence 45-64 years 2% ≥65 years 9% p < 0.05	X		
	Powell 1998				X
ii. Gender					
	Hariyani 2018				X
	Bidinotto 2018			X	
	Sanchez-Garcia 2011	X	X		
	Powell 1998				X
	Locker 1996	X		At 3 years Mean (SD) Male 0.77 (1.81) Female 0.48 (1.05) p < 0.05	
iii. Ethnicity/race					
	Powell 1998		At 3 years RR [95% CI] Others ref Asian 1.85 [1.16,2.95] p = 0.009		
	Lawrence 1996 & 1995	X			
iv. Living region					
	Hariyani 2018				X
	Bidinotto 2018			incidence rate (100 root-yr) (mean ± SD) Urban 4.05 ± 8.35 Rural 5.87 ± 9.33 p = 0.02	At 4 years IRR [95% CI] Urban ref. Rural 1.69 [1.10-2.60]
v. Education level					
	Hariyani 2018				X
	Bidinotto 2018			X	X
	Sanchez-Garcia 2011	X	X		
	Ellefsen 2009		At 1 year RR [95% CI] ≤7 years ref. > 7 years 0.16 [0.03, 0.74]		
	Powell 1998		X		
vi. Household income					X
	Hariyanie 2018				
	Bidinotto 2018			X	X
vii. Private dental insurance					
	Hariyani 2018				X
viii. Retired					
	Lawrence 1996 & 1995		Lawrence 1995: in Whites At 3 years RR [95% CI] No ref. Yes 3.17 [1.32, 7.61]		

(*continued on next page*)

Table 2 (*continued*)

Associated factors	Study	Crude analysis (Incidence)	Adjusted analysis (Incidence)	Crude analysis (Increment)	Adjusted analysis (Increment)
ix. Marital status					
	Bidinotto 2018			X	X
	Sanchez-Garcia 2011	X	X		
General health conditions					
i. Systemic disease					
	Hayes 2017			X	
ii. Medication intake					
	Sanchez-Garcia 2011	X	X		
	Fure 2004 & 1998				Fure 2004 At 10 years Number of drugs/day: Partial corr = 0.27 Beta = 1.76
	Lawrence 1996 & 1995		Lawrence 1995: in Whites At 3 years RR [95% CI] No ref. Yes 4.00 [1.45, 11.00]		
iii. Chemotherapy/radiotherapy					
	Sanchez-Garcia 2011	X	X		
iv. Self-care ability					
	Sanchez-Garcia 2011	X	X		
	Ellefsen 2009		X		
	Powell 1998		X		
	Lawrence 1996 & 1995		Lawrence 1995: in Black At 3 years RR [95% CI] Not impaired ref. Impaired 1.67 [1.12, 2.50]		
v. Self-rated general health					
	Sanchez-Garcia 2011	X	X		
	Ellefsen 2009		X		
vi. Cognitive deterioration					
	Sanchez-Garcia 2011	X	X		
	Ellefsen 2009	X	At 1 year RR [95% CI] No dementia ref. Alzheimer 0.08 [0.01, 0.79] Other dementia 1.01 [0.11, 9.56]		
vii. Depression					
	Sanchez-Garcia 2011	X	X		
viii. Calcium intake					
	Lawrence 1996 & 1995		Lawrence 1995: in Whites At 3 years RR [95% CI] Yes ref. No 2.45 [1.08, 5.57]		
General behaviors					
i. Tobacco use					
	Hariyani 2018				X
	Bidinotto 2018			X	X
	Sanchez-Garcia 2011	At 1 year RR [95% CI] No ref. Yes 2.0 [1.1, 3.7]	At 1 year RR [95% CI] No ref. Yes 2.0 [1.1, 4.1]		
	Fure 2004 & 1998				Fure 2004 At 10 years Number of cigarettes/day Partial corr. = 0.12 Beta = 0.37
	Powell 1998		X		
	Lock 1996	X		At 3 years Mean (SD) No 0.47 (1.11) Yes 0.75 (1.71) $p < 0.05$	

(*continued on next page*)

Table 2 (*continued*)

Associated factors	Study	Crude analysis (Incidence)	Adjusted analysis (Incidence)	Crude analysis (Increment)	Adjusted analysis (Increment)
ii. Coffee/tea consumption					
	Sanchez-Garcia 2011	X	X		
iii. Carbohydrate consumption					
	Fure 2004 & 1998				Fure 2004 At 10 years Number of carbohydrate intakes/ day: Partial corr. = 0.05 Beta = -0.42
iv. Salt consumption					
	Sanchez-Garcia 2011	X	X		
Fluoride exposure					
	Hayes 2017			At 2 years Mean (SD) Max programme 0.00 (0.00) Additional F 0.17 (0.67) Daily F toothpaste 0.75 (1.54) No F 3.07 (3.89) p < 0.001	
Oral health habits **i. Tooth brushing frequency**					
	Hariyani 2018				X
	Bidinotto 2018			incidence rate (100 root-yr) (mean ± SD) < 1 time/day 7.87 ± 11.03 ≥1 time/day 4.69 ± 8.65 p = 0.02	At 4 years IRR [95% CI] > 1 time/day ref. ≤1 time/day 1.94 [1.06, 3.54]
	Sanchez-Garcia 2011	X	X		
ii. Frequency of interdental cleaning					
	Hariyani 2018				Est . SE ≥1 time/day ref. < 1 time/day 0.81 0.39 p = 0.04
iii. Frequency of snack between meals					
	Hayes 2017			At 2 years Mean (SD) 3 meals/d 0.61 (2.12) 4-5 meals/d 0.48 (1.20) 6-7 meals/d 1.17 (2.00) > 7 meals/d 1.81 (1.68) p < 0.001	
	Sanchez-Garcia 2011	X	X		
iv. Mouthwash use					
	Sanchez-Garcia 2011	At 1 year RR [95% CI] Yes ref. No 1.6 [1.0, 2.5] p < 0.05	At 1 year RR [95% CI] Yes ref. No 1.7 [1.0, 2.8] p < 0.05		
v. Last dental visit					
	Hariyani 2018				Est. SE ≥ 1 year ref. < 1 year 1.22 0.44 p < 0.01
	Bidinotto 2018			X	
	Sanchez-Garcia 2011	X	X		
vi. Reason of visit					
	Hariyani 2018				X
	Bidinotto 2018				X
Oral health condition **i. Number of teeth at baseline**					
	Ellefsen 2009		At 1 year RR [95% CI] 1-9 teeth ref. 10-19 teeth 2.10 [0.40, 11.12] 20-32 teeth 7.31 [1.35, 9.48] p = 0.02		
	Fure 2004 & 1998				Fure 2004

(*continued on next page*)

Table 2 (*continued*)

Associated factors	Study	Crude analysis (Incidence)	Adjusted analysis (Incidence)	Crude analysis (Increment)	Adjusted analysis (Increment)
					10-year DFRS% increment Number of remaining teeth Partial corr. = -0.45 Beta = -0.85 p < 0.0001 Fure 1998 (at 5 years) Linear regression analysis: DMFRS% increment Part. corr. = -0.35 Beta = -0.16 p = 0.0001
	Gilbert 2001	At 2 years RR [95% CI] 25-32 teeth ref. 1-8 teeth 1.3 [0.6, 2.6] 9-16 teeth 1.9 [1.1, 3.4] 17-24 teeth 1.2 [0.8, 1.9]	X		
	Joshi 1993		At 2 years RR [95% CI] < 22 teeth ref. ≥ 22 teeth 2.63 [1.22, 5.66]		
ii. Coronal DMFT or DMFS					
	Sanchez-Garcia 2011	At 1 year RR [95% CI] < 16 ref. ≥17 1.6 [1.0, 2.5]	X		
	Ellefsen 2009		At 1 year RR [95% CI] 0 ref. 1-2 27.35 [1.70, 441.1] ≥3 400.3 [12.43, 12,884] p < 0.001		
	Gilbert 2001	At 2 years Yes 7% No 4% p < 0.05	At 2 years RR No ref. Yes 3.5 p < 0.05		
	Powell 1998		X		
iii. Root caries experience					
	Sanchez-Garcia 2011	At 1 year RR [95% CI] RCI ≤8% ref. RCI > 8% 5.1 [3.2, 8.2] p < 0.001	At 1 year RR [95% CI] RCI ≤8% ref. RCI > 8% 5.4 [3.2, 9.1] p < 0.001		
	Gilbert 2001	At 2 years RR [95% CI] No ref. Yes 2.3 [1.4, 3.7]	At 2 years RR No ref. Yes 3.9 p < 0.05		
	Locker 1996	No 15.2% Yes 33.3% p < 0.001		X	
	Lawrence 1996 & 1995		Lawrence 1995: At 3 years RR [95% CI] No ref. Yes 3.31 [1.28, 8.58]		
	Scheinin 1994 & 1992	Scheinin 1994 At 3 years RR = 12.0 p < 0.0001	Scheinin 1994 At 3 years RR [95% CI] 12.8[2.8, 58.5]		
	Joshi 1993		At 2 years RR [95% CI] 1.14 [1.05, 1.23] p = 0.004		
iv. Number of surfaces with recession					
	Hariyani 2018				60+-year-old Est. SE 0.10 0.01

(*continued on next page*)

Table 2 (*continued*)

Associated factors	Study	Crude analysis (Incidence)	Adjusted analysis (Incidence)	Crude analysis (Increment)	Adjusted analysis (Increment)
	Sanchez-Garcia 2011	At 1 year RR [95% CI] < 6 ref. ≥6 5.1 [3.2, 8.2] $p < 0.001$	At 1 year RR [95% CI] < 6 ref. ≥6 5.4 [3.2, 9.1] $p < 0.001$		
v. Gingival Recession					
	Lawrence 1996 & 1995		Lawrence 1995 (in Whites) At 3 years RR [95% CI] < 4mm ref. ≥4mm 4.50 [1.95, 10.39]		
vi. Attachment Loss					
	Sanchez-Garcia 2011		X		
	Gilbert 2001		X		
vii. Oral hygiene					
	Bidinotto 2018				X
	Hayes 2017			At 2 years Mean (SD) Good 0.36 (1.01) Fair 0.51 (1.15) Poor 1.54 (3.11) $p < 0.001$	
	Scheinin 1994 & 1992	Scheinin 1994 At 3 years % teeth with plaque RR = 1.5 $p < 0.05$			
	Joshi 1993		At 2 years Mean PI score RR [95%CI] < 2 ref. ≥2 2.69 [1.11,6.50]		
viii. Plaque on root surface					
	Fure 2004 & 1998				Fure 2004 (at 10 years) % surfaces with plaque Partial corr. = 0.14 Beta = 0.03 $p < 0.05$
ix. Gingivitis					
	Hariyani 2018				X
x. Denture wearing					
	Bidinotto 2018			X	X
	Locker 1996	At 3 years No 23.6% Yes 33.0% $p < 0.05$		X	
	Lawrence 1996 & 1995		Lawrence 1995 (in Blacks) At 3 years RR [95% CI] No ref. Yes 3.43 [1.52, 7.76]		
Oral microbiota **i. *Streptococcus mutans* count**					
	Hayes 2017			X	
	Sanchez-Garcia 2011	At 1 year RR [95% CI] < 10^5 CFU/ml ref. ≥10^5 CFU/ml 1.6 [1.0, 2.7] $p < 0.001$	At 1 year RR [95% CI] < 10^5 CFU/ml ref. ≥10^5 CFU/ml 2.1 [1.1, 4.0] $p < 0.001$		
	Fure 2004 & 1998				Fure 2004: 10-year (log_{10} CFU/ml) Partial corr. = 0.31 Beta = 2.44 Fure 1998: 5-year Part. Corr. = 0.38 Beta = 0.23 $p < 0.05$
	Scheinin 1994 & 1992	Scheinin 1994 At 3 years RR < 10^5 CFU/ml ref.			

(*continued on next page*)

Table 2 (*continued*)

Associated factors	Study	Crude analysis (Incidence)	Adjusted analysis (Incidence)	Crude analysis (Increment)	Adjusted analysis (Increment)
		$\geq 10^5$ CFU/ml 6.3 $p < 0.001$			
ii. *Lacobacilli sp.* count					
	Hayes 2017			X	
	Sanchez-Garcia 2011	X	X		
	Fure 2004 & 1998				Fure 2004: 10-year ($\log_{10}$ CFU/ml) Partial corr. = 0.37 Beta = 2.78 Fure 1998: 5-year: Partial corr. = 0.37 Beta = 0.61 $p < 0.05$
	Scheinin 1994 & 1992	Scheinin 1994 At 3 years RR $< 10^4$ CFU/ml ref. $\geq 10^4$ CFU/ml 11.9 $p < 0.001$	Scheinin 1994 At 3 years RR [95% CI] 8.6 [2.4, 31.2]		
iii. *Streptococcus mutans* and *Lacobacillus* count					
	Powell 1998		At 3 years RR [95% CI] $\log_{10}$ bacterial count 1.29 [1.16-2.95] p=0.002		
iv. *S. sobrinus*					
	Fure 2004 & 1998			Fure 1998 (at 5 years) S.sobrinus DFRS % increment Detected 6.6 ± 8.5 Not detected 3.0 ± 5.3 p=0.02	
v. *Prevotella intermedia*					
	Lawrence 1996 & 1995		Lawrence 1995 (in Blacks) At 3 years RR [95% CI] Present ref. Absent 2.74 [1.27, 5.92]		
vi. Candida					
	Scheinin 1994 & 1992			Scheinin 1994 At 3 years RR $< 10^3$ CFU/ml ref. $\geq 10^3$ CFU/ml 4.4 $p < 0.001$	
Salivary parameters **i. Salivary Flow**					
	Bidinotto 2018				At 4 years IRR [95% CI] Higher stimulated saliva flow 0.90 [0.83, 0.98]
	Hayes 2017			At 2 years Mean (SD) < 0.7 ml/min 0.53 (1.30) ≥ 0.7 ml/min 2.81 (4.62) $p < 0.001$	
	Sanchez-Garcia 2011	X	X		
	Fure 2004 & 1998				Fure 2004 (at 10 years) Unstimulated rate (ml/min) Partial corr. = -0.17 Beta = 1.36 Stimulated rate (ml/min) Partial corr. = -0.17 Beta = -0.57 $p < 0.05$
	Powell 1998		X		
ii. Saliva buffering capacity					
	Hayes 2017			X	
	Sanchez-Garcia 2011	X	X		
	Powell 1998		X		
	Fure 2004 & 1998				X
	Scheinin 1994 & 1992	Scheinin 1994			

(*continued on next page*)

Table 2 (*continued*)

Associated factors	Study	Crude analysis (Incidence)	Adjusted analysis (Incidence)	Crude analysis (Increment)	Adjusted analysis (Increment)
		At 3 years RR High ref. Low 2.0 p < 0.005			
iii. sIgA in saliva					
	Senpuku 2010			X	

X = No statistically significant correlation.

positive correlation between D-root and denture wearing [7,27,31].

4.7. Oral microbiota

A positive correlation between new root caries and *Streptococcus mutans* was found in 3 of the 4 studies [9,21,30] while in 2 studies a positive association with *Lactobacilli* sp. was reported [9,30]. Meanwhile, Powell and co-workers also reported a positive correlation between DF-root and the co-existence of the above two species of bacteria [8]. In addition, 1 study reported presence of *Streptococcus sobrinus* [29] and another study found the number of Candida [30] to be positively related to the increment of DF-root. Besides, presence of *Prevotella* was associated with a lower incidence of DF-root in the adjusted data analysis of another study [23].

Regarding D-root, only 1 study assessed the correlation with oral microbiota in which a positive correlation with the number of Lactobacilli was found [20].

4.8. Salivary parameters

Two of 4 studies found a higher risk of developing new DF-root among people who had a lower salivary flow [9,24] while 1 study reported the contrary [18]. Only 1 of the 5 studies found a positive correlation between salivary buffer capacity and incidence of DF-root in its crude data analysis [30] while the other 4 studies did not.

5. Discussion

Due to the heterogeneity in the measurements of the various factors among the included studies in this systematic review, it was not possible to conduct a meta-analysis. Moreover, different diagnostic criteria and measurement scales were used in root caries assessment. While continuous variables such as RCI and increment of new root caries were adopted in some studies, other studies used a binary variable such as incidence of root caries in their data analysis. Furthermore, the risk predictors in different studies were assessed differently. For example, regarding the number of remaining teeth, some studies used the exact number of teeth while other studies used categories in their data analysis.

A recent systematic review on cross-sectional studies on root caries conducted by the authors of this paper found that poor oral hygiene and some oral microbiota such as *Lactobacilli sp.* or *Streptococcus mutans* were associated with root caries experience [14]. The present systematic review on longitudinal studies found these factors to be predictors of new root caries as well. These findings highlight the importance of achieving good oral hygiene, especially the reduction of plaque on exposed root surfaces, in the prevention of root caries. However, these findings should be interpreted with caution because there may not be a cause-effect relationship between the presence of these bacteria and root caries since the information comes from observational studies only. Well-designed laboratory studies and clinical trials are needed so as to have an in-depth understanding of the relationship.

Presence or the amount of gingival recession was reported to be positively correlated with the number of DF-root in cross-sectional studies [14,32]. Findings of the present systematic review further show that these factors are predictors of new root caries. This is an expected correlation because having exposed root surfaces is a basic condition for root caries development and an increase in the amount of exposed surface would increase the risk. As the amount of gingival recession increases with age among older adults [33], this can partly explain why age was consistently reported to be a predictor of root caries in the studies included in this review.

Regarding the number of teeth, different directions of association with DF-root or D-root increment were reported in the included studies of this systematic review, making it difficult to draw a conclusion on this factor. Regarding past caries experience, this review found that root caries experience is a consistent and significant predictor of new root caries. Thus, clinically it is important to provide more intensive prevention for patients who have decayed and/or filled root surfaces.

Consistent with the findings of reviews on cross-sectional studies [14,34], a positive association between use of tobacco and new root caries was also found in most of the included cohort studies in the present systematic review. This may be because tobacco users usually have poor oral health habits and poor oral hygiene, and more advanced periodontal diseases [35].

Disparity in dental caries among different social classes has been reported [36]. People at a lower education or income level are more likely to have less knowledge of oral health and poorer oral health related behaviors [36,37]. Moreover, people who live in rural areas usually have poorer access to preventive dental care [38]. This systematic review found that these factors are important predictors of root caries and there is a need to provide more dental caries prevention to these disadvantaged population groups.

The cohort study included this review found a negative relationship between fluoride exposure and new root caries. This is in agreement with a number of clinical trials which found that the use of topical fluorides can prevent root caries [39,40]. Another clinical trial also found that participants who used higher concentration fluoride toothpaste developed less root caries [41].

This systematic review has a few strengths. First, in order to reduce the risk of bias in drawing conclusions, only studies with a follow-up rate higher than 50% were included. In addition, in order to provide more comprehensive information, findings from both the crude and the adjusted data analysis of the included studies were extracted and presented. Furthermore, only papers published after 1990 were included in this review so that the information obtained would be closer to the current situation in the aging populations. Besides, to the best of our knowledge, this is the first systematic review summarizing all risk predictors of root caries and further classifying them into defined categories. The grouping of potential risk factors of root caries in this review can offer guidance for developing effective strategies for root caries prevention.

A major limitation of in this systematic review is that a meta-analysis could not be conducted because of the heterogeneity of the included studies. Thus, the results of this review do not contain any quantitative findings such as pooled relative risk for the different identified predictors.

It is interesting to note that the risk factors associated with root caries in cross-sectional studies found in a previous systematic review [14] and the risk predictors of new root caries found in this systematic review overlap to a great extent even though the studies included in the two reviews were completely different. The findings of this systematic review are valuable for assessing the risk of new root caries development. They are also useful in developing prediction models of root caries. These models can be used to identify persons who need more root caries prevention before the development of root caries. Appropriate prevention and management strategies can be adopted according to the predicted root caries risk of individuals and population groups. Improvement in oral hygiene, prevention of gingival recession and use of fluoride would be good strategies for root caries prevention. Furthermore, results of this systematic review would be useful for government and dental public health workers when designing community based preventive strategy for root caries, especially for the aging populations.

6. Conclusion

This systematic review discovered a number of root caries risk predictors in different categories. People who are older, in lower socioeconomic status or tobacco users, and those with more caries experience, gingival recession and poorer oral hygiene are at higher risk of developing new root caries.

Declaration of Competing Interest

We declare there is no conflict of interest in this article.

Acknowledgment

We thank Ms. Samantha Li for her statistical support.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jdent.2019.07.004.

References

[1] United Nations, Department of Economic and Social Affairs, Population Division, World Population Ageing, 2015.
[2] R. Gluzman, R.V. Katz, B.J. Frey, R. McGowan, Prevention of root caries: a literature review of primary and secondary preventive agents, Spec. Care Dent. 33 (3) (2013) 133–140.
[3] S. Griffin, P. Griffin, J. Swann, N. Zlobin, Estimating rates of new root caries in older adults, J. Dent. Res. 83 (8) (2004) 634–638.
[4] D. Locker, J.L. Leake, Coronal and root decay experience in older adults in Ontario, Canada, J. Pub. Health Dent. 53 (3) (1993) 158–164.
[5] J.K. Kim, L.A. Baker, H. Seirawan, E.M. Crimmins, Prevalence of oral health problems in US adults, NHANES 1999–2004: exploring differences by age, education, and race/ethnicity, Spec. Care Dent. 32 (6) (2012) 234–241.
[6] Y. Gao, T. Hu, X. Zhou, R. Shao, R. Cheng, G. Wang, Y. Yang, X. Li, B. Yuan, T. Xu, How root caries differs between middle-aged people and the elderly: findings from the 4th national oral health survey of China, Chin. J. Dent. Res. 21 (3) (2018) 221–229.
[7] D. Locker, Incidence of root caries in an older Canadian population, Community Dent. Oral Epidemiol. 24 (6) (1996) 403–407.
[8] L.V. Powell, B.G. Leroux, R.E. Persson, H.A. Kiyak, Factors associated with caries incidence in an elderly population, Community Dent. Oral Epidemiol. 26 (3) (1998) 170–176.
[9] S. Fure, Ten-year cross-sectional and incidence study of coronal and root caries and some related factors in elderly Swedish individuals, Gerodontology 21 (3) (2004) 130–140.
[10] M. Cronin, S. Meaney, N.J. Jepson, P.F. Allen, A qualitative study of trends in patient preferences for the management of the partially dentate state, Gerodontology 26 (2) (2009) 137–142.
[11] A.E. Gerritsen, P.F. Allen, D.J. Witter, E.M. Bronkhorst, N.H. Creugers, Tooth loss and oral health–related quality of life: a systematic review and meta-analysis, Health Quality Life Outcomes 8 (1) (2010) 126.
[12] N. Hariyani, A.J. Spencer, J.D.L. Luzzi, L.G. Do, Root surface caries among older Australians, Community Dent. Oral Epidemiol. 46 (6) (2018) 535–544.
[13] A.V. Ritter, J.S. Preisser, Y. Chung, J.D. Bader, D.A. Shugars, B.T. Amaechi, S.K. Makhija, K.A. Funkhouser, W.M. Vollmer, Risk indicators for the presence and extent of root caries among caries-active adults enrolled in the xylitol for adult caries trial (X-ACT), Clin. Oral Invest. 16 (6) (2012) 1647–1657.
[14] J. Zhang, D. Sardana, M.C.M. Wong, K.C.M. Leung, E.C.M. Lo, Factors associated with dental root caries: a systematic review, JDR Clin Trans Res. (2019), https://doi.org/10.1177/2380084419849045 Epub ahead of print.
[15] A.V. Ritter, D.A. Shugars, J.D. Bader, Root caries risk indicators: a systematic review of risk models, Community Dent. Oral Epidemiol. 38 (5) (2010) 383–397.
[16] G. Wells, B. Shea, D. O'connell, J. Peterson, V. Welch, M. Losos, P. Tugwell, The Newcastle-Ottawa Scale (nos) for assessing the quality of nonrandomised studies in meta-analyses, Ottawa Hospital Research Institute, Ottawa, 2016.
[17] P. Jüni, A. Witschi, R. Bloch, M. Egger, The hazards of scoring the quality of clinical trials for meta-analysis, J. Am. Med. Assoc. 282 (11) (1999) 1054–1060.
[18] M. Hayes, C. Da Mata, G. McKenna, F.M. Burke, P.F. Allen, Evaluation of the Cariogram for root caries prediction, J. Dent. 62 (2017) 25–30.
[19] H. Senpuku, H. Miyazaki, S. Yoneda, A. Yoshihara, A. Tada, A quick statistically accurate diagnosis for caries risk in the elderly, Clin. Laboratory 56 (11-12) (2010) 505–512.
[20] N. Takano, Y. Ando, A. Yoshihara, H. Miyazaki, Factors associated with root caries incidence in an elderly population, Community Dent. Health 20 (4) (2003) 217–222.
[21] S. Sánchez-García, H. Reyes-Morales, T. Juárez-Cedillo, C. Espinel-Bermúdez, F. Solórzano-Santos, C. García-Peña, A prediction model for root caries in an elderly population, Community Dent. Oral Epidemiol. 39 (1) (2011) 44–52.
[22] H.P. Lawrence, R.J. Hunt, J.D. Beck, G.M. Davies, Five-year incidence rates and intraoral distribution of root caries among community-dwelling older adults, Caries Res. 30 (3) (1996) 169–179.
[23] H.P. Lawrence, R.J. Hunt, J.D. Beck, Three-year root caries incidence and risk modeling in older adults in North Carolina, J. Public Health Dent. 55 (2) (1995) 69–78.
[24] A.B. Bidinotto, A.B. Martins, C.M. dos Santos, F.N. Hugo, J.B. Hilgert, R.K. Celeste, R.J. De Marchi, Four-year incidence rate and predictors of root caries among community-dwelling south Brazilian older adults, Community Dent. Oral Epidemiol. 46 (2) (2018) 125–131.
[25] B. Ellefsen, P. Holm-Pedersen, D.E. Morse, M. Schroll, B.B. Andersen, G. Waldemar, Assessing caries increments in elderly patients with and without dementia: a one-year follow-up study, J. Am. Dent. Assoc. 140 (11) (2009) 1392–1400.
[26] N. Sugihara, Y. Maki, A. Kurokawa, T. Matsukubo, Cohort study on incidence of coronal and root caries in Japanese adults, Bulletin Tokyo Dent. College 55 (3) (2014) 125–130.
[27] G.H. Gilbert, R.P. Duncan, T.A. Dolan, U. Foerster, Twenty–four month incidence of root caries among a diverse group of adults, Caries Res. 35 (5) (2001) 366–375.
[28] A. Joshi, A.S. Papas, J. Giunta, Root caries incidence and associated risk factors in middle-aged and older adults, Gerodontology 10 (2) (1993) 83–89.
[29] S. Fure, Five-year incidence of caries, salivary and microbial conditions in 60-, 70- and 80-year-old Swedish individuals, Caries Res. 32 (3) (1998) 166–174.
[30] A. Scheinin, K. Pienihäkkinen, J. Tiekso, S. Holmberg, M. Fukuda, A. Suzuki, Multifactorial modeling for root caries prediction: 3-year follow-up results, Community Dent. Oral Epidemiol. 22 (2) (1994) 126–129.
[31] W.M. Thomson, A.J. Spencer, G.D. Slade, J.M. Chalmers, Is medication a risk factor for dental caries among older people? Evidence from a longitudinal study in South Australia, Community Dent. Oral Epidemiol. 30 (3) (2002) 224–232.
[32] I. Bignozzi, A. Crea, D. Capri, C. Littarru, C. Lajolo, D.N. Tatakis, Root caries: a periodontal perspective, J. Perio. Res. 49 (2) (2014) 143–163.
[33] M.M. Kassab, R.E. Cohen, The etiology and prevalence of gingival recession, J Am. Dent. Assoc. 134 (2) (2003) 220–225.
[34] D.M. Winn, Tobacco use and oral disease, J. Dent. Educ. 65 (4) (2001) 306–312.
[35] F.R.M. Leite, G.G. Nascimento, F. Scheutz, R. López, Effect of smoking on periodontitis: a systematic review and meta-regression, Am. J. Preventive Med. 54 (2018) 831–841.
[36] S.M. Costa, C.C. Martins, L. Bonfim Mde, L.G. Zina, S.M. Paiva, I.A. Pordeus, M.H. Abreu, A systematic review of socioeconomic indicators and dental caries in adults, Int. J. Enviro. Res. Public Health 9 (10) (2012) 3540–3574.
[37] S. Listl, Income-related inequalities in dental service utilization by Europeans aged 50+, J. Dent. Res. 90 (6) (2011) 717–723.
[38] D. Brennan, A.J. Spencer, F. Szuster, Rates of dental service provision between capital city and noncapital locations in Australian private general practice, Aus. J. Rural Health 6 (1) (1998) 12–17.
[39] W. Zhang, C. McGrath, E.C.M. Lo, J.Y. Li, Silver diamine fluoride and education to prevent and arrest root caries among community-dwelling elders, Caries Res. 47 (4) (2013) 284–290.
[40] H.P. Tan, E.C.M. Lo, J.E. Dyson, Y. Luo, E.F. Corbet, A randomized trial on root caries prevention in elders, J. Dent. Res. 89 (10) (2010) 1086–1090.
[41] K.R. Ekstrand, J.E. Poulsen, B. Hede, S. Twetman, V. Qvist, R.P. Ellwood, A randomized clinical trial of the anti-caries efficacy of 5,000 compared to 1,450 ppm fluoridated toothpaste on root caries lesions in elderly disabled nursing home residents, Caries Res. 47 (5) (2013) 391–398.