



Periodontitis assessed with a new screening tool and oral health-related quality of life: cross-sectional findings among general-population adults

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Abstract

Introduction Periodontitis, as a chronic, multifactorial inflammatory disease, has complex relationships with other diseases and ultimately with well-being. The aim of this cross-sectional study was to investigate the association between self-report periodontitis, as measured with the recently developed and validated modified Periodontal Screening Score (mPESS), and oral health-related quality of life (OHRQoL) in a large population-based sample derived from the French NutriNet-Santé e-cohort.

Methods The sample was composed of 32,714 adults (75.5% women) with a mean age of 48.8 ± 13.9 years. Periodontitis was assessed based on age, smoking, and oral health status data obtained in 2011–2012, which allowed calculating the mPESS. An $mPESS \geq 5$ was used to identify individuals at risk of severe periodontitis (main exposure). OHRQoL was measured with the Oral Health Impact Profile (OHIP-14) (main outcome) and the total score was dichotomized for analysis. Multivariable logistic regression analyses, considering physical health status, dietary and lifestyle confounding variables, were performed.

Results Overall, 6407 participants (19.6%) were at a high risk of severe periodontitis. A total of 7383 participants (22.6%) presented a relatively poor OHRQoL (OHIP-14 > 8, highest quartile). In the multivariable model, each of the following variables was independently and significantly associated with lower OHRQoL: older age (50–64 years), female sex, obesity, snacking between meals, frequent consumption of soft drinks and sweets/chocolate, risk of severe periodontitis, and having < 20 natural teeth were significantly. An $mPESS \geq 5$ showed the highest odds for relatively poor OHRQoL (OR = 3.45; 95% CI 3.21–3.72).

Conclusion The results support the association between periodontitis and OHRQoL in non-clinical samples. The use of mPESS could be tested in future prevention programs aiming at improving OHRQoL.

Keywords Oral health related quality of life · Oral health · Periodontitis · Questionnaire · Nutrition

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Introduction

Health-related quality of life (HRQoL) is an individual's or a group's perceived physical and mental health and comfort over time [1]. There is no doubt that oral health, as part of general health, has an impact on the individual's well-being and quality of life (QoL) overall [1, 2].

Oral health-related quality of life (OHRQoL) is a person-centered outcome based on multidimensional and subjective concepts [3]. It measures the possible impact an oral disease, symptom and/or treatment may have on different dimensions of a person's life. Previous studies have shown an association between OHRQoL and periodontal diseases, including gingivitis and periodontitis [4–6], but the methodologies were highly heterogeneous. Most of the studies used the Oral Health Impact Profile 14 (OHIP-14) [7], analyzed convenience samples covering an age range of 15–75 years and sample sizes were highly variable, ranging from 24 to 6469 individuals [4]. Further, most of the studies did not address important confounding variables in their analyses, particularly those related to socio-economic characteristics, chronic systemic diseases, oral hygiene or dietary habits. Only a few studies were performed in European countries; a Swedish [8] and a Swiss [9] study included convenience samples of 204 and 215 individuals, respectively. Two larger studies from the UK included community samples and national samples of 3122 [10] and 6318 [11] individuals, respectively. One recent study included a limited number of variables in the multivariable model, none of them related to diet [11]. Nevertheless, the literature has suggested an association between periodontal diseases and OHRQoL [2, 12–16]. Social life, life experiences, and self-confidence are aspects of human nature deeply interwoven with perceptions of happiness and QoL, and all of these aspects are negatively affected by periodontitis [5, 17]. Moreover, periodontitis, as a chronic, multifactorial inflammatory disease, has complex relationships with other diseases, particularly diabetes, hypertension and cardiovascular diseases [18–20], and is linked to many behavioral and lifestyle factors [21], such as smoking habits, psychosocial stress, and nutrition [22, 23]. All of these factors have also been shown to potentially impact QoL and OHRQoL [13, 24–29]. Consequently, research using large non-clinical samples of adults at risk of severe periodontitis are needed, together with control for dietary and other confounding variables, to adequately analyze the relationship between periodontal disease and OHRQoL. The present analysis, which takes into consideration a large array of variables potentially impacting OHRQoL, investigated the association between self-reported periodontitis, as measured with the recently developed modified Periodontal Screening Score (mPESS) and the OHIP-14 score in a large

population-based sample derived from the French NutriNet-Santé e-cohort.

Materials and methods

Study design and study population

The ongoing NutriNet-Santé web cohort (www.etude-nutri-net-sante.fr) was launched in 2009 [30]; it was approved by the human subjects participation ethics board of the French Institute for Health and Medical Research and by the National Commission on Informatics and Liberty. NutriNet-Santé is registered at www.clinicaltrials.gov (#NCT03335644). Prior to inclusion, each participant provides an informed consent and an electronic signature.

All participants are adult volunteers (≥ 18 years) with Internet access, having been recruited via multimedia calls. Participation in the e-cohort consists in completing annual questionnaires about socio-demographic, lifestyle, health status, physical activity, anthropometric, and diet-related parameters. On a regular basis during the follow-up, participants also receive questionnaires on particular health- or diet-related topics.

For the present analyses, we selected 39,971 individuals who had enrolled in the cohort between 2009 and 2012 and who had responded to two oral health questionnaires administered in 2011 and 2012 (described below). Participants reporting pregnancy (at the time of the oral health questionnaire completion), being completely edentulous or wearing a complete denture, or with incomplete data from the oral health questionnaires were not eligible. Due to the observational, cross-sectional nature of the study, the STROBE checklist was used as a reporting guideline [31].

Study outcome assessment

In the present study, the main outcome variable was OHRQoL and it was measured using the OHIP-14 [7]. This is one of the most widely used measures in the domain of OHRQoL, particularly in epidemiological studies assessing the impact of periodontal diseases on various health outcomes [32]. It represents the short version of the OHIP-49, originally developed by Slade et al. in 1994 [33], which provides an evaluation of how various aspects of oral health might affect the physical, psychological, and social aspects of the individual's life [2, 34]. This questionnaire has been translated and validated for use with French-speaking adults [35]. Based on 14 self-report items grouped in 7 dimensions, the OHIP-14 measures functional limitations, physical pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap. The responses are

recorded on a Likert scale with values ranging from 0 to 4, as follows: never (score 0), hardly ever (score 1), occasionally (score 2), fairly often (score 3), and very often (score 4). The higher the average value on each of the 7 dimensions, the more negative the impact of one's oral health on their QoL. The cumulative OHIP-14 score ranges from 0 (best OHRQoL) to 56 (worst OHRQoL), and is calculated by summing up the ordinal values for the 14 items. For each domain, scores can range from 0 to 8. Higher OHIP-14 scores indicate worse OHRQoL and lower OHIP-14 scores indicate better OHRQoL.

Exposure assessment

Periodontitis was the main exposure in this analysis. This variable was obtained using the French version of the Centers for Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP) instrument [36], integrated in the oral health questionnaires, self-administered in 2011 and 2012. In total, $n = 102988$ NutriNet-Santé participants received and $n = 39971$ completed these two questionnaires on a voluntary basis. The CDC/AAP tool allowed us to calculate the modified Periodontal Screening Score, namely the mPESS, based on four specific questions about oral status, plus age and smoking status (Supplemental Table S1) [37]. The mPESS was validated against a clinical diagnosis of periodontitis and was shown to be an accurate self-report tool, with an mPESS ≥ 5 being associated with the highest specificity and sensitivity to detect individuals suffering from severe periodontitis (area under the ROC = 0.815; mPESS sensitivity: 71.3%; specificity: 79.5%) [37, 38]. As a supplemental oral health exposure, we considered the number of natural teeth, dichotomized as $<$ or ≥ 20 teeth [39].

Covariate assessment

Baseline socio-demographic, lifestyle, and health-related variables were also considered as co-exposures. These were obtained from validated questionnaires [40, 41] and included: age, sex, anthropometric measures [based on self-reported weight and height, which allowed the calculation of body mass index (BMI)], education, marital status, socio-professional category, household income, smoking status, mean daily physical activity, mean daily alcohol consumption [38], oral health-related dietary habits (i.e., frequency of snacking, sweets/candy consumption and soft drinks intake), and health status (prevalent diabetes, cancer, and/or major cardiovascular diseases).

Educational level was categorized as high school degree or less, undergraduate or graduate degree. Socio-professional categories included manual workers, administrative staff, self-employed/intermediate-skill professions and

executive staff. Household income included 4 monthly revenue categories in Euros (< 1200 ; 1200–1799; 1800–2699; and ≥ 2700) plus one “not reported” category. Marital status was categorized into married/in a couple or single/divorced/widowed.

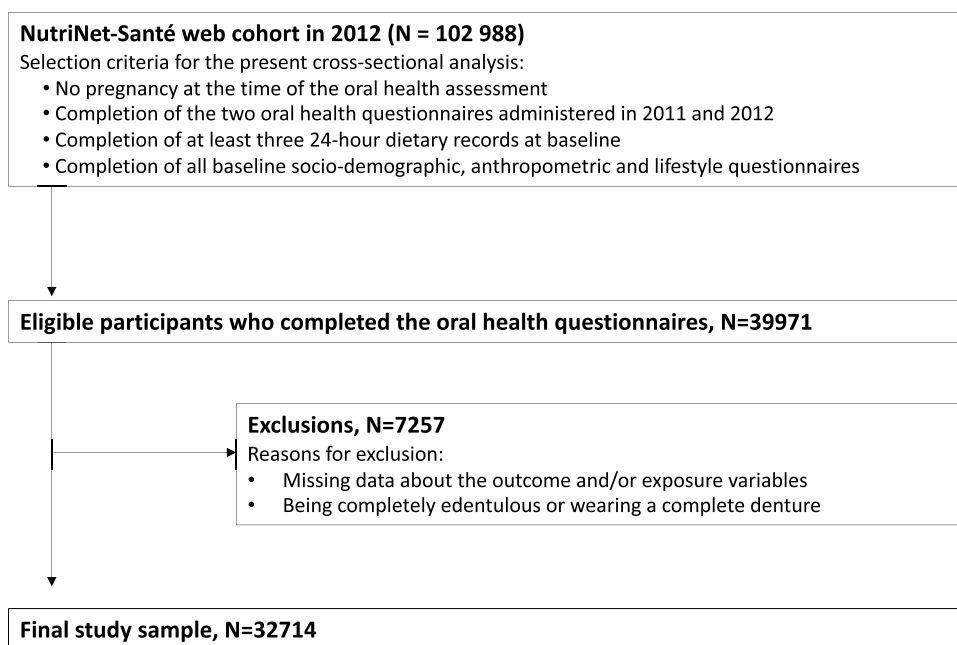
Smoking status was categorized as current smoker (every day or occasionally), former or never smoker. Physical activity was modeled as three categories: < 30 min walking/day; between 30 and 59 min walking/day; and ≥ 60 min walking/day [20, 38]. Alcohol consumption was obtained from 24-h dietary records completed on 3 non-consecutive days and was expressed in g ethanol/day; the variable was dichotomized according to a sex-specific threshold (≥ 20 g/day for women, ≥ 30 g/day for men), as previously reported [38]. Frequency of snacking between meals and consumption of candy, sweets, chocolate and soft drinks were evaluated by specific questions included in the oral health questionnaires (response options ranging from four times/day to never). Self-reported information about prevalent major cardiovascular disease (myocardial infarction, stroke, and acute coronary syndrome), cancer (any type except basal cell carcinoma) and type 1 or type 2 diabetes was obtained from health status questionnaires; these data were validated using hospital records, reported treatment, and linkage with national medico-administrative databases.

Statistical analyses

Descriptive analyses were used to evaluate OHRQoL in the full sample; results are reported as frequency (%) of OHIP-14 “fairly often or very often” responses and as mean values (standard deviation, SD). Next, given the absence of an established cutoff, the sample was divided into two groups based on the highest OHIP-14 total score quartile, identifying individuals with the poorest OHRQoL. Group comparisons were performed regarding socio-demographics, lifestyle, general health, and oral health variables by Chi-squared tests. The Pearson correlation between mPESS and OHIP-14 as continuous variables was also calculated. Interaction by sex was tested since males and females might differ in their reports of OHRQoL [42] and QoL [43].

Multivariable logistic regression analyses were conducted to assess the association between self-reported severe periodontitis (mPESS ≥ 5) and poor OHRQoL (highest OHIP-14 quartile). First, a partially adjusted model was tested, including age (continuous scale) and sex as covariables (Model 1); then, a fully adjusted model was run including all covariables that reached a significant difference between the two groups in the bivariate analysis (Model 2). To maintain the total sample size, the “I don't know” and “Not reported” responses were modeled as a separate response category. Adjusted odds ratios (OR) along with 95% confidence intervals (CI) assessed the strength of the associations for each

Fig. 1 Flowchart of participant selection from the NutriNet-Santé web cohort



exposure variable. A sensitivity analysis was carried out to assess the relationship between the main exposure and outcome in participants without chronic diseases, which might confound QoL measures. Statistical analyses were carried out with SPSS (IBM Statistics, version 23). All tests were two-sided and a p value < 0.05 was considered statistically significant.

Results

Sample characteristics

From the sample of 39,971 individuals who completed the two oral health questionnaires, 32,714 adults met the inclusion criteria and were selected for the present analyses (Fig. 1).

The study sample had a mean age of 48.8 ± 13.9 years; the majority were aged between 26 and 49 years (43.6%) and between 50 and 64 years (37.7%). More than 2/3 of the sample was composed of women. The mean BMI was 23.8 ± 4.3 kg/m².

According to mPESS, 6407 individuals (19.6%) had self-reported severe periodontitis (4591 females and 1816 males). A significantly higher percentage of individuals with an mPESS ≥ 5 was found among males than females (22.7% vs. 18.6%, respectively; $p < 0.0001$). Overall, 4899 individuals (15.5%) reported having < 20 natural teeth.

The overall mean OHIP-14 score was 5.63 ± 6.54 (range 0–56), and it was not normally distributed. The items most frequently endorsed were: being self-conscious of oral

diseases or having problems with gums and teeth (8.1%), feeling aching in the mouth (4.9%), being uncomfortable when eating (4.3%), feeling tense (3.8%) or embarrassed (3.6%) due to problems with teeth, mouth or dentures (Table 1). The OHIP-14 dimensions that were the most frequently endorsed were physical pain and psychological discomfort. A significant positive correlation was found between the mPESS and the OHIP-14 values (Pearson r : 0.25; $p < 0.0001$), with a significant quantitative interaction by sex ($p < 0.0001$). Overall, 7383 participants (22.6%) had an OHIP-14 > 8 (highest quartile cutoff) and were considered to have a low OHRQoL.

Association between self-reported periodontitis and OHRQoL in the full sample and by sex

All socio-demographic, lifestyle, general health, and oral health variables except for alcohol intake were significantly different by OHRQoL status [OHIP-14 ≤ 8 (good/average OHRQoL) versus OHIP > 8 (low OHRQoL)] (Table 2).

In the full sample, the multivariable analysis adjusted for age and sex only (Model 1) showed a number of significant associations with poor OHRQoL; particularly, mPESS ≥ 5 increased the odds of having OHIP-14 > 8 (OR = 3.95; 95% CI 3.7–4.32). Older age, female sex, being overweight or obese, being a current or former smoker, living alone, suffering from diabetes or cardiovascular diseases, snacking between meals, frequently consuming candy, sweets, chocolate or soft drinks were also associated with higher odds of poor OHRQoL (Table 3). Conversely, daily physical activity of > 30 min of walking, monthly household income > 2700 €,

Table 1 OHIP-14 questions and dimension scores in the full sample, 2009–2012, NutriNet-Santé web cohort, France ($n = 32,714$)

OHIP-14 questions			OHIP-14 dimensions	
Item	Frequency of reporting “fairly/very often”	Mean value (SD)	Dimension	Mean value (SD)
Having trouble pronouncing words	0.6%	0.11 (0.42)	Functional limitations	0.32 (0.80)
Experiencing worsened sense of taste	1.0%	0.22 (0.50)		
Feeling painful aching in the mouth	4.9%	1.09 (0.88)	Physical pain	1.76 (1.57)
Being uncomfortable to eat	4.3%	0.67 (0.92)		
Being self-conscious	8.1%	0.97 (1.02)	Psychological discomfort	1.48 (1.71)
Feeling tense	3.8%	0.51 (0.86)		
Avoiding some food—having an unsatisfactory diet	3.0%	0.47 (0.82)	Physical disability	0.58 (1.08)
Interrupting meals	0.4%	0.11 (0.41)		
Difficulty relaxing	1.0%	0.22 (0.58)	Psychological disability	0.84 (1.28)
Feeling embarrassed	3.6%	0.62 (0.87)		
Being irritable	0.9%	0.22 (0.57)	Social disability	0.31 (0.84)
Difficulty doing usual tasks	0.4%	0.09 (0.38)		
Perceiving life as less satisfying	1.8%	0.25 (0.65)	Handicap	0.32 (0.85)
Feeling completely unable to function	0.2%	0.07 (0.32)		
Total score ^a	–	5.63 (6.54) range (0–56)		

OHRQoL Oral health-related quality of life, *OHIP-14* Oral Health Impact Profile

^aThe OHIP-14 score range goes from 0 (best OHRQoL) to 56 (worst OHRQoL)

and higher socio-professional categories were found to be protective factors regarding OHRQoL. After a full adjustment (Model 2), severe periodontitis in the total sample was associated with higher odds (OR = 3.45, 95% CI 3.21–3.72) of poor OHRQoL. Having < 20 natural teeth in the oral cavity was also associated with higher odds (OR = 1.48, 95% CI 1.29–1.71) of poor OHRQoL. Some lifestyle habits were associated with low OHRQoL, such as smoking (OR = 1.24, 95% CI 1.06–1.46), snacking between meals (OR = 1.64, 95% CI 1.42–1.90), and consuming chocolate, candies, and sweets (OR = 1.23, 95% CI 1.16–1.31). Overweight or obese or participants had a poorer OHRQoL as compared to participants with a BMI < 25. Older participants had a greater likelihood of reduced OHRQoL compared to their younger counterparts.

The sex-specific results were largely consistent with the main results, however differences in magnitude emerged (Table 4).

Due to the inverse association between QoL measures and chronic illness [44, 45], a sensitivity analysis was performed in a subgroup of $n = 29,510$ individuals after excluding all participants with prevalent cancer, major cardiovascular diseases and/or diabetes. The results largely replicated the main findings, showing that periodontitis (mPESS ≥ 5) remained significantly associated with OHIP-14 > 8 (fully adjusted OR = 3.69; 95% CI 3.42–3.97) (data not tabulated).

Discussion

This population-based cross-sectional study investigated the association between self-reported severe periodontitis and OHRQoL, taking into consideration socio-demographic, dietary, lifestyle, and general health status variables. The results, based on a large, heterogeneous sample of French adults enrolled in the NutriNet-Santé web cohort, showed that the risk of severe periodontitis, assessed via a new screening tool—the mPESS—was strongly linked to OHRQoL. It is important to note that an mPESS ≥ 5 was independently associated with a 3.4 times increased odds of having poorer OHRQoL. The direction and significance of the associations were consistent across sex, yet the effect sizes were somewhat stronger in males than in females. In addition, the results remained largely unchanged after excluding individuals with chronic diseases.

In accordance with previous reports, the most affected OHRQoL domains in the NutriNet-Santé e-cohort were physical pain, psychological discomfort and disabilities [4, 9, 10, 46, 47]. Assessing the impact of oral health/illness on QoL (i.e., OHRQoL) is complex due to the presence of multiple exposures beyond the oral cavity, which can be interdependent. For instance, the number of teeth can affect masticatory capacity, which may lead to changes in dietary habits and ultimately may have consequences regarding BMI status and general health [48–50]. Moreover, some

Table 2 Socio-demographic, lifestyle and health status characteristics for the total study sample and by group of individuals with a total OHIP-14 score ≤ 8 versus those with OHIP-14 > 8 (4th quartile corresponding to poorest OHRQoL)

Variable	Total sample ($n = 32,714$)	Individuals with OHIP score ≤ 8 ($n = 25,331$)	Individuals with OHIP score > 8 ($n = 7383$)	Bivariate analysis P value
Socio-demographic variables				
Age category [n (%)]				< 0.0001
18–25	1709 (5.2)	1383 (5.5)	326 (4.4)	
26–49	14,247 (43.5)	11,276 (44.5)	2971 (40.2)	
50–64	12,346 (37.8)	9288 (36.7)	3058 (41.4)	
≥ 65	4412 (13.5)	3384 (13.4)	1028 (13.9)	
Sex [n (%)]				< 0.0001
Female	24,719 (75.6)	18,822 (74.3)	5897 (79.9)	
Male	7995 (24.4)	6509 (25.7)	1486 (20.1)	
Marital status [n (%)]				< 0.0001
Married, living in a couple	24,004 (73.4)	18,785 (74.2)	5219 (70.7)	
Single, divorced, widowed	8710 (26.6)	6546 (25.8)	2164 (29.3)	
Educational level [n (%)]				< 0.0001
High school or less	10,460 (32.0)	7898 (31.2)	2562 (34.7)	
Undergraduate degree	11,151 (34.1)	8558 (33.8)	2593 (35.1)	
Graduate degree	10,867 (33.2)	8694 (34.3)	2173 (29.4)	
Other/not reported	236 (0.7)	181 (0.7)	55 (0.7)	
Household income (€/month) [n (%)]				< 0.0001
< 1200	2668 (8.2)	1894 (7.5)	774 (10.5)	
1200–1799	3339 (10.2)	2491 (9.8)	848 (11.5)	
1800–2699	4960 (15.2)	3748 (14.8)	1212 (16.4)	
≥ 2700	18,433 (56.3)	14,552 (57.4)	3881 (52.6)	
Not reported	3314 (10.1)	2646 (10.4)	668 (9.0)	
Socio-professional category [n (%)]				< 0.0001
Manual workers/farmers	869 (2.7)	635 (2.5)	234 (3.2)	
Self-employed/artisan/merchant/entrepreneur/intermediate-skills profession	10,227 (31.3)	7880 (31.1)	2347 (31.8)	
Office work/administrative staff	8539 (26.1)			
Intellectual profession/executive staff	11,848 (36.2)	9437 (37.3)	2411 (32.7)	
Not reported	1231 (3.7)	991 (3.9)	240 (3.3)	
Lifestyle behaviors				
Physical activity				0.002
< 30 min of walking/day	6840 (20.9)	5184 (20.5)	1656 (22.5)	
≥ 30 min but < 60 min of walking/day	6797 (20.8)	5313 (21.0)	1484 (20.1)	
≥ 60 min of walking/day	14,620 (44.7)	11,391 (45.0)	3229 (43.7)	
Not reported	4457 (13.6)	3443 (13.6)	1014 (13.7)	
Smoking status and frequency [n (%)]				< 0.0001
Yes, every day	2951 (9.0)	2081 (8.2)	870 (11.8)	
Yes, occasionally	1321 (4.0)	1032 (4.1)	289 (3.9)	
Former smoker	11,761 (36.0)	8982 (35.5)	2779 (37.6)	
Never smoked	16,681 (51.0)	13,236 (52.3)	3445 (46.7)	
Daily alcohol consumption above the sex-specific threshold ^a [n (%)]				0.075
Yes	2793 (8.5)	2125 (8.4)	668 (9.0)	
No	29,921 (91.5)	23,206 (91.6)	6715 (91.0)	
Frequency of snacking between meals [n (%)]				< 0.0001
4 times/day	27 (0.1)	13 (0.1)	14 (0.2)	
1–3 times/day	887 (2.7)	566 (2.2)	321 (4.3)	

Table 2 (continued)

Variable	Total sample (<i>n</i> = 32,714)	Individuals with OHIP score ≤ 8 (<i>n</i> = 25,331)	Individuals with OHIP score > 8 (<i>n</i> = 7383)	Bivariate analysis <i>P</i> value
< once/day	12,259 (37.5)	9233 (36.4)	3026 (41.0)	
Never	19,541 (59.7)	15,519 (79.4)	4022 (54.5)	
Frequency of consumption of chocolate, candies, and sweets [<i>n</i> (%)]				< 0.0001
4 times/day	227 (0.7)	142 (0.6)	85 (1.2)	
1–3 times/day	8993 (27.5)	6707 (26.5)	2286 (31.0)	
< once/day	21,039 (64.3)	16,542 (65.3)	4497 (60.9)	
Never	2455 (7.5)	1940 (7.7)	515 (7.0)	
Frequency of consumption of soft drinks [<i>n</i> (%)]				< 0.0001
4 times/day	169 (0.5)	114 (0.5)	55 (0.7)	
1–3 times/day	4546 (13.9)	3463 (13.6)	1083 (14.7)	
< once/day	15,771 (48.2)	12,187 (48.1)	3584 (48.5)	
Never	12,228 (37.4)	9567 (37.8)	2661 (36.0)	
Physical health status				
BMI category, kg/m ² [<i>n</i> (%)]				< 0.0001
< 25	22,903 (70.0)	17,832 (70.4)	5071 (68.7)	
25–29	7140 (21.8)	5565 (22.0)	1575 (21.3)	
≥ 30	2671 (8.2)	1934 (7.6)	737 (10.0)	
Diabetes (Type I or II, prevalent cases) [<i>n</i> (%)]				< 0.0001
Yes	731 (2.2)	526 (2.1)	205 (2.8)	
No	31,983 (97.8)	24,805 (97.9)	7178 (97.2)	
Cardiovascular diseases (prevalent cases) ^b [<i>n</i> (%)]				0.013
Yes	468 (1.4)	340 (1.3)	128 (1.7)	
No	32,246 (98.6)	24,991 (98.7)	7255 (99.3)	
Cancers (any type or organ, prevalent cases) ^c [<i>n</i> (%)]				0.029
Yes	2174 (6.6)	1642 (6.5)	532 (7.2)	
No	30,540 (93.4)	23,689 (93.5)	6851 (92.8)	
Periodontal health variables				
mPESS (modified Periodontal Screening Score)				< 0.0001
mPESS ≥ 5	6407 (19.6)	3707 (14.6)	2700 (36.6)	
mPESS < 5	26,307 (80.4)	21,624 (85.4)	4683 (63.4)	
Number of natural teeth [<i>n</i> (%)]				< 0.0001
< 20 teeth	4899 (15.0)	2930 (11.6)	1,969 (26.7)	
≥ 20 teeth	26,735 (81.7)	21,623 (85.4)	5112 (69.2)	
I don't know	1080 (3.3)	778 (3.1)	302 (4.1)	

^aThreshold used: ≥ 20 g/day of ethanol for women, ≥ 30 g/day of ethanol for men [38]

^bIncluding myocardial infarction, stroke, and acute coronary syndrome

^cExcluding basal cell carcinoma

oral diseases, including periodontitis, have a multifactorial etiology that includes physical health status and behavioral risk factors, such as smoking, alcohol consumption, poor dietary habits, physical inactivity, and diabetes [38, 51–54]. Most of these factors were assessed in the NutriNet-Santé

e-cohort allowing for an independent evaluation of OHRQoL related to periodontitis. This represents the main novelty and strength of the study, in addition to using a relatively new periodontitis screening tool. While confirming some previous results on the impact of periodontal diseases on

Table 3 Logistic regression analysis of the association between main and supplementary exposures (likelihood of severe periodontitis, number of natural teeth, socio-demographic, general health, and life-style variables) and odds of poorer oral health-related quality of life (OHIP-14 > 8, 4th quartile) in the full sample, 2009–2012, NutriNet-Santé web cohort, France ($n = 32,714$)

Variable	Full sample ($n = 32,714$)	
	Adjusted OR (95% CI) Model 1 ^a	Adjusted OR (95% CI) Model 2 ^b
Age category		
18–25	Reference	Reference
26–49	1.14 (1.01–1.30)	1.52 (1.28–1.81)
50–64	1.44 (1.27–1.64)	1.68 (1.52–1.85)
≥ 65	1.43 (1.24–1.65)	1.22 (1.12–1.34)
Sex		
Female	1.42 (1.33–1.52)	1.35 (1.26–1.45)
Male	Reference	Reference
Marital status		
Married, living in a couple	Reference	Reference
Single, divorced, widowed	1.19 (1.13–1.27)	1.04 (0.96–1.11)
Educational level		
High school or less	Reference	Reference
Undergraduate degree	0.92 (0.68–1.25)	1.03 (0.74–1.42)
Graduate degree	0.97 (0.72–1.32)	0.97 (0.70–1.34)
Other/not reported	1.13 (0.83–1.54)	1.02 (0.74–1.41)
Household income (€/month)		
< 1200	Reference	Reference
1200–1799	0.53 (0.51–0.65)	0.62 (0.54–0.70)
1800–2699	0.73 (0.65–0.82)	0.77 (0.69–0.88)
≥ 2700	0.77 (0.69–0.82)	0.81 (0.72–0.90)
Other/not reported	0.93 (0.84–1.02)	0.91 (0.82–1.00)
Socio-professional category		
Manual workers/farmers	Reference	Reference
Self-employed artisan/merchant / entrepreneur/intermediate-skills profession	1.06 (0.91–1.24)	1.03 (0.86–1.24)
Office work/administrative staff	0.70 (0.56–0.86)	0.81 (0.64–1.02)
Intellectual profession/executive staff	0.84 (0.72–0.98)	0.91 (0.75–1.08)
Other/not reported	0.95 (0.81–1.11)	0.97 (0.81–1.17)
Physical activity		
< 30 min of walking/day	Reference	Reference
≥ 30 min of walking/day	0.90 (0.85–0.95)	0.91 (0.86–0.96)
Smoking status and frequency		
Every day	1.64 (1.51–1.80)	1.24 (1.06–1.46)
Occasionally	1.40 (1.27–1.53)	1.12 (0.97–1.29)
Former smoker	1.45 (1.24–1.69)	1.10 (1.01–1.21)
Never smoked	Reference	Reference
Daily alcohol consumption above the sex-specific threshold^d		
Yes	1.11 (1.00–1.22)	1.03 (0.94–1.14)
No	Reference	Reference
Frequency of snacking between meals		
1–4 times/day	2.02 (1.76–2.32)	1.64 (1.42–1.90)
Less than once/day or never	Reference	Reference
Frequency of consumption of chocolate, candies, sweets		
1–4 times/day	1.27 (1.20–1.34)	1.23 (1.16–1.31)
Less than once/day or never	Reference	Reference

Table 3 (continued)

Variable	Full sample (<i>n</i> = 32,714)	
	Adjusted OR (95% CI) Model 1 ^a	Adjusted OR (95% CI) Model 2 ^b
Frequency of consumption of soft drinks		
1–4 times/day	1.20 (1.11–1.29)	1.15 (1.06–1.24)
Less than once/day or never	Reference	Reference
BMI category (kg/m ²)		
< 25	Reference	Reference
25–29	1.32 (1.20–1.44)	1.15 (1.04–1.27)
≥ 30	1.29 (1.17–1.43)	1.21 (1.09–1.35)
Prevalent diabetes (Type I or type II)		
Yes	1.35 (1.15–1.6)	1.11 (0.92–1.32)
No	Reference	Reference
Prevalent major cardiovascular disease		
Yes	1.32 (1.07–1.62)	1.19 (0.95–1.49)
No	Reference	Reference
Prevalent cancer		
Yes	1.03 (0.93–1.14)	0.99 (0.88–1.11)
No	Reference	Reference
mPESS (modified Periodontal Screening Score)		
mPESS ≥ 5	3.95 (3.70–4.32)	3.45 (3.21–3.72)
mPESS < 5	Reference	Reference
Number of natural teeth [<i>n</i> (%)]		
< 20 teeth	1.65 (1.44–1.89)	1.48 (1.29–1.71)
≥ 20 teeth	Reference	Reference

^aModel 1 is adjusted for age (continuous variable) and sex

^bModel 2 is adjusted for age (continuous variable), sex, sociodemographic variables, lifestyle habits, physical health status, and periodontal health

Table 4 Logistic regression analysis of the association between likelihood of severe periodontitis and oral health-related quality of life (OHIP-14 > 8, 4th quartile) in women and men, 2009–2012, NutriNet-Santé web cohort, France

Exposure	Women (<i>n</i> = 24,719)		Men (<i>n</i> = 7995)	
	Adjusted OR (95% CI) Model 1 ^a	Adjusted OR (95% CI) Model 2 ^b	Adjusted OR (95% CI) Model 1 ^a	Adjusted OR (95% CI) Model 2 ^b
mPESS (modified Periodontal Screening Score)				
mPESS ≥ 5	3.95 (3.65–4.27)	3.46 (3.18–3.76)	4.42 (3.84–5.09)	3.88 (3.33–4.51)
mPESS < 5	Reference	Reference	Reference	Reference
Number of natural teeth [<i>n</i> (%)]				
< 20 teeth	1.59 (1.36–1.86)	1.44 (1.22–1.69)	1.86 (1.40–2.47)	1.77 (1.31–2.38)
≥ 20 teeth	Reference	Reference	Reference	Reference

^aModel 1 is adjusted for age (continuous variable)

^bModel 2 is adjusted for sociodemographic variables, lifestyle habits, physical health status and periodontal health

OHRQoL [4], our analysis showed that BMI, physical activity, lifestyle and nutritional habits are associated with OHIP-14.

Another strength of the present study was the size and diversity of the sample, which is unique in the literature, and would be hard to attain using clinical approaches, which are time-consuming and not easily applicable in large-scale

epidemiological studies [36, 37, 55, 56]. Indeed, the present results showed for the first time that a self-report-based tool developed to identify individuals likely to suffer from severe periodontitis, the mPESS [37, 38], is strongly associated with the OHIP-14 score. The mPESS calculated among the participants in the NutriNet-Santé e-cohort showed similar sensitivity and specificity as those in the original sample (PESS sensitivity: 78.9%; specificity: 74.8%) [38]. The mPESS takes into account 4 signs and symptoms of periodontitis plus age and current smoking status, which are known risk factors for periodontitis [57]. Thus, this easily employed tool allows for the assessment of multidimensional aspects of periodontitis, and could better capture their impact on OHRQoL compared to other oral health measures, such as epidemiological indices, e.g., the community periodontal index (CPI), and clinical parameters, e.g., clinical attachment level [4]. Moreover, at the present time in which the Covid-19 pandemic has negatively impacted patients' attitudes (e.g., fear of getting infected with the SARS-Cov-2 virus in the dentist's office) and access to dental care [58–61], the self-reported evaluation of periodontitis may be a valuable supporting tool to reinforce prevention and treatment.

Tooth loss is one of the worst types of damage to oral health; the main reasons for tooth loss in adulthood are periodontitis and caries. Tooth loss can cause both esthetic and functional problems [62, 63], and it has been shown to be associated with impaired OHRQoL [63, 64]. The location and distribution of missing teeth also affect the degree of this impairment [65], with a negative impact that increases sharply once the number of remaining teeth drops below 20 [65]. Consistent with the literature, the present study showed that having fewer than 20 teeth in the oral cavity increased the odds of low OHRQoL by 48%. However, it must be noted that both periodontal status and number of teeth were self-reported and thus comparisons with previous studies employing parameters assessed clinically (e.g., periodontal probing, clinical attachment level measurements, gingival inflammation evaluation) require a cautious interpretation. Different measures could generate different data, partly explaining the heterogeneity of the findings [4, 8, 9].

Regarding the socio-demographic variables (modeled as supplementary exposures), poorer OHRQoL appeared to be associated with female sex, older age, and decreased household income. These results are in agreement with previous studies [66–68], although contrasting results have also been reported [69, 70], raising issues about the relative weight of these factors.

Compromised general health, comorbidities, and medication use are also supported as conditions that can enhance the effects that oral pathologies might have on OHRQoL, as seen in diabetic or overweight individuals [29, 71]. In the present study, diabetes, cancer, and major

cardiovascular diseases were not significantly associated with poor OHRQoL, whereas a BMI > 25 was associated with an increased odds of having a reduced OHRQoL (OHIP-14 score > 8: OR = 1.15 (95% CI 1.04–1.27) for overweight and 1.21 (95% CI 1.09–1.35) for obese individuals).

Another important finding of the present study was that the OHIP-14 score appeared to be independently related to some unhealthy dietary habits, such as snacking between meals (increased odds by 64%), as well as intake of soft drinks (increased odds by 15%) and sweets/chocolate consumption more than once per day (increased odds by 23%). These dietary habits are known to impact general and oral health (i.e. odds of caries). Andreeva et al. [24] found that adherence to French dietary guidelines, as assessed by the modified Program National Nutrition Santé-Guidelines Score (PNNS-GS), was positively yet modestly correlated with OHRQoL assessed with the Geriatric Oral Health Assessment Index (GOHAI). In another study, lower OHIP-14 global score was found in patients with eating disorders, who presented with more functional limitations, physical disability, psychological and social disability, and handicap [72]. However, to our knowledge, no previous periodontitis study has taken into consideration the role of nutritional habits in OHRQoL as measured with the OHIP-14 in a sample derived from the general population.

The pros and cons of web-based questionnaires have been widely discussed elsewhere [20, 24, 38, 73, 74]. Next, as a cross-sectional investigation, no conclusion about causality between periodontitis and OHRQoL can be drawn. The study sample, although recruited from the French general population, cannot be considered fully representative, and care must be taken when generalizing the findings [74]. In fact, the proportions of women, relatively well-educated individuals and those who are married/cohabiting, are larger in the cohort compared with the corresponding national figures [74]. However, we have also observed that the cohort exhibited geographical and socio-demographic diversity, including volunteers belonging to typically under-represented subgroups in traditional surveys. Next, given the Internet-based design of NutriNet-Santé, and the fact that older age has been associated with reduced Internet access [75], and with increased risk of dental enamel erosion and oral health problems [76], we could speculate that the findings might be somewhat biased owing to the potentially low representation in the sample of individuals with compromised dental status. Nonetheless, the estimated prevalence of severe periodontitis in the cohort was similar to the national estimate [37, 38, 77]. Next, prior oral health research in the NutriNet-Santé cohort revealed socio-demographic and lifestyle differences between those who did and did not meet the analysis eligibility criteria [73]. Finally, in an effort to prevent over-adjustment of the statistical models, only major comorbidities with a good level of evidence in terms of association

with periodontitis were retained as covariates. However, it cannot be excluded that other comorbidities might also have an impact on periodontitis risk. Similarly, in this epidemiological cohort we could not assess clinical parameters such as dental caries and/or malocclusion, which may contribute to OHQoL.

Conclusion

The mPSS, as a new, validated indicator of the likelihood of severe periodontitis, was shown to be strongly associated with a lower OHRQoL across sex and age in a large non-clinical sample of adults. These results suggest that mPSS could be tested in future prevention programs aiming at improving oral health-related quality of life.

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Author contributions LJ and ZH contributed to data analyses, data interpretation, and drafting the manuscript. SH and MT developed and implemented the NutriNet-Santé web cohort. CJ, SH, MT, and VAA coordinated the data collection and participated in data interpretation. PB contributed to study design and data interpretation, and provided theoretical and methodological guidance. MCC contributed to study design, data analysis, data interpretation, literature review and drafting the manuscript. VAA coordinates the oral health working group within NutriNet-Santé; she contributed to data analysis, data interpretation, and drafting the manuscript. All authors read and critically revised the manuscript for important intellectual content. All authors approved the final version of the manuscript and its submission.

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Declarations

Conflict of interest All authors have no relevant financial or non-financial interests to disclose.

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Consent to participate Prior to inclusion in the e-cohort, each participant provides an informed consent and an electronic signature.

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