Oral health determinants of incident malnutrition in community-dwelling older adults

Eva Kiesswetter[a,b,*], Linda M Hengeveld[a], Bart JF Keijser[c,d], Dorothee Volkert[b], Marjolein Visser[a]

[a] Department of Health Sciences, Faculty of Science, Amsterdam Public Health Research Institute, Vrije Universiteit Amsterdam, De Boelelaan 1085, 1081 HV, Amsterdam, the Netherlands
[b] Institute for Biomedicine of Aging, Friedrich-Alexander-Universität Erlangen-Nürnberg, Kobergerstr. 60, 90408, Nürnberg, Germany
[c] Research Group Microbiology and Systems Biology, TNO, Utrechtseweg 48, 3704HE, Zeist, the Netherlands
[d] Department of Preventive Dentistry, Academic Center for Dentistry Amsterdam (ACTA), University of Amsterdam, Gustav Mahlerlaan 3004, 1081 LA, Amsterdam, the Netherlands

ARTICLE INFO

ABSTRACT

Objective: Poor oral health might be a modifiable determinant of malnutrition in older age. We aimed to investigate the associations of multiple oral health characteristics with incident malnutrition in community-dwelling older adults.

Methods: This exploratory analysis is based on prospective data from 893 participants, aged 55–80 years without malnutrition in 2005/06 from the Longitudinal Aging Study Amsterdam. In 2007, 19 oral health characteristics from the domains teeth/dentures, oral hygiene, oral problems, and self-rated oral health were assessed by questionnaire. Incident malnutrition was defined as presence of low body mass index ($< 20 \, \text{kg/m}^2$ in people < 70 years, $< 22 \, \text{kg/m}^2 \geq 70$ years) and/or self-reported involuntary weight loss $\geq 5\%$ in previous 6 months at any of the follow-ups (2008/09, 2012/13, 2015/16). Associations of oral aspects with incident malnutrition were analyzed by cox proportional hazard models and adjusted for confounders.

Results: The 9-year incidence of malnutrition was 13.5%. Sixteen of 19 oral health aspects were not associated with incident malnutrition in the crude models. Adjusted hazard ratios for incident malnutrition were 2.14 (1.10–4.19, p = 0.026) for toothache while chewing, 2.10 (0.88–4.98, p = 0.094) for an unhealthy oral health status, and 1.99 (0.93–4.28, p = 0.077) for xerostomia in edentulous participants, however, the two latter ones failing to reach statistical significance.

Conclusions: We identified toothache while chewing as determinant of incident malnutrition in community-dwelling older adults, and found indications that poor oral health and xerostomia in combination with having no teeth may play a role in developing malnutrition. However, these outlined tendencies need to be proven in further studies.

Clinical Significance: Regarding the development of strategies to prevent malnutrition in older people toothache while chewing, xerostomia, and self-rated oral health would be of specific interest as these factors are modifiable and can be easily assessed by self-reports.

1. Introduction

Malnutrition is a state of energy or protein deficiency, which causes measurable changes in body functions and leads, if it is untreated, to negative clinical outcomes [1]. In the literature different criteria and cut-off values are used to diagnose malnutrition [2–4]. Most of these criteria have in common that both involuntary weight loss (WL) and low body mass index (BMI) are considered as important indicators of malnutrition.

Among older people malnutrition is widespread and is associated with frailty, functional decline, poor quality of life, increased risk of mortality, and increased health care costs [5–8]. Depending on sampling characteristics and diagnostic criteria, studies have reported up to 22% of community-dwelling older adults to be affected by malnutrition [9–11]. With the increasing proportion of older people in modern societies [12], the reduction of incident malnutrition becomes an

important public health issue.

The origin of malnutrition in older age is multifactorial. Besides disease-related, functional, psychological, and socio-economic factors [13], poor oral health might be considered as a potential determinant of malnutrition. Mastication and insalivation are important steps in the processes of eating and digesting, and several systematic literature reviews have indicated that impaired oral health negatively affects dietary intake [14–16]. As many oral health issues can be treated, knowledge about the relation between poor oral health and the development of malnutrition is crucial with regard to preventive strategies [17].

Most evidence for an association of oral health with malnutrition has been derived from cross-sectional studies [18,19]. Prospective studies are less common, and findings have been more heterogeneous which may be partly due to different diagnostic criteria, used to assess both oral health and malnutrition [20–29]. Furthermore, some of these studies have not specifically focused on the association of oral health with malnutrition and therefore, only considered single oral health measures, such as dental status, having chewing problems or oral health related quality of life [20–26]. Comprehensive approaches including multiple oral health domains are scarce [27–29]. With regard to the outcome, only one study has considered whether WL was unintended or not [24] and moreover, only few studies looked at incident malnutrition [22,24,25]. A prospective design, where the exposure is measured before the outcome, would, however, limit reverse causality. Additionally, the transferability of findings from nursing home or hospital settings [21,23,25,27,29] and, moreover, from Asian countries [21,22,25] to the situation of community-dwelling older adults living in Western countries is limited due to differences in general health status, ethnicity, socio-economic factors, and health care systems [30].

Prospective research approaches with a comprehensive assessment of oral health can help to clarify the role of poor oral health as potential determinant of incident malnutrition in community-dwelling older adults. The aim of this exploratory analysis was to investigate the association of multiple oral health characteristics with 9-year incidence of malnutrition in community-dwelling older adults.

2. Methods

2.1. Study design

This study was performed within the Longitudinal Aging Study Amsterdam (LASA), an ongoing cohort study on determinants and consequences of aging [31,32]. The study population is representative for Dutch older people aged 55–85 years. The first wave was established in 1992/93. Since then, follow-up examinations have been performed every 3 years, and side studies in-between. In 2002/03, an additional cohort of people aged 55–65 years was established. Each examination consists of a general and a medical interview. The study protocol was approved by the Medical Ethics Committee of the VU University Medical Centre Amsterdam, and written informed consent was obtained from every participant.

2.2. Study sample

Baseline data in this analysis come from participants taking part in the 2005/06 LASA wave and additionally in the LASA Lifestyle Side Study in 2007 (n = 1035). For this side study, an extensive lifestyle questionnaire was sent to selected participants meeting the following inclusion criteria: age < 80 years, having no cognitive impairment according to Mini Mental State Examination (MMSE ≥ 24), and living independently [33]. For this analysis, further exclusion criteria were defined: malnutrition in 2005/06 assessed by low BMI ($< 20\,kg/m^2$ and $< 22\,kg/m^2$ in participants < 70 and ≥ 70 years, respectively) and/or self-reported involuntary WL ≥ 5% in previous 6 months, complete missing data on oral health factors, and missing data on BMI

LASA Lifestyle Study 2007
(n=1035)

- Age 55-80 years
- MMSE ≥ 24 points
- Living independently

- Malnutrition at 2005/06 (n=47)
- (Complete) missing data on:
  - oral health factors (n=4)
  - weight or weight loss at 2005/06 (n=13)
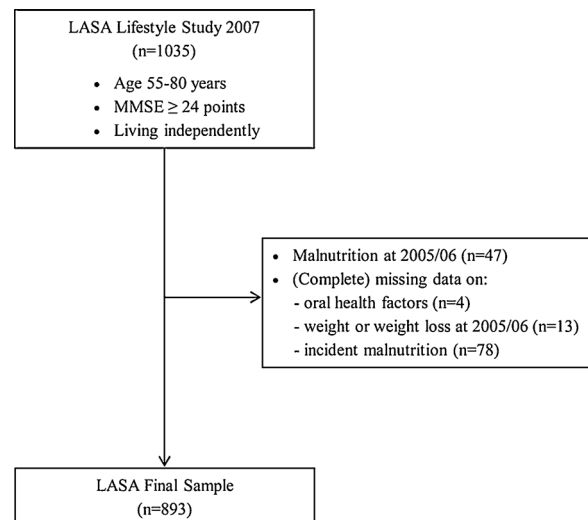 - incident malnutrition (n=78)

LASA Final Sample
(n=893)

Fig. 1. Flow Chart of participants' selection.
LASA Longitudinal Aging Study Amsterdam; MMSE Mini Mental State Examination.

and/or self-reported WL in 2005/06 or at all follow-up examinations. The final sample consisted of 893 participants (Fig. 1). Participants were followed up until they developed malnutrition but for a maximum of 9 years covering the LASA waves 2008/09, 2011/12, and 2015/16.

2.3. Malnutrition

Nutritional status was assessed in 2005/06 and at each follow-up. Body height and weight were measured during the medical interviews. Body Mass Index (BMI) was calculated as body weight (kg) divided by body height (m) squared, using baseline height for each wave. In two cases with missing data on baseline height, height from a subsequent wave was considered. For each wave, the percentage WL was calculated based on self-reported WL (kg) in the previous 6 months and measured body weight. Whether WL was involuntary, was determined by a question on reasons for WL. At each follow-up incident malnutrition was defined by self-reported involuntary WL ≥ 5% in the previous 6 months and/or low BMI. Low BMI was defined as $< 20\,kg/m^2$ and $< 22\,kg/m^2$ in participants < 70 and ≥ 70 years, respectively, as proposed by the European Society for Clinical Nutrition and Metabolism [2].

2.4. Oral health characteristics

In the LASA Lifestyle Study (2007), oral health was assessed by a self-administered questionnaire (22 items) with predefined answer categories focusing on the following four different oral health domains: teeth and dentures, oral hygiene, oral problems, and self-rated oral health status (Table 1). The questionnaire was developed in cooperation with experts on oral health from the Academic Centrum Tandheelkunde Amsterdam (ACTA) and the Netherlands Organization for Applied Scientific Research (TNO) specifically for the LASA Lifestyle Study. Variables were selected based on former reports [34,35].

2.5. Participants' characteristics

Participants' characteristics were assessed during the main and medical interviews (2005/06). Demographic variables included age, gender, and level of urbanization. The level of urbanization represents the mean number of addresses per squared kilometer within a circle with a radius of one kilometer which is matched with the postal codes of the participants' homes. The variable was categorized as not/little

Table 1
Description of oral health factors assessed in the LASA Life Style Study 2007 by a self-administered questionnaire.

Oral health domain	Item	Answer categories	Summary of categories
Teeth and dentures	Number of teeth and molars upper jaw	none, 1–7 teeth, > 7 teeth	no teeth, at least one jaw with 1–7 teeth, both
	Number of teeth and molars lower jaw	none, 1–7 teeth, > 7 teeth	jaws with > 7 teeth
	Denture use upper jaw	none, partial denture, complete denture	no dentures, partial dentures, complete dentures
	Denture use lower jaw	none, partial denture, complete denture	or combined (partial + complete) dentures
Oral hygiene	Brushing teeth	never, sometimes but not daily, 1x daily, 2x daily, > 2x daily	never/sometimes but not daily, 1x daily, 2x daily, > 2x daily
	Using dental floss	never, 1–3times/month, 1–3times/week, > 3 times/week	
	Using interdental brushes	never, 1–3 times/month, 1–3 times/week, > 3 times/week	
	Using tooth picks	never, 1–3 times/month, 1–3 times/week, > 3 times/week	
	Dental checks (last 2 years)	never, 1–2 times, ≥3 times	
	Dental cleanings (last 2 years)	never, 1–2 times, ≥3 times	
Oral problems	Dental caries (last 6 months)	yes, no	
	Lost, loose or broken teeth (last 6 months)	yes, no	
	Bleeding gums (last 6 months)	yes, no	
	Red and/or swollen gums (last 6 months)	yes, no	
	Blisters or sores in the mouth (last 6 months)	yes, no	
	Toothache while drinking hot/cold drinks (last 6 months)	yes, no	
	Toothache while chewing (last 6 months)	yes, no	
	Halitosis (last 6 months)	yes, no	
	Xerostomia (last 6 months)	yes, no	
	Gingivitis diagnosed by a dentist or dental assistant in last 2 years	yes, no	
Self-rated oral health status	Self-rated oral health status	very unhealthy, unhealthy, not healthy/not unhealthy, healthy, very healthy	very unhealthy/unhealthy, not healthy/not unhealthy, healthy/very healthy

(< 500–1000), somewhat (1000–1500), and highly/very highly (1500– > 2500) urbanized. Socio-economic position was represented by education and income. Education used the levels low (elementary education or less), middle (general intermediate and lower vocational education), and high (intermediate or higher vocational and general secondary education, college and university). Net monthly household income was categorized as low (< 1135 euro), middle (1,135–1,816 euro), or high (> 1816 euro per month) [36]. For participants with a partner living in the same household the total household income was multiplied by 0.7 to make it comparable to incomes of single-person households [37]. Social factors included marital status (married/registered partnership, never married/divorced, widowed) and living situation (living alone vs. living with others). Smoking status was categorized as never, former, or current smoker. Health status was assessed by the number of chronic diseases and prescribed drugs. Cognitive status was measured by MMSE (0–30 points) [38] and depressive symptoms by the Dutch version of the Center for Epidemiologic Studies Depression Scale (0–60 points) [39]. Physical function was assessed by difficulties with 7 activities of daily living (ADL: climbing stairs, dressing, rising from a chair, cutting toenails, walking 5 min outside, using public transportation, and bathing), and categorized as none, 1, or ≥2 limitations with ADL.

2.6. Statistical analyses

Participants' characteristics are given as mean ± standard deviation for continuous variables and as relative frequencies for nominal and ordinal variables; correspondingly, group comparisons were conducted with *t*-tests or Chi²-tests. An exploratory approach was used to investigate the association between the different oral health characteristics and incident malnutrition. For each oral health aspect, separate Cox proportional hazard regression models were established. In model 1, the crude associations were estimated. Effect modification by dental status (teeth/no teeth) was tested by adding the interaction term to the univariate models. In the event of an interaction (p ≤ 0.10), results are given stratified by dental status. In model 2, associations were adjusted for gender, age, education, and income. In model 3, those results with a p-value ≤ 0.10 were further adjusted for MMSE score, number of chronic diseases, number of drugs, ADL limitations, smoking, living situation, and level of urbanization. Adjustment variables were included based on the literature [19,40,41] and by testing their influence on the respective associations. Data are presented as hazard ratios and 95% confidence intervals. For incident malnutrition, time to event was defined as the number of days between the LASA Life Style Study (2007) and the first follow-up examination, where malnutrition was present, using the waves 2008/09, 2011/12 and 2015/16. The follow-up time for censored participants was calculated based on the date of the 9-year follow-up examination, the date of the last follow-up examination, or the date of death, whichever came first. Statistical analyses were performed with SPSS Version 24 (IBM SPSS Statistics, Chicago, IL).

Table 2
Baseline characteristics for the total sample and stratified for participants without and with incident malnutrition (MN) during 9 years of follow-up.

	Total N = 893	No MN N = 772	MN N = 121	p-value
Age [years]	67.6 ± 6.1	67.5 ± 6.1	68.3 ± 6.4	.182
Female gender [%]	53.1	51.6	62.8	.021
Level of urbanization [%]				
Little	44.0	45.1	37.2	.184
Somewhat	20.5	19.7	25.6	
Highly	35.5	35.2	37.2	
Education [%]				
Low	20.3	20.3	19.8	.894
Middle	58.2	58.4	57.0	
High	21.5	21.2	23.1	
Income [%]				
Low	25.6	25.6	25.6	.195
Middle	53.9	54.5	49.6	
High	12.9	13.0	12.4	
Missing	7.6	6.9	12.4	
Marital status [%]				
Married/registered partnership	74.6	75.8	66.9	.090
Never married/divorced	10.3	9.6	14.9	
Widowed	15.1	14.6	18.2	
Living situation [%]				
Living alone	21.8	20.6	29.8	.023
Living with others	78.2	79.4	70.2	
Smoking [%]				
Never	31.1	29.9	38.8	.025
Former	55.2	57.0	43.8	
Current	13.7	13.1	17.4	
Body Mass Index [kg/m²]	27.7 ± 3.9	27.9 ± 3.8	26.2 ± 4.4	< .001
Number of chronic diseases	1.7 ± 1.3	1.6 ± 1.3	1.8 ± 1.4	.151
Number of medications	2.3 ± 2.2	2.2 ± 2.2	2.5 ± 2.3	.270
Cognitive status [MMSE 24-30 p]	28.2 ± 1.5	28.2 ± 1.5	28.1 ± 1.5	.548
Depressive symptoms [CES-D 0-60 p]	6.8 ± 6.3	6.8 ± 6.3	7.1 ± 6.9	.691
Limitations in 7 ADL [%]				
None	57.7	58.4	52.9	.160
One	19.4	19.7	17.4	
Two or more	23.0	21.9	29.8	

For continuous variables mean ± standard deviation is presented; Comparison between participants without and with incident malnutrition: for nominal or categorical variables Chi²-test and for continuous variables t-test; MN Malnutrition; MMSE Mini Mental State Examination; CES-D Center for Epidemiologic Studies Depression Scale; p points; ADL Activities of Daily Living.

3. Results

During the 9-year follow-up (mean 7.4 ± 2.6 years), 121 (13.5%) out of the 893 included participants developed malnutrition. Of those who were malnourished, 47.1% were identified by involuntary WL at one of the follow-ups, 42.9% because of a low BMI, and 9.9% because of the coincidence of both indicators.

Seventy-eight people were excluded due to missing follow-up data. These people were older, had lower educational level, were more often current smokers, and took more drugs than the included 893 participants (Supplementary file 1). Participants had a mean age of 67.6 ± 6.1 years and an equal gender distribution (Table 2). The proportion of women was higher in the group developing malnutrition than in the group that did not. Participants with incident malnutrition had a lower baseline BMI, lived more often alone, tended to be less often married, and reported more often to have never smoked than participants without incident malnutrition.

Oral health characteristics of included participants and the 78 excluded participants only differed in the frequency of brushing teeth, that was less often performed by excluded participants (Supplementary file 2). Oral health characteristics of the domains teeth and dentures, oral hygiene, oral problems, and self-rated oral health status are presented for the total sample as well as stratified by nutritional status in Table 3. No differences in relative frequencies of oral health characteristics relating to teeth and dentures as well as oral hygiene were found between groups with and without incident malnutrition.

Regarding oral health problems, xerostomia was the oral problem which was most frequently reported by participants during the previous 6 months (24.4%). Xerostomia was more pronounced in people without teeth and with incident malnutrition than in their counterparts with teeth and without incident malnutrition (Supplementary file 3). Toothache while chewing in the previous 6 months was the oral health problem with the lowest prevalence (4.5%), and was more often reported by participants who developed malnutrition than by participants who did not. Only 2.7% of the participants rated their oral status as unhealthy or very unhealthy, with a higher proportion in participants with incident malnutrition than in those without.

Oral health characteristics of the domains teeth and dentures as well as oral hygiene showed no association with incident malnutrition (Table 4). From the domain oral problems, toothache while chewing and xerostomia were associated with incident malnutrition in the crude models. The association between xerostomia and incident malnutrition was moderated by dental status; only in edentulous participants the hazard for developing malnutrition was increased. For both variables the associations were significant after adjusting for age, gender, education, and income (model 2). In model 3, the association between toothache while chewing and incident malnutrition remained significant (2.14 (1.10–4.19, p = 0.026)), while significance was lost for the association of xerostomia and incident malnutrition in edentulous participants (1.99 (0.93–4.28, p = 0.077)). Regarding an unhealthy oral status the hazard ratio for incident malnutrition was 2.10 (0.88–4.98, p = 0.094) in model 3.

Table 3
Baseline oral health characteristics of the total sample and stratified by participants without and with incident malnutrition (MN) during 9 years of follow-up [%].

	Total	No MN	MN	p-value
Number of teeth	N = 886	N = 767	N = 104	
Both jaws > 7 teeth	38.0	38.6	34.5	.674
At least one jaw with 1-7 teeth	27.7	27.5	28.6	
No teeth	34.3	33.9	37.0	
Dentures	N = 880	N = 778	N = 102	
No dentures	38.8	38.5	40.2	.921
Partial dentures	15.7	16.0	13.7	
Complete dentures	38.3	38.1	39.3	
Combined dentures	7.3	7.3	6.8	
Oral hygiene				
Brushing teeth	N = 874	N = 755	N = 119	
More than twice daily	11.6	11.3	13.4	.895
Twice daily	50.1	50.1	50.4	
Once daily	34.9	35.2	32.8	
Sometimes not daily/never	3.4	3.4	3.4	
Using dental floss[*]	N = 402	N = 352	N = 50	
More than 3 times/week	18.2	17.3	24.0	.326
1–3 times/week	12.9	12.2	18.0	
1–3 times/month	13.9	13.9	14.0	
Never	55.0	56.5	44.0	
Using interdental brushes	N = 704	N = 607	N = 97	
More than 3 times/week	14.6	13.8	19.6	.468
1–3 times/week	5.0	5.1	4.1	
1–3 times/month	4.3	4.4	3.1	
Never	76.1	76.6	73.2	
Using tooth picks[*]	N = 499	N = 438	N = 61	
More than 3 times/week	43.5	43.4	44.3	.926
1–3 times/week	18.6	18.9	16.4	
1–3 times/month	11.0	11.2	9.8	
Never	26.9	26.5	29.5	
Dental checks (last 2 years)	N = 824	N = 716	N = 108	
3 or more times	39.2	38.8	41.7	.721
1–2 times	35.6	35.5	36.1	
Never	25.2	25.7	22.2	
Dental cleanings (last 2 years)	N = 698	N = 604	N = 94	
3 or more times	29.9	30.3	27.7	.838
1–2 times	29.8	29.5	31.9	
Never	40.3	40.2	40.4	
Oral problems	N = 794	N = 687	N = 107	
Dental caries[*,+]	20.5	20.3	21.9	.753
Lost, loose, broken teeth[*,+]	7.9	7.2	12.3	.132
Bleeding gums	12.0	12.4	9.3	.370
Red and/or swollen gums	8.6	8.7	7.5	.666
Blisters or sores in the mouth	9.1	8.6	12.1	.233
Toothache while drinking	8.7	9.2	5.6	.224
Toothache while chewing	4.5	3.8	9.3	.010
Halitosis	6.3	6.1	7.5	.589
Xerostomia	24.4	23.1	32.7	.032
Gingivitis (last 2 years)	N = 836	N = 728	N = 108	
	7.8	8.0	6.5	.591
Self-rated oral health status	N = 830	N = 721	N = 109	
Very healthy/healthy	70.0	70.2	68.8	.135
Not healthy/not unhealthy	27.3	27.6	25.7	
Very unhealthy/Unhealthy	2.7	2.2	5.5	

Comparison between participants without and with incident malnutrition: Chi²-test.

[*] refers only to participants having teeth.

[+] refers to n = 570.

4. Discussion

In this large-scale, prospective study in community-dwelling older adults including 19 potential oral health determinants, toothache while chewing was identified as determinant of incident malnutrition. For xerostomia and a poor self-rated oral health status we only found indications that they may play a role in the development of malnutrition.

During the 9-year follow-up, 13.5% of the participants developed malnutrition. The incidence is similar to a former LASA analysis reporting 13.9% based on the time period between 1992/93 and 2001/02 and a slightly different definition of malnutrition [24]. These results suggest that about one out of seven Dutch older adults will experience malnutrition during a 10-year follow-up, highlighting the importance of identifying modifiable determinants of malnutrition, in order to prevent malnutrition and its negative consequences.

4.1. Toothache while chewing

In our study the hazard of developing malnutrition was increased by about 2-folds when participants reported toothache while chewing at baseline. The association remained significant even after adjusting for various confounders. Surprisingly, this question was also answered by edentulous participants (wearing dentures), indicating that it was interpreted more generally as pain while chewing. The corresponding prevalence was similar between participants with and without teeth and no interaction effect was detected with regard to malnutrition. A study in US community-dwelling older adults (mean age > 70 years) did not find any associations between more general oral pain and subsequent 1-year WL of $\geq$ 4% and $\geq$ 10% [28]. In a study in residents of sheltered housings mouth pain was neither associated with a BMI < 22 kg/m² , nor with WL of 5% and 10% after 1-year follow-up [27]. None of the two aforementioned studies specified whether WL was unintended or not. These differences in results could suggest that pain during mastication might be more relevant regarding the risk of malnutrition than oral pain in general. As pain while chewing can have different causes, e.g. ill-fitting dentures, (root) caries or dentinal hypersensitivity, that may also occur concurrently, diagnosing and treating these causes may contribute to the prevention of malnutrition in older age.

4.2. Xerostomia

Xerostomia was reported by 24% of participants in our study. This is within the range of prevalence rates reported by other studies in community-dwelling older adults (17–40%) [42]. Xerostomia showed an association with incident malnutrition in edentulous people in the crude model as well as in the model adjusted for age, gender, education, and income. Statistical significance was lost in the model adjusted for further confounders (1.99, 0.93–4.28, p = 0.077). As the subgroup of edentulous people was small, the statistical power might have been too low to detect an association in the multivariate model. Furthermore, it can be discussed whether the used 1-item question (yes/no) fully captures the problem of xerostomia and sufficiently discriminates with regard to the severity of xerostomia or whether a more differentiated measure is needed [43,44]. Currently, no gold standard on how to best assess xerostomia exists [44]. To our knowledge, no other longitudinal studies have investigated the association between xerostomia and malnutrition. In a cross-sectional study among European recipients of home care, the odds for unintended WL was 2.6-fold greater in participants suffering from dry mouth than in those not suffering from dry mouth (8%), however, the association was not adjusted for confounders [45]. Xerostomia is the subjective feeling of a dry mouth, but is not necessarily related to a reduced saliva flux [32]. In case xerostomia is associated with hyposalivation, it may negatively affect dietary intake, as insalivation of food is important for food perception and texture modification during eating [16,46]. Furthermore, hyposalivation can reduce the retention of the dentures as well as the comfort of wearing dentures [46]; this may explain the interaction between xerostomia and dental status with regard malnutrition, found in our study.

Table 4

Hazard ratios and 95% confidence intervals for the unadjusted and adjusted associations between oral health factors and 9-year incident malnutrition in community-dwelling older adults.

	Model 1 HR (95%CI)[*]	p	Model 2 HR (95%CI)[**]	p	Model 3 HR (95%CI)[***]	p
Number of teeth	N = 886					
Both jaws > 7 teeth	1		1			
At least one jaw with 1–7 teeth	1.15 (0.73–1.81)	.544	1.35 (0.83–2.17)	.225		
No teeth	1.33 (0.87–2.04)	.186	1.16 (0.73–1.84)	.540		
Dentures	N = 880					
No dentures	1		1			
Partial dentures	0.86 (0.49–1.51)	.597	0.88 (0.49–1.57)	.656		
Complete dentures	1.10 (0.73–1.66)	.641	1.09 (0.69–1.73)	.720		
Combined dentures	0.93 (0.44–1.98)	.859	0.93 (0.43–2.00)	.843		
Oral hygiene						
Brushing teeth	N = 874					
More than twice daily	1		1			
Twice daily	0.97 (0.56–1.68)	.913	1.00 (0.57–1.75)	.992		
Once daily	0.86 (0.48–1.54)	.623	0.95 (0.52–1.73)	.862		
Sometimes not daily/never	1.07 (0.36–3.21)	.900	1.24 (0.41–3.82)	.704		
Using dental floss[#]	N = 703					
> 3 times/week	1		1			
1–3 times/week	1.23 (0.52–2.91)	.646	1.21 (0.49–2.96)	.684		
1–3 times/month	0.74 (0.29–1.87)	.517	0.69 (0.26–1.83)	.463		
Never	0.68 (0.33–1.36)	.275	0.67 (0.32–1.41)	.294		
Using interdental brushes	N = 704					
> 3 times/week	1		1			
1–3 times/week	0.58 (0.20–1.72)	.327	0.60 (0.20–1.80)	.364		
1–3 times/month	0.59 (0.17–1.99)	.393	0.59 (0.17–2.02)	.401		
Never	0.85 (0.51–1.41)	.534	0.89 (0.52–1.51)	.656		
Using tooth picks[#]	N = 499					
More than 3 times/week	1		1			
1–3 times/week	0.97 (0.47–2.02)	.941	0.97 (0.46–2.04)	.938		
1–3 times/month	0.80 (0.33–1.95)	.629	0.84 (0.35–2.06)	.707		
Never	1.12 (0.62–2.04)	.704	1.12 (0.61–2.06)	.708		
Dental checks (last 2 years)	N = 824					
≥3 times	1		1			
1–2 times	0.89 (0.58–1.36)	.583	0.82 (0.53–1.27)	.363		
Never	0.85 (0.52–1.40)	.531	0.77 (0.45–1.32)	.340		
Dental cleanings (last 2 years)	N = 698					
≥3 times	1		1			
1–2 times	1.11 (0.65–1.87)	.710	1.03 (0.60–1.75)	.918		
Never	1.12 (0.68–1.84)	.664	1.00 (0.59–1.69)	.998		
Oral problems	N = 794					
Dental caries[##]	0.99 (0.57–1.73)	.975	1.03 (0.59–1.81)	.906		
Lost, loose broken teeth[##]	1.62 (0.81–3.26)	.174	1.64 (0.80–3.37)	.178		
Bleeding gums	0.62 (0.32–1.20)	.154	0.70 (0.36–1.37)	.300		
Red or swollen gums	0.72 (0.35–1.48)	.373	0.79 (0.38–1.63)	.522		
Blisters and/or sores in the mouth	1.29 (0.72–2.30)	.392	1.02 (0.67–2.16)	.548		
Toothache while drinking	0.60 (0.26–1.36)	.217	0.65 (0.28–1.49)	.309		
Toothache while chewing	**2.09 (1.09–4.01)**	**.027**	**2.34 (1.21–4.54)**	**.012**	2.14 (1.10–4.19)	.026
Halitosis	0.97 (0.47–2.00)	.935	1.15 (0.53–2.30)	.788		
With teeth: Xerostomia	1.13 (0.67–1.93)	.646	1.15 (0.67–1.98)	.614	1.10 (0.62–1.95)	.746
Without teeth: Xerostomia	**2.77 (1.40–5.48)**	**.004**	**2.63 (1.18–6.26)**	**.006**	1.99 (0.93–4.28)	.077
Gingivitis (last 2 years)	N = 836					
	0.65 (0.30–1.41)	.275	0.68 (0.31–1.48)	.333		
Self-rated health oral status	N = 830					
Very healthy/healthy	1		1		1	
Not healthy/not unhealthy	0.93 (0.60–1.43)	.762	0.95 (0.61–1.45)	.814	0.94 (0.60–1.46)	.775
Very unhealthy/unhealthy	1.90 (0.83–4.36)	.131	2.01 (0.87–4.63)	.102	2.10 (0.88–4.98)	.094

Hazard Ratios and 95% Confidence Intervals were obtained from cox proportional hazards regression.

[#] refers only to people with teeth.

[##] refers only to people with teeth (n = 570).

[*] Model 1: Crude.

[**] Model 2: Adjusted for age, gender, education, income.

[***] Model 3: Adjusted for age, gender, education, income, Mini Mental State Examination score, number of chronic diseases, number of drugs, limitations in 7 activities of daily living, smoking, living situation, and level of urbanization.

4.3. Self-rated oral health

A self-rated unhealthy oral status was the second oral factor showing a high but insignificant hazard ratio for incident malnutrition (2.10, 0.88–4.98, p = 0.094) in our study. As the prevalence of 2.7% was very low, the limited statistical power might again be a reason for this insignificant result. Compared to a study with Asian Americans (mean age 69 years), more people of our study rated their oral health as

good or excellent (55% vs. 70%) [47]. In a cross-sectional study with community-dwelling older adults from Brazil an unsatisfied self-rated gingival health, but not an unsatisfied self-rated tooth health, was associated with a risk of malnutrition according to the Mini Nutritional Assessment (MNA) [48]. Evidence from longitudinal studies is lacking.

4.4. Further oral health factors

For 16 of the 19 investigated oral health factors we did not find any evidence for an association with incident malnutrition. This can be attributed to several reasons. Firstly, some of the investigated oral problems, like red or swollen gums, might be more acute and less persistent problems and consequently, might not affect long-term incidence of malnutrition. Furthermore, we did not assess the severity of the problems. Secondly, the oral health of the participants can be generally considered as good, indicated by a majority reporting good self-rated oral health, regular tooth brushing, frequent dentist visits, and low prevalence of gum problems. Moreover, missing teeth were mostly replaced by dentures. The loss of teeth without replacement might affect oral function more negatively [30]. In contrast to our study, Ritchie et al. observed that edentulism was related to an increased risk of malnutrition in community-dwelling older adults [28]. The proportion of edentulous people was comparable in both studies (34% vs. 36%); moreover, in both studies almost all edentulous participants wore dentures. Different was the definition of the outcome, as they used 1-year WL of ≥4% and ≥10% without specification if it was unintended or not, and without excluding malnourished participants at baseline. In a further prospective study in community-dwelling older adults edentulism was not associated with 1-year WL of > 5% [20]. In addition, in a sample of older adults receiving home care neither having ≤19 teeth with dentures nor having ≤19 teeth without dentures was associated with malnutrition (MNA < 7) compared to having ≥20 teeth [22]. These controversial results could imply that additional factors, like occlusal contacts of teeth or the fit of dentures, might be of importance. However, to our knowledge, these aspects have not been investigated with regard to malnutrition prospectively yet. Thirdly, self-assessment of oral health as well as detecting oral-health related problems might have been difficult for the participants, which could have led to an underestimation of some problems. However, some of the self-reported oral health measures have shown good agreement with clinical assessments [34,35].

4.5. Strengths and limitations

The relatively large sample, the prospective design with a long follow-up, the consideration of multiple oral health domains, and the elimination of confounding bias by statistically controlling for multiple confounders were strengths of this study. However, some limitations need to be addressed. Firstly, oral health was assessed questionnaire-based without performing a complementary oral examination. Therefore, some potentially relevant factors, like the loss of occlusal contacts, could not be investigated. Moreover, no formal validation of the questionnaire was conducted for this study. Secondly, as oral health status was investigated in a side study, oral health and participants' characteristics were not assessed at the same time point. Thirdly, missing data in the answers of the oral health questionnaire resulted in different sample sizes for the single regression analyses. Fourthly, the 3-year intervals between the follow-up assessments were relatively long, participants, suffering from WL and/or low BMI in the meantime, might have been missed and correspondingly, the incidence of malnutrition might have been underestimated.

4.6. Conclusions

Our explorative analyses revealed toothache while chewing as determinant of incident malnutrition during a 9-year follow-up in community-dwelling older adults. For reporting a poor self-rated oral health and xerostomia in combination with having no teeth we only found indications that they may play a role in the long-term development of malnutrition. As the p-values of the latter two hazard ratios were above the error probability of 5%, further longitudinal studies focusing on incident malnutrition with large sample sizes are needed to confirm or disprove the outlined tendencies. Regarding the development of strategies to prevent malnutrition in older people these three aspects would be of specific interest as they are modifiable and can be easily assessed by self-reports. In addition, studies focusing on functional related oral health aspects like the number of occlusal contacts of teeth or the fit of dentures can contribute to further gain insight in the relation between oral health and malnutrition in older adults.

Conflict of interest

The authors declare no conflicts of interest.

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.2019.05.017.

References

[1] S.P. Allison, Malnutrition, disease, and outcome, Nutrition 16 (7-8) (2000) 590–593.

[2] T. Cederholm, I. Bosaeus, R. Barazzoni, J. Bauer, A. Van Gossum, S. Klek, M. Muscaritoli, I. Nyulasi, J. Ockenga, S.M. Schneider, M.A. de van der Schueren, P. Singer, Diagnostic criteria for malnutrition - an ESPEN consensus statement, Clin. Nutr. 34 (3) (2015) 335–340.

[3] T. Cederholm, G.L. Jensen, M. Correia, M.C. Gonzalez, R. Fukushima, T. Higashiguchi, G. Baptista, R. Barazzoni, R. Blaauw, A. Coats, A. Crivelli, D.C. Evans, L. Gramlich, V. Fuchs-Tarlovsky, H. Keller, L. Llido, A. Malone, K.M. Mogensen, J.E. Morley, M. Muscaritoli, I. Nyulasi, M. Pirlich, V. Pisprasert, M.A.E. de van der Schueren, S. Siltharm, P. Singer, K. Tappenden, N. Velasco, D. Waitzberg, P. Yamwong, J. Yu, A. Van Gossum, C. Compher, GLIM criteria for the diagnosis of malnutrition - A consensus report from the global clinical nutrition community, Clin. Nutr. 38 (1) (2019) 1–9.

[4] J.V. White, P. Guenter, G. Jensen, A. Malone, M. Schofield, Consensus statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: characteristics recommended for the identification and documentation of adult malnutrition (undernutrition), J. Acad. Nutr. Diet. 112 (5) (2012) 730–738.

[5] P. Abizanda, A. Sinclair, N. Barcons, L. Lizan, L. Rodriguez-Manas, Costs of

malnutrition in institutionalized and community-dwelling older adults: a systematic review, J. Am. Med. Dir. Assoc. 17 (1) (2016) 17–23.

[6] S. Marshall, J. Bauer, E. Isenring, The consequences of malnutrition following discharge from rehabilitation to the community: a systematic review of current evidence in older adults, J. Hum. Nutr. Diet. 27 (2) (2014) 133–141.

[7] M.I. Correia, D.L. Waitzberg, The impact of malnutrition on morbidity, mortality, length of hospital stay and costs evaluated through a multivariate model analysis, Clin. Nutr. 22 (3) (2003) 235–239.

[8] K. Wei, F.S. Thein, M.S.Z. Nyunt, Q. Gao, S.L. Wee, T.P. Ng, Nutritional and Frailty State Transitions in the Singapore Longitudinal Aging Study, J. Nutr. Health Aging 22 (10) (2018) 1221–1227.

[9] J.M. Meijers, R.J. Halfens, M.A. van Bokhorst-de van der Schueren, T. Dassen, J.M. Schols, Malnutrition in Dutch health care: prevalence, prevention, treatment, and quality indicators, Nutrition 25 (5) (2009) 512–519.

[10] A.G. Rojer, H.M. Kruizenga, M.C. Trappenburg, E.M. Reijnierse, S. Sipila, M.V. Narici, J.Y. Hogrel, G. Butler-Browne, J.S. McPhee, M. Paasuke, C.G. Meskers, A.B. Maier, M.A. de van der Schueren, The prevalence of malnutrition according to the new ESPEN definition in four diverse populations, Clin. Nutr. 35 (3) (2016) 758–762.

[11] E. Cereda, C. Pedrolli, C. Klersy, C. Bonardi, L. Quarleri, S. Cappello, A. Turri, M. Rondanelli, R. Caccialanza, Nutritional status in older persons according to healthcare setting: a systematic review and meta-analysis of prevalence data using MNA(R), Clin. Nutr. 35 (6) (2016) 1282–1290.

[12] W. Lutz, W. Sanderson, S. Scherbov, The coming acceleration of global population ageing, Nature 451 (7179) (2008) 716–719.

[13] P. McCormack, Undernutrition in the elderly population living at home in the community: a review of the literature, J. Adv. Nurs. 26 (5) (1997) 856–863.

[14] P. Gaewkhiew, W. Sabbah, E. Bernabe, Does tooth loss affect dietary intake and nutritional status? A systematic review of longitudinal studies, J. Dent. 67 (2017) 1–8.

[15] E. Kiesswetter, E. Poggiogalle, S. Migliaccio, L.M. Donini, C. Sulmont-Rosse, C. Feart, A. Suwalska, K. Wieczorowska-Tobis, W. Palys, D. Lojko, A. Saba, F. Sinesio, A. Polito, E. Moneta, D. Ciarapica, J. Brug, D. Volkert, Functional determinants of dietary intake in community-dwelling older adults: a DEDIPAC (DEterminants of DIet and Physical ACtivity) systematic literature review, Public Health Nutr. (2018) 1–18.

[16] C. Munoz-Gonzalez, M. Vandenberghe-Descamps, G. Feron, F. Canon, H. Laboure, C. Sulmont-Rosse, Association between salivary hypofunction and food consumption in the elderlies, A Systematic Literature Review, J. Nutr. Health Aging 22 (3) (2018) 407–419.

[17] J.S. Lee, M.J. Somerman, The importance of oral health in comprehensive health care, Jama (2018).

[18] A. Van Lancker, S. Verhaeghe, A. Van Hecke, K. Vanderwee, J. Goossens, D. Beeckman, The association between malnutrition and oral health status in elderly in long-term care facilities: a systematic review, Int. J. Nurs. Stud. 49 (12) (2012) 1568–1581.

[19] R. van der Pols-Vijlbrief, H.A. Wijnhoven, L.A. Schaap, C.B. Terwee, M. Visser, Determinants of protein-energy malnutrition in community-dwelling older adults: a systematic review of observational studies, Ageing Res. Rev. 18 (2014) 112–131.

[20] J.S. Lee, R.J. Weyant, P. Corby, S.B. Kritchevsky, T.B. Harris, R. Rooks, S.M. Rubin, A.B. Newman, Edentulism and nutritional status in a biracial sample of well-functioning, community-dwelling elderly: the health, aging, and body composition study, Am. J. Clin. Nutr. 79 (2) (2004) 295–302.

[21] C.C. Chen, S.T. Tang, C. Wang, G.H. Huang, Trajectory and determinants of nutritional health in older patients during and six-month post-hospitalisation, J. Clin. Nurs. 18 (23) (2009) 3299–3307.

[22] Y. Okabe, M. Furuta, S. Akifusa, K. Takeuchi, M. Adachi, T. Kinoshita, T. Kikutani, S. Nakamura, Y. Yamashita, Swallowing Function and Nutritional Status in Japanese Elderly People Receiving Home-care Services: A 1-year Longitudinal Study, J. Nutr. Health Aging 20 (7) (2016) 697–704.

[23] K.T. Knoops, E. Slump, L.C. de Groot, W. Wouters-Wesseling, M.L. Brouwer, W.A. van Staveren, Body weight changes in elderly psychogeriatric nursing home residents, J. Gerontol. A Biol. Sci. Med. Sci. 60 (4) (2005) 536–539.

[24] J. Schilp, H.A. Wijnhoven, D.J. Deeg, M. Visser, Early determinants for the development of undernutrition in an older general population: longitudinal Aging Study Amsterdam, Br. J. Nutr. 106 (5) (2011) 708–717.

[25] S. Izawa, H. Enoki, J. Hasegawa, T. Hirose, M. Kuzuya, Factors associated with

deterioration of mini nutritional assessment-short form status of nursing home residents during a 2-year period, J. Nutr. Health Aging 18 (4) (2014) 372–377.

[26] R.J. Weyant, A.B. Newman, S.B. Kritchevsky, W.A. Bretz, P.M. Corby, D. Ren, L. Weissfeld, S.M. Rubin, T. Harris, Periodontal disease and weight loss in older adults, J. Am. Geriatr. Soc. 52 (4) (2004) 547–553.

[27] A.G. Mamhidir, G. Ljunggren, M. Kihlgren, A. Kihlgren, A. Wimo, Underweight, weight loss and related risk factors among older adults in sheltered housing–a Swedish follow-up study, J. Nutr. Health Aging 10 (4) (2006) 255–262.

[28] C.S. Ritchie, J.L. Locher, D.L. Roth, T. McVie, P. Sawyer, R. Allman, Unintentional weight loss predicts decline in activities of daily living function and life-space mobility over 4 years among community-dwelling older adults, J. Gerontol. A Biol. Sci. Med. Sci. 63 (1) (2008) 67–75.

[29] A.M. Beck, Weight loss, mortality and associated potentially modifiable nutritional risk factors among nursing home residents–a Danish follow-up study, J. Nutr. Health Aging 19 (1) (2015) 96–101.

[30] P.E. Petersen, D. Kandelman, S. Arpin, H. Ogawa, Global oral health of older people–call for public health action, Community Dent. Health 27 (4 Suppl 2) (2010) 257–267.

[31] M. Huisman, J. Poppelaars, M. van der Horst, A.T. Beekman, J. Brug, T.G. van Tilburg, D.J. Deeg, Cohort profile: the longitudinal aging study amsterdam, Int. J. Epidemiol. 40 (4) (2011) 868–876.

[32] E.O. Hoogendijk, D.J. Deeg, J. Poppelaars, M. van der Horst, M.I. Broese van Groenou, H.C. Comijs, H.R. Pasman, N.M. van Schoor, B. Suanet, F. Thomese, T.G. van Tilburg, M. Visser, M. Huisman, The Longitudinal Aging Study Amsterdam: cohort update 2016 and major findings, Eur. J. Epidemiol. 31 (9) (2016) 927–945.

[33] M. Visser, R.J. Brychta, K.Y. Chen, A. Koster, Self-reported adherence to the physical activity recommendation and determinants of misperception in older adults, J. Aging Phys. Act. 22 (2) (2014) 226–234.

[34] B. Blicher, K. Joshipura, P. Eke, Validation of self-reported periodontal disease: a systematic review, J. Dent. Res. 84 (10) (2005) 881–890.

[35] C.W. Douglass, J. Berlin, S. Tennstedt, The validity of self-reported oral health status in the elderly, J. Public Health Dent. 51 (4) (1991) 220–222.

[36] S.C. Dijkstra, J.E. Neter, I.A. Brouwer, M. Huisman, M. Visser, Adherence to dietary guidelines for fruit, vegetables and fish among older Dutch adults; the role of education, income and job prestige, J. Nutr. Health Aging 18 (2) (2014) 115–121.

[37] A. Koster, H. Bosma, M.I. Broese van Groenou, G.I. Kempen, B.W. Penninx, J.T. van Eijk, D.J. Deeg, Explanations of socioeconomic differences in changes in physical function in older adults: results from the Longitudinal Aging Study Amsterdam, BMC Public Health 6 (2006) 244.

[38] M.F. Folstein, S.E. Folstein, P.R. McHugh, "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician, J. Psychiatr. Res. 12 (3) (1975) 189–198.

[39] L.F. Berkman, C.S. Berkman, S. Kasl, D.H. Freeman Jr., L. Leo, A.M. Ostfeld, J. Cornoni-Huntley, J.A. Brody, Depressive symptoms in relation to physical health and functioning in the elderly, Am. J. Epidemiol. 124 (3) (1986) 372–388.

[40] H.A. Kiyak, M. Reichmuth, Barriers to and enablers of older adults' use of dental services, J. Dent. Educ. 69 (9) (2005) 975–986.

[41] G.J. van der Putten, C. de Baat, L. De Visschere, J. Schols, Poor oral health, a potential new geriatric syndrome, Gerodontology 31 (Suppl 1) (2014) 17–24.

[42] B. Liu, M.R. Dion, M.M. Jurasic, G. Gibson, J.A. Jones, Xerostomia and salivary hypofunction in vulnerable elders: prevalence and etiology, Oral Surg. Oral Med. Oral Pathol. Oral Radiol. 114 (1) (2012) 52–60.

[43] W.M. Thomson, Issues in the epidemiological investigation of dry mouth, Gerodontology 22 (2) (2005) 65–76.

[44] W.M. Thomson, Dry mouth and older people, Aust. Dent. J. 60 (Suppl 1) (2015) 54–63.

[45] L.W. Sorbye, M. Schroll, H. Finne Soveri, P.V. Jonsson, E. Topinkova, G. Ljunggren, R. Bernabei, Unintended weight loss in the elderly living at home: the aged in Home Care Project (AdHOC), J. Nutr. Health Aging 12 (1) (2008) 10–16.

[46] M. Turner, L. Jahangiri, J.A. Ship, Hyposalivation, xerostomia and the complete denture: a systematic review, J. Am. Dent. Assoc. 139 (2) (2008) 146–150.

[47] Y. Jang, H. Yoon, N.S. Park, D.A. Chiriboga, Oral health and dental care in older asian americans in Central Texas, J. Am. Geriatr. Soc. 65 (7) (2017) 1554–1558.

[48] R.J. De Marchi, F.N. Hugo, J.B. Hilgert, D.M. Padilha, Association between oral health status and nutritional status in south Brazilian independent-living older people, Nutrition 24 (6) (2008) 546–553.