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# Oral health and nutritional status in care-dependent, community-dwelling older adults in Zurich, Switzerland

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**Keywords**
Geriatric dentistry, Oral Health, Nutrition, Community-dwelling older adults, Gerodontology.

**Abstract**

The aim of this study was to assess the oral health status (OHS), Oral health impact profile (OHIP-G-14), and the nutritional status (NS) in community-dwelling, dependent older adults. Information on OHS including DMF(T), plaque (PI) and gingival (GI) indices, community-periodontal-index-for-treatment-needs (CPITN), OHIP-G-14, maximum bite force (MBF), chewing efficiency [subjective (SA) and quantitative (VoH) assessments] were collected. NS was obtained by Mini-nutritional assessment (MNA) and body mass index (BMI). Cognitive status was evaluated by the mini-mental state examination (MMSE). 240 elders (mean-age = 81.5 ± 8.9y; men =85, women =155) were recruited. Average number of teeth, functional occlusal units and DMF(T), were 18.8 ± 8.9, 7.7 ± 3.5, and 22.3 ± 5.3 respectively. Mean PI, GI, CPITN and OHIP-G-14 were 1.8 ± 0.8, 1.2 ± 0.8, 1.9 ± 1.1, and 8.0 ± 12.0, respectively. MBF, VoH, SA were 219.6 ± 193.6, 0.3 ± 0.2, and 3.3 ± 1.4, respectively. MNA and BMI were 22.9 ± 4.7 and 25.5 ± 5.3, respectively. Number of teeth reduced significantly with age ($P < 0.001$), cognitive decline ($P < 0.001$). Oral hygiene significantly deteriorated with cognitive decline ($P < 0.001$). OHIP scores were negatively affected by increasing cognitive decline ($P < 0.001$). MNA deteriorated in women ($P = 0.026$), with increasing age ($P = 0.015$), and advancing cognitive decline ($P < 0.001$). BMI reduced with advancing age ($P = 0.003$) and in women ($P = 0.016$). Based on the findings of this study, it may be concluded that advancing age and cognitive decline, negatively impacted the oral health, oral function, oral health-related quality of life, and the nutritional state of care-dependent community-dwelling older adults.

## Introduction

As life expectancy increases, the World Health Organization (WHO) has identified older adults as an important target group for improving oral health and reducing disability-adjusted life years (DALY) (1). Poor dental status reduces the ability to chew, thereby affecting dietary intake and nutrition (2, 3) and thus affecting the oral health-related quality of life (OHRQoL). This association has been investigated particularly in institutionalized older adults (4). In this population, maintaining oral hygiene is often a problem (5). They often present with coronal/root caries, periodontal diseases, tooth loss, and malnutrition (6-9). Dental caries does not affect all older adults to the same extent and the reported annual caries incidence is more than twice as high among older adults living in Long Term Care Facilities (LTCFs) than their counterparts living in the community (10). In Switzerland today, the number of people receiving care by a mobile nursing service are twice as many than those living in LTCFs (11). There is limited data on the oral health status and the nutritional uptake of the care-dependent older adults living in the community.

Due to the utilization of preventive agents (fluorides), increased oral health awareness, improved education and advances in medicine, a greater number of older adults retain their natural teeth (12-15). Although this is a very positive trend, it also increases the amount of care required to keep the remaining dentition healthy (5). Maintaining healthy natural dentition or replacing missing teeth with adequate prosthetic reconstructions is of crucial importance for maintaining chewing function (16) and nutrition (17, 18). Older adults who have reduced dentition or are rehabilitated with conventional complete dentures tend to consume less protein and fibers, and other essential nutrients (19-21). In care-dependent community-dwelling older adults it may be further complicated, as these adults lack the autonomy in procuring the utilities themselves and are dependent for their Activities of Daily Living (ADLs). Hence the food choices may be restricted and may entirely be dependent on the choices of the care-provider. In this context, processed and ultra-processed foods may contribute to an ever-increasing share of the energy intake of older adults. Ultra-processed foods are assumed to be, nutritionally, of poorer quality (22, 23). A diet based on ultra-processed foods contains less proteins, fibers, vitamins and microelements and more added sugars than a diet rich in fresh foods (22, 24, 25). This study focused on the relationship between oral health and the nutritional status of care-dependent, community-dwelling older adults. To obtain a more conclusive picture on the food choices of the participants, the participants' refrigerator content was sought. It has been documented that the refrigerator content has been used successfully to predict the frequency of hospitalization in older adults (26).

The aim of this study was to assess the oral health status (OHS), the OHRQoL and the nutritional status (NS) of community-dwelling older adults dependent on care for their ADLs. The study also aimed to identify if the OHS, the OHRQoL, and the NS were influenced by demographic factors. Finally, the study aimed to determine if the quality of the nutritional uptake (refrigerator content) was influenced by any demographic or other related factors.

## Materials and methods

This study was planned as a cross-sectional, unicentric, and regionally-representative (canton of Zurich, Switzerland) study. Ethics authorization was received from the relevant ethics committee (Basec-Nr: 2020-01342) of the canton of Zurich (Kantonale Ethikkommission Zürich). The study has been reported accordingly to STROBE (Strengthening in Reporting of Observational studies in Epidemiology) guidelines (27).

### *Study sample*

The study population consisted of community-dwelling adults living in their own residences in the canton of Zurich, Switzerland. They were dependent for care for some ADLs and were aged 65 years and over. A pathfinder sampling method as prescribed by the WHO was adopted for this study, which recommends a minimum of 25-50 participants per index age group (28). The age-group segments were categorized into: 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, and 95-100. This resulted in the recruitment of 33, 22, 36, 43, 57, 40, and 9 for the age groups segments 65-69, 70-74, 75-79, 80-84, 85-89, 90-94, and 95-100, respectively. Unfortunately, participants for the 95-100 group categories could not be sufficiently recruited. Participation was voluntary and the participants were recruited if they could give an informed consent. If the participant was incapable, then the consent was received from the participants' legal guardian (this was necessary in four cases). Participants were excluded if they were unable to undergo an intraoral examination, or were not willing to sign an informed consent or from whose guardians an informed consent could not be obtained.

### *Study procedure*

Custom-flyers were made to explain the study purpose as well as to invite volunteers to participate in the study. 3200 such flyers were sent to care-dependent older adults living in Zurich. The nursing service SPITEX (SPITEX Zurich Limmat, Switzerland) was contacted for a list of the addresses. A single investigator (L**.** A**.**), who was fluent in the local language (Swiss-German and High-German) contacted the interested older adults by telephone and visited them at their homes. First, the entire study details and study objectives were explained in simple local language (Swiss-German or High-German) and then, a signed informed consent was obtained. Second, an assessment took place where demographic, medical and nutritional information were collected though a structured interview. Then all participants underwent a detailed intraoral examination. At the end of the visit, oral hygiene instructions and other necessary advice for oral health management were provided. If necessary, appropriate referrals for any necessary treatments were made. An oral prophylaxis was provided, free of charge, with a mobile dental unit if it was deemed necessary by the investigator. All the interviews and examinations were carried out by the same investigator for all the participants (L**.** A**.**).

### *Assessments*

#### *General demographic and health information*

Demographic and health information were collected that included age, sex, frequency of hospitalization in the last 5 years, number of drugs taken per day, number of drugs taken per day acting on the oral cavity (i.e. any drug listed in the Swiss Drugs Compendium (compendium.ch) that indicates to have at least one side effect on the oral cavity), bisphosphonate therapy, drugs taken that induce hyposalivation, cumulating illness rating scale (29), Mini-mental State examination (MMSE), physical or social activities and level of mobility according to the Craig Handicap Assessment and Reporting Technique Score (CART Score) (30), level of education (1. no education, 2. vocational education, and 3. high school degree, university degree), economic status (1. welfare recipient, 2. low: taxable wealth < CHF 100,000, 3. middle: taxable wealth CHF 100,000 - 400,000, and 4. high: taxable wealth > CHF 400,000), and smoking and alcohol habits. All the examinations were conducted by a trained investigator (L. A.).

*Assessment of oral health status, oral function and OHRQoL*

The intraoral examination for the assessment of the oral health status took place in the participants' living room, either on the couch or at the dining table. The participants' remaining teeth were examined with a mirror and a probe. For periodontal measurements, the WHO 621 ("Trinity") probe was used. All intraoral examinations were performed under magnification using dental loupes and an attached headlight. The oral health status assessment comprised of gathering information about the teeth present, the amount of plaque, gingival condition, and the need for any periodontal treatment. These were collected by using the appropriate indices including the Decay-missing-filled index (DMFT) (28), Silness-Löe Plaque Index (Pl) (31), Löe-Silness Gingiva Index (GI) (32), Community Periodontal Index of Treatment Need (CPITN) (32, 33). Information on the xerostomia was collected using the Xerostomia Inventory (XI) (34). For a detailed explanation of how these indices were collected please refer to the appendix. Assessment of oral function included two parameters the chewing efficiency (CE) and maximum voluntary bite force (MBF). Chewing efficiency assessment included a subjective- (SA) and a quantitative [variance of hue (VoH)] assessment (35, 36). Oral health-related quality of life (OHRQoL) was assessed using the validated 14-item German version of the Oral Health Impact Profile (OHIP-G-14) (37-39).

*Assessment of nutritional status and quality of nutritional uptake (refrigerator content)*

Nutritional status was assessed using the Mini-Nutritional Assessment (MNA®) (40, 41). For additional information about the quality of food choices, each participant's refrigerator content was examined, and all items present were assessed for expiry date. Standardized photos of all food items were taken and they were then classified according to the NOVA (not an acronym) classification (23, 42). All nutritional values present on the box/label of the food items in the participants' refrigerators were uploaded into the Nutritics software (www.nutritics.com, Swords, Ireland). A macronutrient analysis of the refrigerator content, including carbohydrates, sugar, protein, fat, thus saturated fat and alcohol, was done. Furthermore, the proximity to the nearest supermarket was calculated based on google maps.

*Statistical Analysis*

Demographic information of the participants was reported descriptively. Mean and standard deviations were calculated for all outcome variables. Gaussian distribution was checked using Kolmogorov-Smirnov (K-S) and Shapiro-Wilk's tests ($P$ <0.05). Non-parametric Spearman's rank-order correlation was used to determine the relationship between the OHS, OHRQoL, nutritional status and age, sex, MMSE, level of dependency, level of education as well as the economic status of the participants ($P$ <0.05). Further correlation between oral health, function parameters, sociodemographic parameters and the NOVA Groups were evaluated ($P$ < 0.05). All statistical analysis was performed using a statistical software (IBM SPSS Statistics, version 28.0.1.1, IBM corp., Armank, New York, USA).

## Results

From a total of 3200 flyers circulated, 275 willing participants responded (response rate = 8.6%) and 240 care-dependent older adults (mean age: 81.5 ± 8.9 years) were recruited in the study. The STROBE flow chart in figure 1 shows the recruitment process.

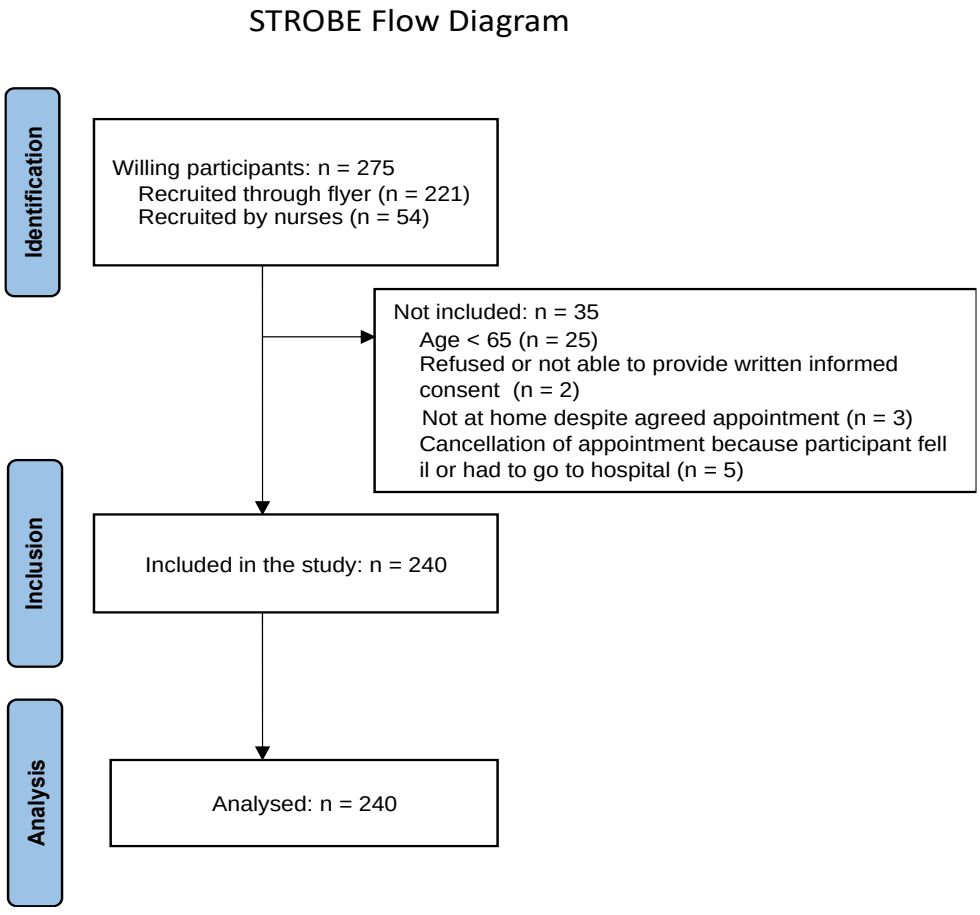


**Figure 1.** STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) flow diagram.

*Participant demographics*

The majority of the participants had a vocational training and belonged to the middle-income group. 10% of the participants were smokers and 45% were teetotalers. Participants required assistance for an average of 7 ADLs. The mean frequency of hospitalization in the last 5 years was 2.4 ± 2.4. The average number of medications consumed, and the CIRS (geriatric) score were 5.7 ± 4.3, and 10.1 ± 4.5, respectively. Cognitive decline was recorded only in 29 (12.1%) participants. The mean MMSE scores of the participants was 27.2 ± 5.2. Majority (87.5%) of the participants were normal, while 4.6 % and 5.8 % had mild and moderate cognitive impairment, respectively. The participants' demographic information is shown in table 1.

**Table 1.** Demographic information of the recruited participants.

| | |
|---|---|
| Number of participants (%) | |
| Women | 155 (64.6) |
| Men | 85 (35.4) |
| Total | 240 (100) |
| Age in years | 81.5 ± 8.9 |
| Participants' frequency of hospitalization in the last 5 years | 2.4 ± 2.4 |
| Medications taken by the participants | 5.7 ± 4.3 |
| Consumed medications that have an influence on the oral cavity | 2.4 ± 2.3 |
| Number of participants receiving bisphosphonate therapy (%) | 30 (12.5) |
| Number of participants consuming medications known to induce hyposalivation (%) | 182 (75.8) |
| Distribution of the number of participants categorized by their highest level of education received (%) | |
| None | 14 (5.8) |
| Secondary school (obligatory) | 12 (5.0) |
| Vocational education (apprenticeship) | 148 (61.7) |
| High school diploma | 38 (15.8) |
| University and higher degree | 27 (11.3) |
| Distribution of the number of participants according to their economic status (%) | |
| Welfare recipient | 39 (16.3) |
| Low-income group | 61 (25.4) |
| Middle-income group | 123 (51.3) |
| High-income group | 15 (6.3) |
| Number of smokers (%) | 28 (11.7) |
| Number of participants who consumed alcohol (%) | 132 (55.0) |
| Mean number of Activities of daily living (ADL) requiring assistance in participants | |
| ADL requiring partial assistance | 6.7 ± 4.7 |

| | |
|---|---|
| ADL requiring complete assistance | 3.7 ± 2.6 |
| | 3.0 ± 3.5 |
| Overall Cumulative Illness Rating Scale (geriatric) score of the participants | 10.1 ± 4.5 |
| Mean Mini-Mental State Examination (MMSE) score of the participants | 27.2 ± 5.2 |
| Distribution of participants categorized based on their MMSE scores (%) | |
| Severe dementia (<10) | 4 (1.7) |
| Moderate (10–18) | 14 (5.8) |
| Mild (19–23) | 11 (4.6) |
| Normal (>24) | 210 (87.5) |
| [a]Level of mobility | 73.3 ± 27.3 |
| [a]Physical or social activities | 61.8 ± 23.4 |
| [a] CART Score (maximum score is 100, higher scores indicate lesser degree of handicap) | |

### *Oral health, Oral function and OHRQoL*

The participants' oral health status, oral function and the OHIP scores are presented in table 2. The participants had an average of 18.8 ± 8.9, and 7.7 ± 3.5, number of teeth present and functional occlusal units, respectively. The mean overall DMF(T) score of the participants was 22.3 ± 5.3 (Decayed = 1.2 ± 2.7, Missing = 9.4 ± 8.6, Filled = 11.8 ± 7.1). Majority of the participants (*N* =124, 51.7%) brushed their teeth twice daily. 61.7% (*N* =148) of the participants visited their dentist within the last year, and 37.5% (*N* =90) indicated that they visited the dentist only for emergencies. Manual toothbrush was the most commonly used device (*N* = 136, 56.7%). Majority of the participants (*N* = 226, 94.2%) were not dependent for their oral care, and did not use any interdental device (*N* = 138, 57.5%). Most of the denture wearers (*N* = 40, 16.7%) slept with their prostheses. Regular fluoridated toothpaste was used by most participants (*N* = 210, 87.5%), while three participants used a high fluoride toothpaste.

**Table 2.** Participants' oral health, oral function, and OHRQoL.

| | |
|---|---|
| Number of teeth present | 18.8 ± 8.9 |
| Functional occlusal units | 7.7 ± 3.5 |
| DMFT | 22.3 ± 5.3 |
| [a]Plaque index | 1.8 ± 0.8 |
| [b]Gingival index | 1.2 ± 0.8 |
| [c]CPITN | 1.9 ± 1.1 |
| Xerostomia inventory | 25.4 ± 10.6 |
| Chewing efficiency | |
| [d]Visual inspection method (subjective assessment score) | 3.3 ± 1.4 |

| | |
|---|---|
| [e]Variance of hue (software calculated color mixing ability score) | 0.3 ± 0.2 |
| Average maximum bite force | 219.6 ± 193.6 |
| Number of participants with tooth loss (%) | 88 (36.7) |
| Distribution of the number of participants categorized by their edentulous state and antagonistic dentition (%) | |
| Fully edentate maxilla opposing fully edentate mandible | 22 (9.2) |
| Partially edentate maxilla opposing fully edentate mandible | 3 (1.3) |
| Fully edentate maxilla opposing partially edentate mandible | 8 (3.3) |
| Partially edentate maxilla opposing partially edentate mandible | 29 (12.1) |
| Fully edentate maxilla opposing natural dentition | 7 (2.9) |
| Natural dentition opposing a fully edentate mandible | 2 (0.8) |
| Partially edentate maxilla opposing natural dentition | 14 (5.8) |
| Natural dentition opposing a partially edentate mandible | 3 (1.3) |
| Average time (in years) of function of the existing prostheses in situ | |
| Maxillary | 16.7 ± 11.5 |
| Mandibular | 17.3 ± 11.3 |
| Prostheses hygiene (Denture calculus index) | |
| Maxillary prostheses | 1.88 ± 0.9 |
| Mandibular prostheses | 1.86 ± 0.9 |
| [f]OHIP-14 (mean ± SD) | 8.0 ± 12.0 |

[a] Silness and Löe plaque index.

[b] Löe and Silness gingival index.

[c] CPITN: Community Periodontal Index of Treatment Needs. Only the average of the highest scores from the sextants is reported.

[d] Scale of 1 – 5. Higher scores indicate better chewing efficiency.

[e] Lower values indicate better color meaning better chewing efficiency.

[f] OHIP-14: Oral Health Impact Profile (German short version with 14-items).

### *Nutritional status and quality of nutritional uptake (refrigerator content)*

The nutritional status along with the quality of the nutritional uptake is shown in table 3. Most of the participants (*N* = 139, 60%) were in the normal MNA category, while 10.8% (*N* = 26) and 30.4% (*N* = 73) were malnourished and were at a risk of malnourishment, respectively. Overweight in general was a greater problem than underweight (*N* = 14, 5.8%), since 15.4% of the participants were overweight and 33.3% were at pre-obesity levels (table 3).

The participants' refrigerators contained on an average, more NOVA G1 (unprocessed: 8.2 ± 4.7) and G2 (processed ingredients: 6.3 ± 3.8) than from G3 (processed: 4.8 ± 2.0) or G4 (ultra-processed: 5.6 ± 3.3) food items (table 3). The overall pooled macronutrient analysis of the

refrigerator contents revealed largely of carbohydrates (4077.7 ± 24075.3 g), with a large part consisting of sugar (3466.3 ± 21883.1 g), followed by proteins (1770.6 ± 13056.2 g), fat (1977.9 ± 6504.4 g), and saturated fat (904.9 ± 3720.1 g). On an average 101.9 ± 230.0 g alcoholic beverages were present in the refrigerators. However, as shown by the high standard deviation, there was a great intra-individual difference in the refrigerator composition among the participants.
The average distance to nearest supermarket was 582.6 ± 531.3 m (minimum: 20m, maximum: 5400 m) from the participants' residence (table 3).
Participants with normal MNA had most food items belonging to the NOVA G1 and NOVA G2 categories in their refrigerators and in general had fuller refrigerators (figure 4).

**Table 3.** Nutritional status of the recruited participants and the quality of the nutritional uptake of the participants.

| | | | | |
|---|---|---|---|---|
| Mini-Nutritional Assessment (MNA) score (overall) | | | | 22.9 ± 4.7 |
| Distribution of the participants according to MNA categories (%) | | | | |
| Malnourished (< 17) | | | | 26 (10.8) |
| Risk of malnourishment (17.5 – 23.5) | | | | 73 (30.4) |
| Normal (24 – 30) | | | | 139 (57.9) |
| Missing info | | | | 2 (0.8) |
| Body Mass Index (BMI) score (overall) | | | | 25.5 ± 5.3 |
| Distribution of the participants according to BMI categories (%) | | | | |
| Underweight (17 – 18.5) | | | | 14 (5.8) |
| Normal (18.6 – 24.9) | | | | 106 (44.2) |
| Pre-Obesity (25 – 29.9) | | | | 80 (33.3) |
| Obesity Cl1 (30 – 34.9) | | | | 26 (10.8) |
| Obesity Cl2 (35.0 – 39.9) | | | | 7 (2.9) |
| Obesity Cl3 (> 40) | | | | 4 (1.7) |
| Quality of the nutritional uptake: distribution of the food items present in the participants' refrigerators categorized according to the [a]NOVA food classification system | | | | |
| NOVA G1: Unprocessed and minimally processed foods | | | | 8.2 ± 4.7 |
| NOVA G2: Processed culinary ingredients | | | | 6.3 ± 3.8 |
| NOVA G3: Processed foods | | | | 4.8 ± 2.0 |
| NOVA G4: Ultra-processed foods | | | | 5.6 ± 3.3 |
| Proximity to Supermarket (in meters) | | | | 582.6 ± 531.3 |
| | | | | |
| Distribution of the average number of food items groups among the participants categorized according to their MNA categories | | | | |
| MNA categories | NOVA G1 | NOVA G2 | NOVA G3 | NOVA G4 |

| | | | | |
|---|---|---|---|---|
| Malnourished | 6.8 ± 3.0 | 4.9 ± 3.3 | 5.0 ± 2.2 | 5.1 ± 3.3 |
| Risk of malnourishment | 7.5 ± 4.9 | 5.4 ± 3.8 | 4.4 ± 1.9 | 5.4 ± 3.2 |
| Normal | 8.8 ± 4.9 | 7.1 ± 3.7 | 4.8 ± 1.9 | 5.9 ± 3.4 |

[a] NOVA: Food classification system designed by the Center for Epidemiological Studies in Health and Nutrition, School of Public Health, University of Sao Paulo, Brazil.

*Correlations between Oral Health Status, OHRQoL, Nutritional Status and demographic parameters*

Correlations of oral health status with demographic parameters

The number of teeth present reduced significantly with advanced age [rs(238) = -0.229, *P* <0.001; table 4], and with cognition decline [rs(238) = 0.352, *P* <0.001; table 4]. Fewer teeth were present in those participants with an increased level of dependency [rs(238) = -0.315, *P* < 0.001; table 4], and with a low socio-economic status [rs(238) = -0.237, *P* < 0.001; table 4].
The DMF(T) scores corresponded to the trends observed with the number of teeth. DMF(T) increased as participants got older [rs(238) = 0.262, *P* < 0.001; table 4] and were more cognitively impaired [rs(238) = -0.251, *P* < 0.001; table 4]. The score was higher in participants with an increased dependency [rs(238) = 0.276, *P* < 0.001; table 4] and belonging to a low socio-economic status [rs(238) = -0.149, *P* = 0.022; table 4].
Oral hygiene parameters significantly declined with cognitive decline demonstrating higher plaque levels [rs(217) = -0.499, *P* < 0.001; table 4] and increased gingival bleeding [rs(216) = -0.460, *P* < 0.001; table 4]. Plaque and gingival indices were also higher in participants with increased level of dependency (*P* < 0.001; table 4) and low socio-economic status (*P* < 0.001; table 4). Gingival index was observed to be significantly higher in men [rs(216) = -0.149, *P* = 0.028; table 4].

*Correlations of OHRQoL with demographic parameters*

Cognition significantly affected the OHRQoL. Lower the MMSE score, the more impaired was the OHRQoL of the participants [rs(235) = -0.402, *P* < 0.001; table 4]. OHRQoL was severely impaired when the participants were more dependent [rs(235) = 0.405, *P* < 0.001; table 4], belonged to a low socio-economic status [rs(235) = -0.341, *P* < 0.001; table 4], and in those with a low educational training [rs(235) = -0.155, *P* = 0.017; table 4].

*Correlations of nutritional status with demographic parameters*

Malnourishment (low MNA scores) was significantly associated with older participants [rs(236) = -0.157, *P* = 0.015; table 4], and more predominant in women [rs(236) = -0.144, *P* = 0.026; table 4]. Malnourishment was pronounced in participants with severe cognitive decline [rs(236) = -0.478, *P* < 0.001; table 4], with increased level of dependency [rs(236) = -0.593, *P* < 0.001; table 4], and low socio-economic status [rs(236) = -0.182, *P* = 0.005; table 4].
BMI followed a similar trend with the demographic parameters as did the MNA. BMI reduced significantly as participants got older [rs(235) = -0.193, *P* = 0.003; table 4]. Men had a

significantly higher BMI than women [rs(235) = -0.156, *P* = 0.016; table 4]. Participants in a higher socio-economic status had higher BMIs [rs(238) = 0.155, *P* = 0.017; table 4].

**Table 4.** Correlations between Oral health status (number of teeth present, plaque index, gingival index) oral health impact profile and nutritional status (MNA, BMI) with demographic factors (age, sex, cognition (MMSE), level of dependency, economic status, and education).

| | | Age | | Sex | | MMSE | |
|---|---|---|---|---|---|---|---|
| | n | r | [a] *P*-value | r | [a]*P*-value | r | [a]*P*-value |
| Teeth present | 240 | -0.229 | <0.001 | 0.032 | 0.619 | 0.352 | <0.001 |
| DMF(T) | 240 | 0.262 | <0.001 | -0.007 | 0.918 | -0.251 | <0.001 |
| [b]Plaque index | 219 | 0.220 | 0.069 | -0.104 | 0.125 | -0.499 | <0.001 |
| [c]Gingival index | 218 | 0.123 | 0.069 | -0.149 | 0.028 | -0.460 | <0.001 |
| [d]OHIP 14 | 237 | 0.006 | 0.927 | 0.062 | 0.339 | -0.402 | <0.001 |
| [e]MNA | 238 | -0.157 | 0.015 | -0.144 | 0.026 | 0.478 | <0.001 |
| [f]BMI | 237 | -0.193 | 0.003 | -0.156 | 0.016 | 0.121 | 0.063 |
| | | Level of dependency | | Economic status | | Education | |
| Teeth present | 240 | -0.315 | <0.001 | 0.237 | <0.001 | 0.088 | 0.179 |
| DMF(T) | 240 | 0.276 | <0.001 | -0.149 | 0.022 | -0.079 | 0.224 |
| [b]Plaque index | 219 | 0.577 | <0.001 | -0.382 | <0.001 | -0.123 | 0.070 |
| [c]Gingival index | 218 | 0.549 | <0.001 | -0.385 | <0.001 | -0.108 | 0.112 |
| [d]OHIP 14 | 237 | 0.405 | <0.001 | -0.341 | <0.001 | -0.155 | 0.017 |
| [e]MNA | 238 | -0.593 | <0.001 | 0.182 | 0.005 | 0.035 | 0.589 |
| [f]BMI | 237 | -0.122 | 0.060 | 0.155 | 0.017 | -0.066 | 0.310 |

[a] P-value: Spearman's rho, significance set at $P < 0.05$.

[b] Silness and Löe.

[c] Löe and Silness.

[d] OHIP-14: Oral Health Impact Profile (German short version with 14-items).

[e] MNA: Mini-Nutritional Assessment

[f] BMI: Body Mass Index

*Correlations between nutritional uptake (refrigerator content) and demographic parameters, oral health status, oral function, nutritional status and proximity to supermarkets*

*Correlations of nutritional uptake (refrigerator content) with demographic parameters*

Women, participants with higher socio-economic status and those with higher MMSE scores had significantly more food items in their refrigerators (table 5). Participants who required less assistance for their ADLs had more unprocessed foods (NOVA G1: $P = 0.020$) and processed ingredients (NOVA G2: $P < 0.001$) in their refrigerators (table 5).

*Correlations of nutritional uptake (refrigerator content) with oral health status and oral function*

The number of processed ingredients (NOVA G2) was more in participants with more teeth (NOVA G2: $P = 0.020$) and a lower DMFT score (NOVA G2: $P = 0.015$; table 5). Oral hygiene parameters (plaque and gingival scores) were better ($p < 0.05$) in participants with a stocked refrigerator especially with NOVA G1, G2 & G4 items (table 5).
The amount of unprocessed/minimally processed food (NOVA G1) and processed ingredients (NOVA G2) were present more in the participants with better chewing efficiency and maximum voluntary bite force ($P < 0.05$; table 5).

**Table 5.** Correlations between quality of the nutritional uptake (NOVA) and the oral health status (teeth present, plaque index, gingival index), oral function (chewing efficiency and bite force), demographic factors (age, sex, cognition (MMSE), level of dependency, economic status, and education), nutritional status and the proximity to supermarkets.

| Variables | | NOVA G1 | NOVA G2 | NOVA G3 | NOVA G4 |
|---|---|---|---|---|---|
| Age | r | -0.011 | -0.087 | 0.106 | -0.063 |
| | [a]*P*-value | 0.887 | 0.252 | 0.161 | 0.409 |
| Sex | r | 0.246 | 0.947 | 0.195 | 0.155 |
| | [a]*P*-value | 0.001 | 0.005 | 0.009 | 0.040 |
| [f]MMSE | r | 0.210 | 0.317 | 0.055 | 0.223 |
| | [a]*P*-value | 0.005 | <0.001 | 0.465 | 0.003 |
| Level of dependency | r | -0.175 | -0.318 | -0.056 | -0.063 |
| | [a]*P*-value | 0.020 | <0.001 | 0.459 | 0.404 |
| Economic status | r | 0.295 | 0.261 | 0.161 | 0.174 |
| | [a]*P*-value | <0.001 | <0.001 | 0.033 | 0.021 |
| Education | r | 0.062 | 0.058 | 0.051 | -0.026 |
| | [a]*P*-value | 0.417 | 0.444 | 0.500 | 0.730 |
| No of Teeth present | r | 0.090 | 0.175 | -0.007 | 0.110 |
| | [a]*P*-value | 0.233 | 0.020 | 0.928 | 0.147 |

| | | | | | |
|---|---|---|---|---|---|
| DMFT total score | r | -0.114 | -0.183 | -0.004 | -0.113 |
| | [a]*P*-value | 0.130 | 0.015 | 0.953 | 0.134 |
| [b]Plaque index | r | -0.210 | -0.274 | -0.078 | -0.219 |
| | [a]*P*-value | 0.008 | 0.001 | 0.329 | 0.006 |
| [c]Gingival index | r | -0.192 | -0.310 | -0.124 | -0.235 |
| | [a]*P*-value | 0.016 | <0.001 | 0.121 | 0.003 |
| [d]SA | r | 0.136 | 0.213 | 0.076 | 0.105 |
| | [a]*P*-value | 0.084 | 0.006 | 0.337 | 0.181 |
| [e]VoH | r | -0.193 | -0.221 | -0.078 | -0.105 |
| | [a]*P*-value | 0.014 | 0.005 | 0.320 | 0.183 |
| Maximum bite force | r | 0.093 | 0.209 | -0.016 | -0.038 |
| | [a]*P*-value | 0.307 | 0.021 | 0.864 | 0.677 |
| [g]MNA | r | 0.161 | 0.247 | 0.018 | 0.094 |
| | [a]*P*-value | 0.033 | 0.001 | 0.811 | 0.216 |
| Proximity to supermarkets | r | -0.121 | -0.130 | -0.097 | -0.092 |
| | [a]*P*-value | 0.109 | 0.085 | 0.200 | 0.225 |

[a] *P*-value: Spearman's rho, significance set at *P* <0.05.

[b] Silness and Löe.

[c] Löe and Silness.

[d] Chewing efficiency visual subjective assessment.

[e] Chewing efficiency software calculated variance of hue.

[f] MMSE: Mini-Mental State Examination

[g] MNA: Mini-Nutritional Assessment

*Correlations of nutritional uptake (refrigerator content) with participants' nutritional status and proximity to the supermarkets*

A significant and positive correlation was observed between the nutritional status and the amount of NOVA G1 and G2 food items (table 5). Participants with better MNA scores had more unprocessed/minimally processed foods (*P* = 0.03) and processed ingredients (*P* = 0.001). However, the closeness to the supermarkets did not influence the refrigerator content.

## Discussion

This study reports cross-sectional data on the oral health status, the OHRQoL and the nutritional status of 240 community-dwelling older adults (aged at least 65 years) dependent on care for their ADLs in an industrialized country. The oral health and nutritional status varied across sociodemographic groups with better oral health status and nutritional status (meaning more teeth present, lower DMFT total score, lower plaque index and higher MNA-Score) in

younger than older participants, in persons with a lower than higher level of dependency and in participants from higher than lower income or cognition levels. Moreover, participants with a better oral health status and better oral function had more unprocessed food items (NOVA G2) in their refrigerators.

To the authors' knowledge, this study is one of the first to analyze OHS and NS in a population of community-dwelling older adults dependent on care in Switzerland and the first study to analyze the quality of nutritional uptake by NOVA classification in older adults. In contrast, other studies mainly focused on institutionalized older adults (6-8, 43) and provided insights into the associations between OHS and MNA scores (2, 9, 44, 45). A single investigator (L. A.) performed all the data collection, and therefore in terms of standardization it may be considered robust. It must be borne in mind, however, that the study comes from a fairly developed country with many resources and does not necessary reflect the reality of many care-dependent older adults from other economically challenged nations. Although the study was conducted with robust methodologies, a few limitations may have existed. Firstly, it must be maintained that only a small proportion (12%) of the included cohort had a reduced level of cognition. Therefore, interpretation of the results relative to the cognitive status (MMSE) should be considered with caution. Secondly, the results from this study are largely representative of the population of community-dwelling, care-dependent older adults living in the canton of Zurich, Switzerland, but inherit a certain selection bias because only those participants were recruited who could respond to the flyer. This bias may be most pronounced in fragile participants than in healthy ones because physically and mentally fit participants were more likely to respond to the flyer and participate in the survey than the vulnerable older adults. Thus, it is quite possible that the study portrays oral health and nutritional status better than it actually is in the reality of many very old and frail adults. To reduce this bias, older adults were also informed by the nurses of the mobile nursing service via word of mouth about the possibility of participating in the study. Furthermore, it would have been interesting to also have examined the role of ethnicity of the participants on the investigated parameters. This information was not collected and its effect could not be assessed. However, it must be borne in mind that all the participants interviewed were Swiss nationals and have been in the region for a considerable amount of time, spoke high German or Swiss-German fluently and therefore could be considered as a representation of the local population.

The oral health status of the examined population was considerably better in comparison to results reported for nursing home residents (7, 8, 43), but not on par with the data reported for the entire Swiss population in 2012 (12, 13, 46). Compared to the total Swiss population aged 15-74 (data from the Swiss Health Survey 2012), where 74.7% reported having visited the dentist or dental hygienist at least once in the last 12 months, only 61.7% of our study population reported having done so (46). This result shows that a large majority of care-dependent older adults in Switzerland, although suffering from various diseases (CIRS total score: 10.1 ± 4.5), having a reduced level of mobility (73.3 ± 27.3) and physical or social activities (61.8 ± 23.4), can nevertheless benefit from a regular recall visit. The participants had an average of 18.8 ± 8.9 teeth and 7.7 ± 3.5 functional occlusal units, and this result is in line with the findings of Schneider et al. (2017), who reported a mean number of 9.0 missing teeth without counting wisdom teeth in the age group of 75 and 84-year-olds in the Swiss population (12). Edentulism was present in 36.7% of the examined care-dependent older adults; this number is smaller than the results of a comparable study in Germany, where 47%

of the study population was edentulous (9). Considering the average DMF(T) score of the study population of 22.3 ± 5.3, the examined population performs better when compared to the results of nursing home residents in Flanders, Belgium, with an average DMF(T) of 27.7 (7), or than in Lower Saxony, Germany, with a DMF-T of 25.0 (which included only dentate persons) (43). It could be assumed, that nursing home residents with a higher average level of care dependency also have poorer oral health than the examined population of care-dependent community-dwelling older adults (8).

Another important finding of the present study was that the oral hygiene indices (plaque- and gingival indices) were generally high. They had one decayed tooth on an average with moderate pocket depths and subgingival calculi. It seemed that the majority of the participants were at a point where their manual and cognitive abilities might be slowly diminishing and the level of oral hygiene decreasing along with it. However, this deficit was not reflected in their DMF(T) score nor in the number of teeth present.

The literature shows that older adults are at an increased risk of malnutrition, especially protein-energy malnutrition (47). Therefore, the present study investigated the nutritional status (MNA) and quality of nutritional uptake (refrigerator content). The present study demonstrated that nearly 60% of the participants were in a normal nutritional state. These results from the present study indicate a better nutritional status of the studied population when compared to previous studies where it was found that 52% (43) or more than 70% (9) of the investigated cohort were at a risk of malnutrition or were malnourished. Furthermore, this study made an exploratory attempt to identify factors that might influence the quality of nutritional uptake. In general, a large intra-individual difference of the refrigerator composition was observed by the macronutrient analysis. The refrigerator contents of the examined population contained free sugar that represented almost 85% of all the carbohydrates present in the refrigerator. This relatively high amount of free sugar in the nutrition of the population could therefore also play an important role in increasing plaque levels (48). Therefore, it is imperative to provide periodic nutritional counselling in order to reduce the high amount of sugar consumed by these older adults along with the regular oral care.

When observing the distribution of the NOVA food items in the refrigerator content, participants had more unprocessed or minimally processed food items (NOVA G1 and G2). This indicated that the majority of the study population still prepare their own meals, which was quite promising.

Cognitive decline, advanced age, sex (female), low economic status and high level of care-dependency (no. of ADL where participants required help) negatively influenced the nutritional state in the current study. The level of dependency had a crucial association on the nutritional state, signifying that participant's with a higher level of dependency were more likely to be at risk of malnourishment or already malnourished. Participants with a high level of care-dependency seemed to generally face more difficulty preparing their own meals made out of fresh foods. Therefore, these participants on their own or with the help of a family member or the caregiver chose to purchase more ready-made meals, which could be easily prepared. These ultra-processed foods, however, contain less protein, fiber, vitamins and microelements and more added sugar than homemade meals out of fresh foods (22, 24, 25). This, in turn, could promote that these older adults have an increased risk of malnutrition (lower mean MNA). Likewise, dementia was an important risk factor for malnutrition in

institutionalized adults (43). The results of this study confirm these findings as participants with low MMSE scores were associated with a higher risk of malnourishment. However, these results must be interpreted with caution, because only a minority (*N* = 29) of the participants had some form of cognitive deficit.

This study was also unable to demonstrate a clear association between the quality of nutritional uptake (NOVA) and the oral health status of care-dependent older adults. Previous reports in literature confirm our findings that it is difficult to draw a clear relationship between the patient's masticatory function and deficient dietary intake (49). However, this study did confirm that participants with better chewing efficiency and bite force had more food products that were in the categories of unprocessed/minimally processed foods (NOVA G1) and processed ingredients (NOVA G2).

In general, this study provides important indications as to which patient group within the sample of care-dependent older adults should receive special attention. A large proportion of the sample had a fairly good oral health and nutritional status, but special attention must be paid to those individuals with a high level of care dependency and those with a low cognitive status, as they seem to be particularly at a risk of poor oral health as well as malnutrition. These individuals would benefit from periodic nutritional counselling or the establishment of a mobile menu service along with regular oral care. However, further studies are warranted to confirm these assumptions.

## Conclusions

Based on the findings of this study, it may be concluded that advanced age, cognitive decline, increased level of dependence, and low socio-economic status negatively impacts the oral health, oral function, OHRQoL and the nutritional state of care-dependent community-dwelling older adults.

## Conflicts of Interests and source of funding statement

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The authors declare that they have no conflicts of interests.

**Zusammenfassung**

*Einleitung*

Ziel dieser Studie war es, den Mundgesundheitsstatus, die mundgesundheitsbezogene Lebensqualität und den Ernährungsstatus von auf ambulante Pflege angewiesene ältere Menschen zu untersuchen.

*Material und Methoden*

Es wurden Informationen zum Mundgesundheitsstatus, d.h. DMF(T), Plaque- (PI) und Gingivaindex (GI), Community-periodontal-index-for-treatment-needs (CPITN), Oral health impact profile (OHIP-G-14), maximale Bisskraft (MBF), Kaueffizienz [subjektive (SA) und quantitative (VoH) Bewertungen] erhoben. Der Ernährungszustand wurde mit dem Mini-nutritional assessment (MNA) und dem Body-Mass-Index (BMI) zusammen mit der Qualität der Nahrungsaufnahme (NOVA-Klassifikation) ermittelt. Der kognitive Status wurde anhand des Mini-Mental-State-Examination-Scores (MMSE) bewertet.

*Resultate*

240 ältere Menschen (Durchschnittsalter = 81,5 ± 8,9 Jahre; Männer = 85, Frauen =155) wurden rekrutiert. Die durchschnittliche Anzahl der vorhandenen Zähne und Kaueinheiten betrug 18,8 ± 8,9 bzw. 7,7 ± 3,5. Der durchschnittlich DMF(T)-Score betrug 22,3 ± 5,3. Die durchschnittlichen PI-, GI-, CPITN- und OHIP-14-Scores betrugen 1,8 ± 0,8, 1,2 ± 0,8, 1,9 ±1 ,1 bzw. 8,0 ±1 2,0. Die durchschnittlichen MBF, VoH und SA lagen bei 219,6 ± 193,6, 0,3 ± 0,2 bzw. 3,3 ±1 ,4. Der durchschnittliche MNA und BMI betrug 22,9 ±4 ,7 bzw. 25,5 ± 5,3. Die Anzahl der vorhandenen Zähne nahm mit dem Alter ($P < 0,001$), dem kognitiven Verfall ($P < 0,001$), der zunehmenden Abhängigkeit ($P < 0,001$) und einem niedrigen sozioökonomischen Status ($P < 0,001$) signifikant ab. Die Mundhygiene verschlechterte sich signifikant bei kognitivem Abbau ($P < 0,001$), zunehmender Pflegeabhängigkeit ($P < 0,001$) und niedrigem sozioökonomischem Status ($P < 0,001$). Die OHIP-Werte wurde durch einen zunehmenden kognitiven Abbau ($P < 0,001$), Pflegeabhängigkeit ($P < 0,001$) und einen niedrigen sozioökonomischen Status ($P < 0,001$) sowie ein niedriges Ausbildungniveau ($P = 0,017$) negativ beeinflusst. Die MNA wurde bei Frauen niedriger ($P = 0,026$), und zwar mit zunehmendem Alter ($P = 0,015$), kognitivem Abbau ($P < 0,001$), erhöhtem Grad an Pflegeanhängigkeit ($P < 0,001$) und bei einem niedrigen sozioökonomischen Status ($P = 0,005$). Der BMI nahm signifikant ab, wenn die Teilnehmer älter wurden ($P = 0,003$) oder einen höheren sozioökonomischen Status hatten ($P = 0,017$). Männer hatten einen signifikant höheren BMI als Frauen ($P = 0,016$).

*Diskussion*

Die Ergebnisse dieser Studie lassen den Schluss zu, dass fortgeschrittenes Alter, kognitive Beeinträchtigungen, ein erhöhtes Maß an Pflegeabhängigkeit und ein niedriger sozioökonomischer Status sich negativ auf die Mundgesundheit, die Mundfunktion, die OHRQoL und den Ernährungszustand von auf ambulante Pflege angewiesene ältere Menschen auswirken.

**Résumé**

*Introduction*

L'objectif de cette étude était d'examiner l'état de santé bucco-dentaire, la qualité de vie liée à la santé bucco-dentaire et l'état nutritionnel des personnes âgées nécessitant des soins ambulatoires.

*Matériels et methodes*

Des informations sur l'état de santé bucco-dentaire, y compris le DMF(T), la plaque (PI) et les indices gingivaux (GI), Community-periodontal-index-for-treatment-needs (CPITN), Oral health impact profile (OHIP-G-14), la force de morsure maximale (MBF), l'efficacité de la mastication [évaluations subjectives (SA) et quantitatives (VoH)], ont été collectées. L'état nutritionnel a été obtenu à l'aide de Mini-nutritional assessment (MNA) et de l'indice de masse corporelle (IMC), ainsi que la qualité de l'absorption nutritionnelle (classification NOVA). L'état cognitif a été évalué à l'aide du score du Mini-Mental-State-Examination (MMSE).

*Résultats*

240 personnes âgées (âge moyeN =81,5 ± 8,9 ans ; hommes = 85, femmes = 155) ont été recrutées. Le nombre moyen de dents et d'unités occlusales fonctionnelles présentes était respectivement de 18,8 ± 8,9 et 7,7 ± 3,5. Le score DMF(T) moyen était de 22,3 ± 5,3. Les scores moyens PI, GI, CPITN et OHIP-14 étaient respectivement de 1,8 ± 0,8, 1,2 ± 0,8, 1,9 ± 1,1 et 8,0 ± 12,0. Les moyennes de la MBF, VoH, SA étaient 219.6 ± 193.6, 0.3 ± 0.2, et 3.3 ± 1.4, respectivement. L'indice de masse corporelle et l'indice de masse corporelle moyens étaient respectivement de 22,9 ± 4,7 et 25,5 ± 5,3. Le nombre de dents présentes diminuait significativement avec l'âge (P < 0.001), le déclin cognitif (P < 0.001), l'augmentation de la dépendance (P < 0.001) et un faible statut socio-économique (P < 0.001). L'hygiène bucco-dentaire se détériore significativement avec le déclin cognitif (P < 0,001), l'augmentation de la dépendance (P < 0,001) et le faible statut socio-économique (P < 0,001). Les scores OHIP étaient négativement affectés par l'augmentation du déclin cognitif (P < 0,001), de la dépendance (P < 0,001) et d'un faible statut socio-économique (P < 0,001) et d'une faible formation (P = 0,017). L'IMC avait un impact négatif chez les femmes (P = 0,026), avec l'augmentation de l'âge (P = 0,015), le déclin cognitif (P < 0,001), l'augmentation du niveau de dépendance (P < 0,001) et un faible statut socio-économique (P = 0,005). L'IMC diminuait significativement avec l'âge (P = 0,003) ou le statut socio-économique (P = 0,017). Les hommes avaient un IMC significativement plus élevé que les femmes (P = 0,016).

*Discussion*

Sur la base des résultats de cette étude, on peut conclure que l'âge avancé, le déclin cognitif, le niveau accru de dépendance et le faible statut socio-économique ont un impact négatif sur la santé bucco-dentaire, la fonction bucco-dentaire, l'OHRQoL et l'état nutritionnel des personnes âgées vivant dans la communauté et dépendantes de soins.

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**Appendix**

**Detailed explanation on certain indices used for assessing the oral health and nutritional status**

**Decay-missing-filled index (DMFT):** All participants' remaining teeth were examined with a mirror and a probe to assess dental caries experience and dental treatment needs.

**Silness-Löe Plaque Index (PI)** (31) measures the state of oral hygiene based on recording the soft debris and mineralized deposits on teeth 16, 12, 24, 36, 32 and 44. Those teeth were examined using a mirror and a probe. They were not stained. The values were added for the four surfaces of the tooth and divided by four to determine the PI of the tooth. The PI of the individual was determined by adding the values of each tooth and dividing them by the number of teeth examined. A high index score indicates poor oral hygiene. Four grades were distinguished: 0: No plaque (inspection and probing); 1: A film of plaque adhering to the free gingival margin (detectable only by probing); 2: Moderate accumulation of plaque (visible with naked eye, interdental spaces free); 3: Abundance of plaque (interdental spaces filled with plaques); X: Tooth not present.

**Löe-Silness Gingiva Index (GI)** (32) measures the degree of inflammation in the gingiva. The gingiva was assessed by careful probing along the sulcus. The bleeding behavior was measured as an indicator of inflammation. In addition, the examiner considered color, redness, swelling, ulceration and stippling loss of the gingiva. As with the Plaque Index, the values were added for the four surfaces of teeth 16, 12, 24, 36, 32 and 44 and divided by four to determine the GI of the tooth. The GI of the individual was determined by adding the values of each tooth and dividing them by the number of teeth examined. Four levels of gingival health were distinguished: 0: normal gingiva, no inflammation, no discoloration, no bleeding; 1: low inflammation, slight color change, no bleeding; 2: moderate inflammation, redness, edema, bleeding on probing, loss of stippling; 3: severe inflammation, redness, edema, tendency toward spontaneous bleeding, ulceration; X: tooth not present.

**Community Periodontal Index of Treatment Need (CPITN)** (32, 33) is a screening method used to assess periodontium. For this purpose, the participant's dentition was divided into sextants. With a periodontal probe, all teeth were measured, but only the highest index degree per sextant was recorded. The WHO 621 periodontal probe had a spherical end of 0.5 mm diameter and black marking between 3.5 and 5.5 mm. Additional notch markings were

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8.5 mm and 11.5 mm. The advantage of this index is that it indicates not only the assessment of periodontal status but also the treatment needs for the underlying periodontal disease. Five levels of periodontal health were distinguished: 0: healthy (no bleeding on probing, no marginal irritation, no pockets): no treatment; 1: no pockets, bleeding on probing, no calculus, no overhangs. Treatment: Oral hygiene instructions (OHI); 2: pockets <3 mm, sub gingival calculus present, and/or iatrogenic marginal irritations (overhanging restoration margins). Treatment: OHI, scaling and correction of overhangs; 3: deepest pockets between 4 and 5 mm. Treatment: OHI, scaling and root planning; 4: probing depth > 6 mm. Treatment: Scaling and root planning, and/or flap as required.

**Xerostomia Inventory (XI)** was used to assess the participant's subjective feeling of dry mouth (34). The response options for each item were given on a five-point scale between 1 and 5 as follows: very often = “5,” fairly often = “4,” occasionally = “3,” hardly ever = “2,” and never = “1.” A higher score reflects more severe subjective feeling of dry mouth.

**Chewing efficiency (CE)** was assessed with two-color chewing gum examinations, as described by Schimmel et al. (35, 36). For this, the participants had to sit upright and chew the two-colored chewing gum for 20 chewing cycles. The gum was flattened to a wafer thickness of 1 mm. Both sides of the wafer were scanned using a flatbed photo scanner. The two images were brought together on a single frame using Photoshop software. This single image was then imported into the software (ViewGum). The software calculated the variance of hue (VoH) for each chewing gum color. VoH is a numerical value, and the lower the value, the better the chewing efficiency. A visual subjective assessment (SA) of the chewing gum was also performed. The following grades were allotted: SA 1: chewing gum not mixed, impressions of cusps or folded once; SA 2: large parts of chewing gum unmixed; SA 3: bolus slightly mixed but bits of unmixed original color; SA 4: bolus well mixed but color not uniform; SA 5: bolus perfectly mixed with uniform color.

**Maximum bite force (MBF)** was measured using a bite force meter. Measurements were taken on the right and left side in the region between the first molars and three repetitions were done per side. Then, the mean of the maximum bite force per side was calculated and, finally, the mean for the participants. This value was used for the analysis.

**The mini nutritional Assessment (MNA®)** (40, 41) is a short, structured recording of a patient’s nutritional situation, which enables identification of undernourishment and malnutrition. The instrument has a two-stage structure: anamnesis with 6 items (A–F) with a maximum of 14 points and anamnesis with a further 12 items (G–R), including 2 anthropometric measurements (upper arm circumference and calf circumference), with a maximum of 16 points. The assessment further includes body mass index (BMI), calculated using the weight and height of the participant. Four the MNA four categories are distinguished: 0 = BMI < 19; 1 = 19 ≤ BMI < 21; 2 = 21 ≤ BMI < 23; 3 = BMI ≥ 23. The anamnesis includes information on the living situation,medication intake and skin condition. A maximum of 30 points can be achieved. Based on the MNA scores, the participants were categorized into three categories: 24–30 points: Normal nutritional status; 17–23.5 points: Risk of malnourishment; < 17 points: Malnourished.

**The NOVA (not an acronym) Classification** (23, 42) system groups all foods according to the industrial processes they underwent. Four different groups of products are distinguished. Group 1 includes unprocessed or minimally processed foods, such as fresh, dry or frozen

vegetables or fruit, grains, legumes, meat, fish, egg, nuts and seeds. Minimal processing includes the removal of unwanted parts of the food; in this group, no substances are added to the original food. Group 2 includes processed ingredients, such as plant oils (e.g., olive oil, coconut oil), animal fats (e.g., cream, butter, lard), maple syrup, sugar, honey and salt. This group includes substances derived from group 1 foods or from nature by processes including pressing, refining, grinding, milling and drying. Group 3 includes processed foods, such as canned or pickled vegetables, meat, fish or fruit, artisanal bread, cheese, salted meats, wine, beer and cider. This group includes foods that are processed foods from groups 1 or 2 with the addition of oil, salt or sugar by means of canning, pickling, smoking, curing or fermentation. Finally, NOVA group 4 includes ultra-processed foods, such as sugar-sweetened beverages, sweet and savory packaged snacks, reconstituted meat products, pre-prepared frozen dishes, canned or instant soups, chicken nuggets, and ice cream. The foods in this group are formulations made from a series of processes, including extraction and chemical modification, and foods in this group include very little intact group 1 foods.