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# Influence of dental status on dietary intake and survival in community-dwelling elderly subjects

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## Abstract

**Objective:** to evaluate the relationships between a functional measure of dental status (FDS), the nutrients intake profile (NIP) and mortality in a community elderly population.
**Design:** cross-sectional analysis for FDS and NIP and a prospective study for mortality.
**Setting:** the central district of Brescia, northern Italy.
**Participants:** of the entire cohort of 70–75-year-old elderly subjects living in the district ($n = 1303$), 1189 subjects were interviewed and examined at baseline. Fifty-two of these were lost to follow-up; data are presented for the remaining 1137 subjects.
**Measurements:** baseline data were collected by a door-to-door interview using a standardized questionnaire which included a section about the dietary intake in the 24 h preceding the interview. The 24-h NIP was calculated and compared with the US Food and Drug Administration's 1980 Recommended Dietary Allowances to obtain a percentage value of each nutrient for each respondent. The dental examination considered the direct assessment of the number and position of residual teeth as well as the use of dentures; subjects were classified into three groups: naturally adequate or naturally inadequate dentition and denture wearers. Association of NIP with FDS was computed using ANCOVA and multiple logistic regression models. Mortality data were collected over a 78-month follow-up period. Association of survival with FDS was estimated by Kaplan-Meier analysis and multivariate Cox proportional hazard models.
**Results:** multiple logistic regression showed a significant and independent association between the dental status and the intake of micronutrients, but not of macronutrients. Moreover, denture wearers had a dietary intake very similar to adequate dentition and substantially better than inadequate dentition. Inadequate dentition in women was associated with higher mortality than adequate dentition. In elderly women, both inadequate dental status and folate intake were significant and independent predictors of mortality in a multivariate analysis based on nutritional parameters. However, inadequate dentition did not remain an independent predictor of mortality in a general multivariate model.
**Conclusion:** in this cohort of urban elderly people, FDS is significantly associated with the NIP and indirectly with mortality.

Keywords: *dental status, mortality, nutrients intake profile*

## Introduction

Several studies (but not all—see [1] for an opposite view) have documented nutritional inadequacies (both deficiencies and excesses) in older populations [2], although the use of different measures of nutritional status sometimes makes it difficult to compare such studies [3].

Nutritional well-being plays an essential role in health promotion and maintenance in older people [4-8]; thus, it is important to identify the main determinants of nutritional status in the elderly population. Dietary habits, food intake and oral health changes are important factors, but their reciprocal effects and relationships with overall nutritional status are complex and controversial [9, 10]. In addition, methodological problems and inconsistencies among the different studies have clouded this area of research [9, 11].

Furthermore, the effects of food intake and oral health status on the general health and survival of old people have received little attention. Our previous studies suggest that most daily nutrient intakes (with some exceptions, e.g. folates) are related to socioeconomic and physical factors [12]. Furthermore, dental status is related to education, cognitive function and a global measure of somatic health represented by the health service utilization scale [13]. The relationships between dietary intake and dental status and effects on quality of life (QOL) and survival of old people have yet to be unravelled [10]. These are the reasons which prompted us to carry out the present analysis.

## Subjects and methods

### Sample and data collection

The target population was the entire cohort of 70-75-year-old subjects living in the historical centre of Brescia. All inhabitants in this area and living at home were considered eligible for inclusion ($n = 1303$). The study was carried out in two phases. During the first phase (February-June 1986), data collection was undertaken using a door-to-door method by 10 specifically trained doctors. Of the target population, 1189 subjects (91.3%) agreed to answer a multidimensional questionnaire and to undergo a standardized physical examination, including a comprehensive dental assessment. The reasons for exclusions were (i) refused interview ($n = 27$) and/or (ii) dental examination ($n = 12$); (iii) out of town ($n = 65$) or (iv) hospitalized ($n = 10$) during the period of the inquiry. Gender distribution and mean age were no different between included and excluded subjects. Further details about this phase of the study have been reported previously [14, 15].

In the second phase of the study, the names of subjects who had died after 6½ years were obtained from the government registry office. The survival status of 52 subjects (4.4% of the phase 1 sample) could not be ascertained (mainly because they had moved to a different town) and they were excluded. Thus, a final sample of 1137 elderly people (87.4% of the initial population) constituted the present study. Those lost to follow-up were not statistically different from the study sample in terms of age, sex, functional and mental or dental status (see below).

### Questionnaire

Several baseline demographic variables were recorded using a self-report method: age, gender, educational level, marital status, economic situation and living conditions were documented (Table 1).

A number of rating scales were administered covering most of the health-related domains and the main components of QOL [14-16]. We did not consider a specific oral health-related QOL domain, but used an overall health-related QOL profile and correlated this with a number of functional variables [17, 18], among which there was a functional measure of dental status.

Briefly, the affective domain was evaluated using a scale comprising a revised version of Beck's Depression Inventory plus the Anxiety and Personal Wellbeing scale [19]. The cognitive function was quantified by the Mental Status Questionnaire [20]. Functional status was assessed by the Instrumental Activities of Daily Living scale [21]. Social relationships were scored with Linn's self-evaluation of life function (SELF) scale [22]. As both the Instrumental Activities of Daily Living and the SELF variables (but not Beck's Depression Inventory or the Mental Status Questionnaire) are strong predictors of mortality in the study population [23], only the former parameters were used.

Somatic health was assessed by three components: health status, health behaviours and health care utilization. In the health status component we checked for the presence of 13 different chronic conditions (based on self-report) and subsequently computed the total number of these for each respondent. In addition, a standardized list of symptoms was completed by asking about the occurrence of each of them in the preceding month and ranking those present on a four-level scale. In the present study, we consider two of these symptoms, possibly influencing dietary intake—lack of appetite and dyspepsia, dichotomizing the responses (absent + mild *vs* moderate + severe).

The health behaviours component incorporates the self-reported level of motor activity, alcohol intake and use of tobacco products. These behaviours were not combined.

The health care utilization component was assessed through a scale quantifying health services referrals and physical complaints during the month before the interview. The assessment of physical health status based on use of medical services is a reasonable method for assessing the health status of elderly people in a uniform and restricted setting [24]. In the study population this index is the most important predictor of mortality among the above somatic health indicators [23].

### Dietary intake

Dietary intake was evaluated by 24-h recall [25]. Information was obtained about consumption of food (meals, snacks and drinks) during the day preceding the interview.

The method is rapid and simple to administer, although it has some disadvantages: (i) it tends to underestimate caloric intake; (ii) decreased short-term memory, hearing loss and poor communication skills may affect the validity and reliability of information; and (iii) it cannot measure day-to-day variations [26, 27]. However, several researchers have reported that the 24-h dietary recall method is adequate for obtaining the mean nutrient intake when the sample size is sufficiently large. In addition, 24-h recall has been found to be valid when used to compare the dietary intake of different groups [28-30].

The 24-h nutrient intake was calculated with a computerized system based on data from the National Department of Nutrition of Italy [31]. Then, the data were compared with the 1980 Recommended Dietary Allowances (RDA), produced by the US Food and Drug Administration [32] and a percentage value of each nutrient for each respondent was obtained. The percentage dietary intake was computed for calories, proteins, vitamins A, C and B12, thiamine, riboflavin, niacin, folate and iron.

As in other studies [26, 33, 34], two-thirds of the RDA was used as the lower limit for considering sufficient nutritional intake; although the RDA is not intended to represent individual dietary intake, it is recommended for population studies.

## Categorization of dentition

The dental examination focused on 'ecologically' relevant impairment. Clinical functioning of teeth has been classified by several indices, including the number of sound plus filled teeth [35-37]. However, the relationship between number and position of retained teeth and functional relevance is uncertain [38]. For example, Leake demonstrated that the absence of functioning opposing pairs of natural posterior teeth was the most important factor influencing chewing ability [39]; however, the advent of processed foods has made it possible to eat an adequate diet without chewing.

Brocklehurst [40] suggested guidelines for adequate (although not necessarily optimal) functional masticatory efficiency. In particular, he reported that Jackson

Table 1. Frequency distributions in the three subgroups for baseline variables

| Variable | Number (and %), by group[a] | | | $\chi^2$ | *P*-value |
|---|---|---|---|---|---|
| | A (*n* = 287) | B (*n* = 687) | C (*n* = 163) | | |
| Gender | | | | | |
| Male | 96 (33.4) | 227 (33.0) | 48 (29.4) | 0.9 | 0.640 |
| Female | 191 (66.6) | 460 (67.0) | 115 (70.6) | | |
| Education (years) | | | | | |
| 0-5 | 58 (20.2) | 192 (27.9)[d] | 74 (45.4)[b, c] | 32.6 | <0.001 |
| > 5 | 229 (79.8) | 495 (72.1) | 89 (54.6) | | |
| Marital status | | | | | |
| Single | 50 (17.4) | 142 (20.7) | 28 (17.2)[b] | | |
| Married | 132 (46.0) | 266 (38.7) | 53 (32.5) | 11.5 | 0.021 |
| Widowed/divorced | 105 (36.6) | 279 (40.6) | 82 (50.3) | | |
| Economic conditions | | | | | |
| Satisfactory | 69 (24.2) | 142 (20.6) | 10 (6.1)[b, c] | | |
| Sufficient | 131 (45.6) | 316 (45.9) | 64 (39.3) | 42.2 | <0.001 |
| Insufficient | 87 (30.2) | 229 (33.4) | 89 (54.6) | | |
| Living conditions | | | | | |
| Alone | 107 (37.3) | 281 (40.9) | 67 (41.1) | 1.2 | 0.549 |
| With other(s) | 180 (62.7) | 406 (59.1) | 96 (58.9) | | |
| Motor activities | | | | | |
| None | 225 (78.4) | 568 (82.7) | 147 (90.2) | | |
| Occasional | 49 (17.1) | 97 (14.1) | 15 (9.2) | 11.5 | 0.075 |
| Regular | 13 (4.5) | 22 (3.2) | 1 (0.6) | | |
| Smoking | | | | | |
| Yes | 49 (17.1) | 171 (24.9)[d] | 28 (17.3) | 8.8 | 0.012 |
| No | 183 (63.6) | 375 (54.5) | 104 (63.6) | | |
| Past | 55 (19.2) | 141 (20.6) | 31 (19.1) | | |

[a]Group A, naturally adequate dentition; group B, denture wearers; group C, inadequate dentition and no dentures.
Significant *post hoc* pair-wise comparisons: [b]group A *vs* C; [c]group B *vs* C; [d]group A *vs* B.

and Murray [41] had set at 16 the lowest acceptable number of natural teeth in persons older than 60 for an adequate masticatory function, while Manson [42] had further refined this to 10 teeth in the upper jaw and six in the lower jaw.

At the end of the dental examination, our physicians used the latter criteria to classify the elderly subjects into two groups (those with or without adequate natural dentition, respectively). Furthermore, all individuals wearing dentures, irrespective of the type as well as the eventual presence and number of residual natural teeth, were placed in a third group. This benchmark standard of 16 is essentially a normative clinical judgment rather than an empirically derived number that corresponds to acceptable function and well-being.

Based on the above criteria, the 1137 subjects were subdivided into: (i) group A—287 subjects (25.2%) whose dental status was considered adequate without the use of dentures; (ii) group B—687 subjects (60.4%) who were wearing dentures (either partial or complete); and (iii) group C—163 subjects (14.3%) with an inadequate natural dental status and not using dentures.

Of the 52 subjects lost to follow-up, the corresponding values were 25% ($n = 13$), 67.3% ($n = 35$) and 8.3% ($n = 4$), respectively. These did not differ from the study sample ($\chi^2 = 1.952$, $d.f. = 2$, $P = 0.377$).

## Data analysis

The SPSS package was used [43] for statistical analysis.

### *Univariate analysis*

The frequency distribution of all relevant ordinal variables were examined, whereas continuous variables were initially evaluated by standard descriptive measures (mean, SD).

Comparisons among the three groups defined on the basis of the dental status were computed using contingency tables and the $\chi^2$ statistics for ordinal variables. Given that the three groups were not balanced in terms of years of formal education and self-reported income, one-way analysis of covariance (ANCOVA) was performed for continuous variables, using the above demographic variables as covariates. Where appropriate, ANCOVA was subsequently followed by *post hoc* pair-wise analysis, adjusted for multiple comparisons (the least-significance difference and the Bonferroni procedures, both embedded into SPSS ANOVA, were employed).

In addition, crude survival by dental status was initially explored by the Kaplan-Meier method and overall differences among levels were tested with the log rank test; *post hoc* pair-wise comparisons were subsequently computed.

### *Multivariate analysis*

Dental conditions were subsequently entered into multivariate models together with the nutritional and QOL indexes. Because of the large number of variables considered, we required univariate associations entered into multivariate models to be significant at or above the $P < 0.05$ level.

The values of independent variables of a categorical nature were recoded and dummy variables created. The number of new variables required in this case is one less than the number of categories. Within SPSS, the logistic regression procedure automatically creates new variables for variables declared as categorical and the choice is about the type of coding scheme and the type of contrast to apply. We used the so-called 'indicator-variable' coding scheme by virtue of which the coefficients for the new variables represent the effect of each category compared with a reference category (the coefficient for the latter is set to 0).

Using this coding scheme, the interpretation of the resulting coefficients for two-category variables, such as sex, is straightforward because it tells the difference between the log odds when a case is a member of the 'reference' category and when it is not. In case of variables that have more than two categories, the only statement which can be made about the effect of a particular category is in comparison with the corresponding reference category. Using this coding scheme, we were able to analyse all dental categories together, by transformation into a dummy variable with one subgroup as the reference category.

The backward step-wise logistic regression procedure was employed to arrive at the final models; the iterative maximum likelihood method was employed. Backward elimination starts with all chosen variables in the model. Then, at each step, variables are evaluated for entry and removal; SPSS always uses the score statistic for determining whether variables should be entered into the model (at the $P < 0.05$ level), but various statistics are available to select variables for removal and for this we employed the Wald statistic (at the $P < 0.1$ level). Using these relatively lax significant levels, the final models contain all variables remaining under the $P < 0.1$ level.

Regression coefficients ($b$) were converted to odds ratios (ORs) for ease of reading ($OR = e^b$). In addition, 95% confidence intervals (95% CI) were constructed by transformation of the asymptotic confidence interval about the regression coefficient ($e^{b \pm 1.96SE(b)}$). A predictor was considered statistically significant when its 95% CI excluded unity.

Cox's proportional hazard models were employed to assess differential survival by dental status with adjustment for confounders. The assumption of baseline hazard functions being proportional was checked with log-minus-log survival plots, where survival curves by dental status were linear and remarkably parallel, indicating proportionality of hazards. Adjusted survival curves by dental status were graphically represented by plotting the estimated cumulative survival functions as computed at the mean values of covariates from the adjusted Cox model. The measure of association in Cox models was the relative risk (RR) and its 95% CI; significant values on Wald statistic were also computed.

## Results

### Dental status and baseline variables

The overall comparisons based on the frequency distributions among the three groups in the demographic parameters and in the health behaviour component of health status are reported in Table 1: education, economic situation, marital status and smoking had a significantly different distribution. *Post hoc* tests revealed better education in group A than in both other groups, a higher prevalence of married subjects in group A (*vs* group C only) and a lower prevalence of smoking in group A (*vs* group B only). Groups B and C differed significantly for number of years of formal education and economic conditions, with those in group B having more years of education and better economic conditions.

Figure 1 shows the frequency distribution for gastrointestinal symptoms: the percentage of subjects reporting low appetite or complaining of dyspepsia was significantly higher in group C than in the other two groups. By contrast, frequency distribution was similar for groups A and B.

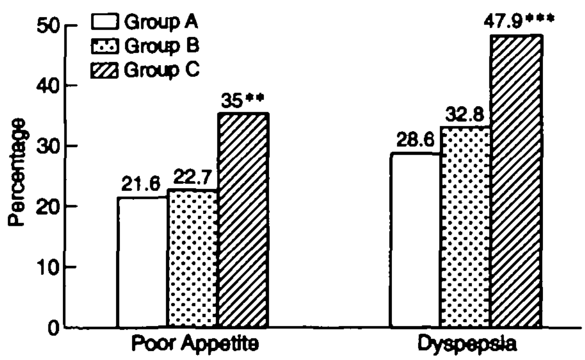


Figure 1. Frequency distribution for the symptoms 'poor appetite' and 'dyspepsia' in the dentate groups: A, adequate dentition; B, use of dentures; and C, inadequate dental status and no dentures. Numbers above each bar are the corresponding percentages of subjects whose answers were in the moderate or severe ranking. $^{**}P < 0.01$ and $^{***}P < 0.001$ at the overall comparison among the three groups. *Post hoc* pair-wise comparisons—group C *vs* A: for poor appetite, $\chi^2 = 9.55$, $P = 0.002$; for dyspepsia, $\chi^2 = 16.87$, $P < 0.0001$; group C *vs* B: for poor appetite, $\chi^2 = 10.55$, $P = 0.001$; for dyspepsia, $\chi^2 = 13.10$, $P < 0.001$; group B *vs* A: for poor appetite, $\chi^2 = 0.14$, $P = 0.706$; for dyspepsia, $\chi^2 = 1.64$, $P = 0.201$.

An ANCOVA procedure considering, as covariates, the demographic variables differently distributed among the three groups (e.g. education and income) was used for the remaining somatic health components. The score at the health care utilization scale was significantly different (group A, 5.7 ± 1.6; group B, 5.9 ± 1.9; group C, 6.4 ± 2.3; $F = 4.3$, *d.f.* = 2, 2, 1132; $P = 0.013$), whereas the mean number of reported chronic diseases/conditions was similar in the three groups (group A, 2.4 ± 1.4; group B, 2.4 ± 1.4; group C, 2.7 ± 1.4; $F = 1.5$, *d.f.* = 2, 2, 1132; $P = 0.229$). Adjusted *post hoc* pair-wise tests showed a significantly more frequent use of health services in group C compared with both the other groups (which did not differ from each other).

### Dental status and nutritional intake

*Univariate analysis*

Figure 2 shows the percentage of men and women whose daily nutrient intakes are below two-thirds of the 1980 RDA. On the whole, as already reported [15], 90% of the older people had an inadequate intake of folates, thiamine and vitamin B6, while 30-40% had a deficient intake of the other vitamins and iron and about 10% had an inadequate protein intake.

The corresponding mean percentages (± SD) of nutrient intake by dental status is reported in Table 2: with the exception of thiamine, an overall significant difference between the three groups is present for each nutrient at the ANCOVA (considering education and income as covariates). *Post hoc* tests demonstrated that group C differed from both the other groups in all nutrients, whereas group B had lower mean percentile intake than group A only for folates, vitamin A and vitamin C.

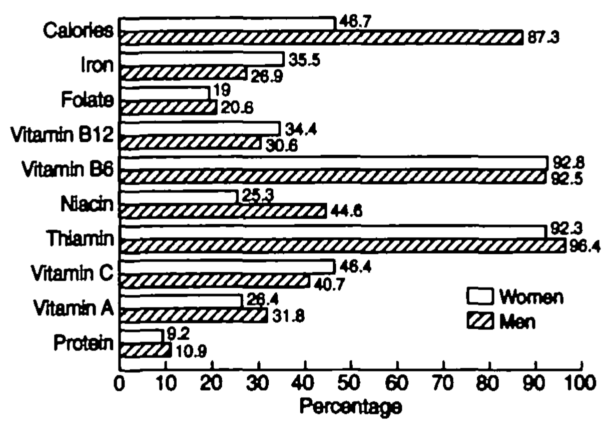


Figure 2. Percentages (numbers by each bar) of subjects with daily intake less than two-thirds of the US Food and Drug Administration's 1980 Recommended Dietary Allowances by gender.

Table 2. Mean percentage of nutrient intakes by dental status

| Nutrient | Mean ( ± SD) daily consumption[a], by dentition Adequate ($n = 287$) | Denture wearer ($n = 687$) | Inadequate ($n = 163$) | F-ANCOVA ($d.f. = 2, 2, 1132$) |
|---|---|---|---|---|
| Vitamin C | 85.2 ± 50.6 | 74.1 ± 43.3[d] | 66.8 ± 50.2[b] | 5.5** |
| Vitamin A | 91.4 ± 30.1 | 82.1 ± 31.7[d] | 72.0 ± 35.3[b, c] | 14.5*** |
| Vitamin B6 | 47.0 ± 13.8 | 44.9 ± 14.3 | 40.2 ± 16.3[b, c] | 7.7*** |
| Vitamin B12 | 72.4 ± 30.4 | 72.2 ± 31.0 | 66.4 ± 33.9 | 1.5 |
| Niacin | 75.2 ± 23.3 | 73.6 ± 24.1 | 68.4 ± 27.5[b, c] | 3.2* |
| Thiamine | 46.4 ± 13.9 | 47.2 ± 14.0 | 44.8 ± 16.1 | 1.9 |
| Proteins | 104.5 ± 27.9 | 102.4 ± 30.5 | 95.8 ± 35.1[b, c] | 3.7* |
| Calories | 63.5 ± 15.8 | 62.5 ± 16.9 | 57.4 ± 20.0[b, c] | 5.5** |
| Iron | 77.1 ± 18.9 | 75.0 ± 19.5 | 67.5 ± 23.1[b, c] | 6.7** |
| Folic acid | 20.6 ± 5.3 | 19.5 ± 5.7[d] | 17.3 ± 6.3[b, c] | 11.3*** |

[a]As a percentage of US Food and Drug Administration Recommended Dietary Allowances.
Significant *post hoc* pair-wise comparisons for group A (naturally adequate dentition), group B (denture wearers) and group C (inadequate dentition and no dentures): [b]group A *vs* C; [c]group B *vs* C; [d]group A *vs* B.
Both overall and pair-wise comparisons have been covariate for the demographic variables (economic situation and educational level): *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$ at the overall comparison among the three groups. All others were non-significant.

*Multivariate analysis*

Using the backward step-wise method, we built up three multiple logistic regression models in order to identify if any intake index was significantly and independently associated with the dental status. The first model (Table 3A) considers groups A and C and shows that the variables remaining significant and independent predictors of the dental status are educational level, economic situation, percentage intake of vitamins A and B6 and the symptom of dyspepsia. The second model (Table 3B) takes into account groups B and C and shows quite similar results: education, economic condition, intake of vitamin B6, niacin and folates and dyspepsia remain significantly and independently different between the two groups. The third model (Table 3C) considers groups A and B and shows that only education and intake of vitamin A are independently different between the two groups.

## Dental status and survival

*Univariate analysis*

After 6 years 79.4% of the elderly subjects in group A were alive, the corresponding percentages for groups B and C were 73.6 and 68.7% respectively and overall crude association of dental status with survival, as assessed with the Kaplan-Meier method, was significant (log rank test: $\chi^2 = 6.80$, $d.f. = 2$, $P < 0.05$).

However, gender played a significant role on survival: 80.2% of women compared with 62.5% of men were alive after 6 years: the crude association between gender and survival was significant (log rank test: $\chi^2 = 45.97$, $d.f. = 1$, $P < 0.001$). Furthermore, after stratifying this association by dental status, the significant gender difference for survival appeared particularly evident in the groups A and B (log rank test: $\chi^2 = 13.1$, $d.f. = 1$, $P < 0.001$ and $\chi^2 = 30.5$, $d.f. = 1$, $P < 0.0001$, respectively), whereas it was only marginally significant for group C (log rank test: $\chi^2 = 3.65$, $d.f. = 1$, $P = 0.05$).

Thus, the analysis of the crude association between dental status and survival was at this point stratified by gender (Figure 3) and survival curves were significantly different in relation to the dental status in women (log rank test: $\chi^2 = 7.23$; $d.f. = 2$; $P < 0.03$), but not in men (log rank test: $\chi^2 = 1.52$; $d.f. = 2$; $P = 0.47$). *Post hoc* pair-wise comparisons detected a significant difference between female subgroups A and C (log rank test: $\chi^2 = 7.26$; $d.f. = 1$, $P < 0.01$) and a trend between female subgroups B and C (log rank test: $\chi^2 = 2.80$; $d.f. = 1$, $P = 0.09$), but a substantial overlap between female subgroups A and B (log rank test: $\chi^2 = 2.65$; $d.f. = 1$, $P = 0.10$).

*Multivariate analysis*

Multivariate Cox regression models, including only women, were done to control the role of dental status on survival for the effects of possible confounders. Mortality was the dependent variable and the backward stepwise method was chosen.

In the first model, we entered the dental status (with group C as the reference category) and the 10 nutritional parameters as independent variables. In this model, only two parameters remained significantly and independently related to mortality: the dental

Table 3. Multiple logistic regression analysis for the dentate status adjusted for the demographic and nutritional variables and including (a) groups A and C, (b) groups B and C and (c) groups A and B

| Variable | B | RR | 95% confidence interval for RR | P-value |
|---|---|---|---|---|
| **(a) Groups A (adequate dentition) and C (inadequate dentition)[a]** | | | | |
| Education | −0.528 | 0.590 | 0.48-0.73 | <0.001 |
| Economic situation | 0.618 | 1.855 | 1.33-2.59 | <0.001 |
| Vitamin A | −0.016 | 0.984 | 0.98-0.99 | <0.001 |
| Vitamin B6 | −0.042 | 0.959 | 0.93-0.98 | 0.002 |
| Proteins | 0.018 | 1.018 | 1.00-1.03 | 0.092 |
| Dyspepsia | 0.392 | 1.480 | 1.11-1.97 | 0.007 |
| Residual $\chi^2$ | | 6.963 (*d.f.* = 7) | | 0.433 |
| **(b) Groups B (denture wearers) and C (inadequate dentition)[b]** | | | | |
| Education | −0.283 | 0.753 | 0.63-0.90 | 0.003 |
| Economic situation | 0.632 | 1.882 | 1.43-2.48 | <0.001 |
| Vitamin B6 | −0.042 | 0.959 | 0.92-0.99 | 0.024 |
| Niacin | 0.022 | 1.023 | 1.00-1.04 | 0.036 |
| Folic acid | −0.037 | 0.963 | 0.93-1.00 | 0.043 |
| HCU scale | 0.074 | 1.077 | 0.99-1.17 | 0.068 |
| Dyspepsia | 0.282 | 1.326 | 1.06-1.65 | 0.012 |
| Residual $\chi^2$ | | 5.258 (*d.f.* = 7) | | 0.629 |
| **(c) Groups A (adequate dentition) and B (denture wearers)[c]** | | | | |
| Education | −0.271 | 0.762 | 0.68-0.85 | <0.001 |
| Vitamin A | −0.009 | 0.991 | 0.98-0.99 | <0.001 |
| Residual $\chi^2$ | | 4.118 (*d.f.* = 7) | | 0.249 |

HCU, health care utilization.
[a]Variables excluded during the backward procedure: vitamin C, niacin, iron, calories, folates, HCU scale and the symptom 'lack of appetite'.
[b]Variables excluded during the backward procedure: vitamins A and C, thiamine, iron, proteins, calories and the symptom 'poor appetite'.
[c]Variables excluded during the backward procedure: vitamin C, folates, HCU scale and smoking.

status (specifically, group A *vs* group C: RR = 0.57, 95% CI = 0.34-0.95, Wald = 4.609, $P$ = 0.032) and the folate intake (RR = 0.96, 95% CI = 0.94-0.99, Wald = 8.975, $P$ = 0.003).

At this point, a very general survival model was created where the dental status and the folate intake were entered together with the demographic, somatic health and QOL parameters which were already known from previous studies [44] to be significantly and independently associated with mortality in our sample (e.g. smoking, functional status, social relationships and the health service utilization scale). Table 4 presents this model.

All the entered parameters now survived the multivariate computation, with the exceptions of the dental and the functional status.

## Discussion

The results from this study can be summarized as follows: (i) there is a significant association between the functionally defined dental status and the dietary intake, particularly of micronutrients; (ii) among nutritional variables, inadequate dental status and folate intake are independent predictors of mortality at 6 years, at least in women; (iii) in elderly people who wear dentures there is a significantly higher nutrient intake than in subjects with inadequate dental status, although they do not completely overlap with the food intake profile shown by those with naturally adequate dentition; (iv) the relationship between dentures and mortality remains ill-defined.

Unlike older inconsistent data [45], recent studies agree that dental status and dietary intake are significantly and reciprocally correlated [10, 46-48].

This is true for micronutrients (vitamins and minerals), but less true for macronutrients and for overall energy intake [2, 49]; accordingly, in our population the protein and the caloric intakes did not enter either one of the final regression models. Micronutrients are present in fruits and vegetables; thus, it is possible that the above correlation might be due to the preferential choice of predominantly soft, easy-to-chew foods by edentulous elderly subjects. Masticatory ability deteriorates with the loss of teeth [10, 46, 50, 51], whereas ageing *per se* only slightly decreases chewing efficiency.

However the masticatory ability cannot be considered to be a unique intermediate factor acting between dental status and dietary intake. Although restorative

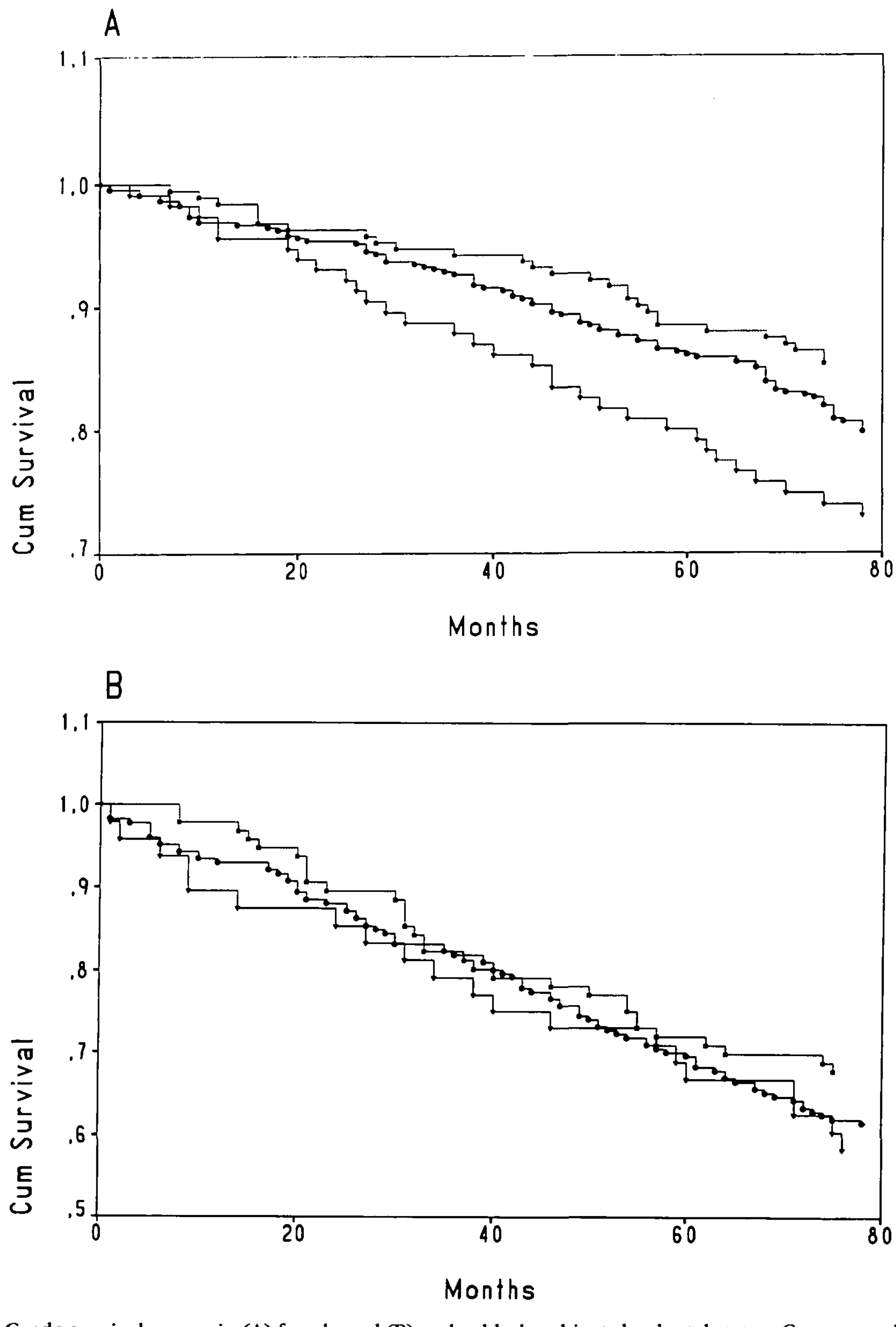


Figure 3. Crude survival curves in (A) female and (B) male elderly subjects by dental status. Curves are derived from Kaplan-Meier analysis. Groups are: ■, adequate dentition; ●, using dentures; ▼, inadequate dental status and no dentures. Test for overall difference of survival among the three dentate groups on log-rank test: $P < 0.03$ (A) and $P = 0.472$ (B).

Table 4. Survival in female elderly subjects by dental status in Cox regression models.

| Variable | RR | 95% CI for RR | Wald statistics | P-value |
|---|---|---|---|---|
| **Unadjusted** | | | | |
| Dental status | | 7.055 | 0.029 | |
| Group A *vs* C | 0.500 | 0.30-0.83 | 7.046 | 0.008 |
| Group B *vs* C | 0.709 | 0.47-1.06 | 2.752 | 0.097 |
| **Adjustment for nutrient intake** | | | | |
| Dental status | | 4.609 | 0.099 | |
| Group A *vs* C | 0.566 | 0.34-0.95 | 4.609 | 0.032 |
| Group B *vs* C | 0.763 | 0.50-1.15 | 1.675 | 0.196 |
| Folic acid | 0.961 | 0.94-0.98 | 8.975 | 0.003 |
| **Overall adjustment** | | | | |
| Dental status | | 2.101 | 0.350 | |
| Group A *vs* C | 0.673 | 0.39-1.15 | 2.099 | 0.147 |
| Group B *vs* C | 0.827 | 0.54-1.27 | 0.767 | 0.381 |
| Folic acid | 0.971 | 0.94-0.99 | 4.317 | 0.038 |
| Assessment scale[a] | | | | |
| HCU | 1.130 | 1.05-1.22 | 11.473 | <0.001 |
| SELF | 0.976 | 0.95-0.99 | 4.337 | 0.037 |
| IADL | 1.574 | 0.58-4.29 | 0.788 | 0.375 |
| Smoking | | | 10.417 | 0.005 |
| Never *vs* actual | 0.562 | 0.37-0.84 | 7.738 | 0.005 |
| Previous *vs* actual | 0.965 | 0.56-1.67 | 0.017 | 0.897 |

CI, confidence interval; RR, relative risk; *P*-value: significance at the Wald statistics.
The model adjusted for nutrient intake includes all the nutrient variables as covariates; apart from folates, the other nutrient variables are not significant (data not shown).
[a]HCU, health care utilization; IADL, Instrumental Activities of Daily Living; SELF, self-evaluation of life function.

prosthetic therapy can lead to improvement in masticatory function, bite force in complete denture wearers remains substantially lower than in dentate subjects [50, 52]. In addition, denture wearers perceive their dentures as interfering with chewing ability [53, 54]. Thus, an inadequate dietary intake might be expected in denture wearers, too; but in the present study this group had a significantly more adequate intake for micronutrients than edentulous subjects. Such a result is not an isolated finding [55-58].

Food selection is influenced not only by chewing ability but also by the texture of food item, changes resulting from industrial processing and the altered taste perception associated with ageing [50, 59-62]. Moreover, dietary habits are influenced by cultural, social and medical factors [2, 46]. In our population the educational level and the economic condition played a role in influencing nutrient intake: these demographic indices entered all three final nutritional models. Finally, the connection between food intake and dental status is bi-directional. Just as poor health status affects food choices, inadequate nutrition can affect the oral health [48]: at every age, an adequate supply of nutrients is necessary to maintain optimal oral health [47].

Given these complex interrelations between dental status, chewing ability and dietary intake, it is not surprising that their respective relationships with nutritional and general health status and, ultimately, with survival in elderly people are unclear.

It has been shown that food intake is correlated with mortality in community-dwelling, healthy older people [12] and in frail, nursing-home-resident subjects [63]. Chewing problems have been correlated with diminished protein and caloric intake [57] and, more recently, with sensitive and specific indicators of protein-energy undernutrition, such as body mass index and weight loss [64].

Nutritional status is widely considered a prognostic determinant of health status and survival in old age [65-68]. However, studies in this field are few and have mainly focused on nursing-home residents, rather than community-dwelling individuals [69, 70]. Furthermore, the nutritional status cannot probably be considered the unique intermediate factor between food intake and mortality. In fact, non-dietary factors, such as socio-economic conditions and physical health, played an important intermediate role between food intake and mortality in the study by Magni *et al.* [12], while Frisoni *et al.* found neither somatic health nor nutritional assessment to be as predictive as food intake for mortality [63].

It is not known how often the changes in dietary habits and food intake contribute to the development of protein-energy undernutrition in elderly people [9, 10].

Overall, data both from the present study and from a parallel [13] investigation confirm the intuitive notion of close inter-relations between a functionally defined dental status and nutrient intake. One marker for successful ageing is the maintenance of a natural, healthy and functional dentition which confers both social and biological benefits, including aesthetics, self-esteem, comfort and the ability to chew, taste, speak and eat.

Finally, they support the notion that any effort in providing and using dentures is worthwhile as dental prostheses can help improve both nutrient intake and QOL.

Thus, health professionals should consider the association between the oral cavity and general health. Oral health issues have long been neglected by all but specialists in gerodontology [71]. Several oral health assessments have recently appeared, such as the Geriatric Oral Health Assessment Index [72], the Oral Health Impact Profile [73] and the Decayed, Missing, Filled Teeth Index [74] and simple and inexpensive screening instruments for promoting dental referrals in older adults [75].

We urge further links between dentistry and gerontology [76]; this development is important for dental treatment, health care policy, and health and allied health care professional training.

## Key points

- A functionally inadequate dental status has a detrimental impact upon the dietary intake of community-dwelling elderly subjects.
- The use of dentures is able to counteract such effect and is associated with a satisfactory dietary intake.
- Dental status is among the major nutritional predictors of long-term mortality, although its contribution becomes less significant in more general models.

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