INTRODUCTION

The proportion of older people in many populations is increasing rapidly. The number of people above 80 years of age is growing fast and globally is expected to nearly triple, to 426 million by 2050. In Sweden, it is expected that the number of individuals aged 80 and over will have increased by 50%, from 500,000 to almost 755,000 by 2028. This development is positive, but it is also a challenge for both dental and nursing personnel due to their greater need for help with dental care and daily oral hygiene. A longer life expectancy and more retained natural teeth increases the risk for oral diseases such as periodontitis. Periodontitis is an inflammatory condition that affects the tooth-supporting tissues. It arises from a dysbiosis in the microbial biofilm that can develop on the root surface below the gingival margin. If untreated, it can lead to alveolar bone loss (ABL) and eventually to tooth loss, negatively affecting chewing function, aesthetics and quality of life.

Sweden is a highly developed country, and most citizens (78%) visit for dental care regularly, at least every two years. The
proportion of individuals who retain their natural teeth into old age is increasing, while the proportion of edentulous individuals is decreasing.\textsuperscript{7,8} The prevalence of moderate periodontal disease ranges between 22\% and 33\%, and the more severe form affects between 6\% and 9\% of Swedes.\textsuperscript{6,7} Mean number of teeth among older people (\textgreater 65 years of age) is somewhere between 20.0 and 22.5.\textsuperscript{7,9} The prevalence of periodontal disease differs among countries, races and ethnic groups.\textsuperscript{10-12} and periodontitis is, together with dental caries, the most common reason for tooth loss in adults.\textsuperscript{13-16}

A study by Elter et al\textsuperscript{17} identified risk factors for periodontitis in adults using longitudinal data, confirming a multifactorial aetiology. A longitudinal population-based study of periodontal disease by Thomson et al found that most attachment loss in older people manifests as an increase in gingival recession rather than probing depth, and the 5-year incidence estimate for attachment loss was higher among those with diabetes and those who had lost at least one tooth since baseline. Smoking was not a significant predictor in that age group.\textsuperscript{18} Smoking is a known risk factor for the development and progression of periodontitis.\textsuperscript{19,20} Irregular use, or no use of dental health services, single status and low socioeconomic status have been shown to be associated with tooth loss and periodontitis.\textsuperscript{21-24} Maintaining good oral health requires adequate oral hygiene to prevent oral health problems. This could be especially challenging for older people living on their own if they are dependent on others for help with, for example, their personal hygiene. Since the older population is increasing, and to be able to plan for future dental resources, it is vital to investigate the occurrence and influence of poor oral health in older people. The aim of this study was to investigate ABL and its possible risk factors in an older population followed between 2008 and 2018.

Since 1983, cross-sectional epidemiological and clinical studies have been performed every five years in Region Dalarna County (Sweden), showing improved oral health in the population. The latest in this series of studies was performed in 2018. In an attempt to contribute to longitudinal studies investigating the progression of periodontitis among older individuals over a longer period, the 2018 investigation also included a follow-up of individuals who participated in 2008 and who at that time were in the age groups of 65 or 75 years old.

2 | METHODS

This study was approved by the Swedish Ethical Review Authority (No: 2017/237) and conducted in accordance with the international ethical principles established by the Declaration of Helsinki. The study was registered at ClinicalTrials.gov (NCT04081025) and performed in accordance with STROBE guidelines.

2.1 | Study design and participants

In 2008, a random sample of 360 individuals in each of the age groups 65 and 75 years was selected from the Dalarna population registry. In 2018, according to the Dalarna population registry, 420 of the 720 individuals who participated in the 2008 study were eligible and thus invited to participate in the 2018 study (Figure 1). Those not eligible had either died or moved out of the Region or to other countries.

All individuals were mailed an invitation to participate together with information about the study and a questionnaire. Written informed consent was obtained from all participants. Further details are given elsewhere.\textsuperscript{7}

2.2 | Measures

The clinical examination, including 2-6 bitewing radiographs, was conducted by each participant’s regular dental practitioner. The dental practitioners used their ordinary X-ray equipment, X-ray holders and clinical examination procedures. Individuals without regular dental contact were offered a referral to a dental practitioner of their choice.

A standardized examination protocol with comprehensive written information was used. All documents and radiographs were coded, and personal identification details were deleted before data processing. Two calibrated reviewers, one of whom was a periodontist and one a registered dental hygienist, reviewed all radiographs.

2.2.1 | Questionnaire

The questionnaire focussed on sociodemographic characteristics (such as education, marital status and financial resources for dental care), self-perceived general health and medication, oral hygiene and dental care habits, and tobacco use. Clinical belonging (private or public dental care) was also requested.

2.2.2 | Clinical examination

Clinical measures used in regular clinical examinations were requested, such as number of existing teeth (third molar included), probing pocket depth (PPD) \textgreater 6 mm and bleeding on probing measured on premolars and molars at two interproximal sites, mesiobuccal and distobuccal, and furcation defects. PPD distal of second molars when third molars were present, partially erupted or nonerupted, was not included. A standardized protocol was used, with detailed written information on what to be included in the examination. The examiners used their usual equipment for the clinical examination.

2.2.3 | Alveolar bone loss

Classification of ABL into no, moderate, or advanced bone loss was based on bone level at interproximal sites as seen on radiographs in the premolar and molar regions in both jaws. All individuals classified
with advanced ABL in 2008 remained in the same classification in 2018. Calculus visible on bitewing radiographs was recorded. For further details about the classification of ABL, see Edman et al.⁷

2.3 | Loss to follow-up

According to the Dalarna population registry, 419 of the original 720 participants in the age of 65 years and 75 years from 2008 were still available in December 2017. The participation rate for both the questionnaire and clinical examination was 72% in 2008 and 65% in 2018. The most common reasons for not participating in the study were illness and unwillingness to participate.

2.4 | Statistical analysis

Marital status was dichotomized into 'cohabiting' and 'living as a single'. A common interval for visiting dental care in Sweden is every two years. Dental care was dichotomized into 'regular' (at least every two years) and 'irregular'. Financial resources were dichotomized into 'fewer dental visits due to limited financial resources' and 'no changes in dental visits'. Daily medication was dichotomized into 'no daily medication' and 'daily medication'. Smoking was registered as never smoked and 'current/former smoker'. Perceived general health and chewing ability were dichotomized into 'good' and 'bad'. Living condition was dichotomized into "independent" and "dependent" (in need of help from others). Xerostomia during the past six months was divided into 'never', 'sometimes' and 'daily/almost daily'. Education was dichotomized into 'high' (university or college of higher learning) and 'low' (up to secondary school).

Data were analysed using version 26.0 of IBM SPSS (SPSS Inc.). Mean values, standard deviations (SDs), frequencies, distributions and 95% confidence intervals (CIs) were calculated. McNemar's test was used on paired nominal data and a P-value ≤ .05 was considered to indicate statistical significance. A paired-samples t test was used when calculating mean values, and binary logistic regression was used to analyse factors that could have an influence on ABL. Cohen's kappa value for inter-individual agreement between the two reviewers who performed the classification of ABL was 0.73.

3 | RESULTS

At baseline, 419 individuals answered a questionnaire and were clinically examined, and 273 (65.2%) of these were re-examined after 10 years. Characteristics among those lost to follow-up are displayed in Table 1. Those lost to follow-up had more missing teeth and alveolar bone loss (ABL) at baseline. Calculus visible on bitewing radiographs were more prevalent among those lost to follow-up,
mean number of teeth with PPD ≥6 mm were higher and proportionately fewer made regular dental visits. Those lost to follow-up also reported smoking to a higher degree.

Clinical variables are presented in Table 2. In 2008, 1.8% (n = 5) of the respondents were edentulous; by 2018 this had increased to 2.5% (n = 7), as one dentate individual with advanced ABL and another with moderate ABL had become edentulous. Among all examined participants, the mean number of teeth per individual decreased, regardless of ABL status, and the tooth loss over this ten-year period was the same in both age groups. The proportion of participants with moderate ABL increased as well as calculus visible on bitewing radiographs.

No differences were found between female and male participants in mean number of teeth, ABL or calculus visible on radiographs, or PPD ≥6 mm.

In 2018, the mean number of sites bleeding on probing was 20.0% in the total group; it was 18.7% among women, and 21.6% among men. Data for bleeding on probing in 2008 were not available.

Most respondents (98.8% in 2008 and 99.6% in 2018) brushed their teeth at least once a day. Interproximal cleaning was reported at least once a day by 67.4% of the participants in 2008 and 69.7% in 2018. In those with moderate or advanced bone loss, 71% used interproximal cleaning devices at least once a day. No differences were seen in oral hygiene habits between participants with or without bone loss. More women than men performed interproximal cleaning at least once a day. No differences were seen in smoking and other habits between participants with or without bone loss. More women than men performed interproximal cleaning at least once a day. No differences were seen in smoking and other habits between participants with or without bone loss.

In 2018, current smoking was reported by 7% of the participants and former smoking by 36%; the corresponding figures in 2008 were 6% and 40%, respectively. The majority of the participants visited private dental clinics and 2% reported no permanent belonging to any dental clinic.

Table 4 presents the univariate and the adjusted multivariate analysis. In the univariate analysis, low level of education, irregular dental visits, mean number of teeth, and smoking were all associated with ABL. The proportion of participants with ABL was somewhat higher among those visiting public clinics (P = .069). The variables

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**TABLE 1** Baseline characteristics of the study population and those who were lost to follow-up

|                           | Lost to follow-up (n = 147) | Examined (n = 273) | P-value |
|---------------------------|----------------------------|-------------------|---------|
|                           | 65y | 75y | Total | 65y | 75y | Total |         |
| **Sociodemographic characteristics** |     |     |       |     |     |       |         |
| Female                    | 49 (58.3) | 44 (69.8) | 93 (63.3) | 95 (57.9) | 60 (55.0) | 155 (56.8) | .197 |
| Financial limitation for dental care | 13 (15.7) | 9 (15.0) | 22 (15.4) | 19 (11.7) | 8 (7.3) | 27 (10.0) | .104 |
| Living singly             | 21 (25.0) | 25 (39.7) | 46 (31.3) | 39 (23.9) | 25 (22.9) | 64 (23.5) | .085 |
| **Dental characteristics** |     |     |       |     |     |       |         |
| Regular dental visitors   | 61 (72.6)b | 44 (69.8) | 105 (71.4) | 133 (81.6) | 89 (81.7) | 222 (81.6) | .001 |
| Brush teeth at least once/day | 81 (96.4) | 59 (96.7) | 140 (96.6) | 160 (98.2) | 109 (100) | 269 (98.9) | .096 |
| Interproximal cleaning at least once/day | 78 (92.9) | 53 (88.3) | 131 (91.0) | 147 (91.9) | 101 (92.7) | 248 (92.2) | .709 |
| **Dental status**         |     |     |       |     |     |       |         |
| No ABLc                   | 36 (45.6) | 36 (59.0) | 72 (51.4) | 108 (66.3) | 75 (71.4) | 183 (68.3) | <.001 |
| Moderate ABL              | 22 (27.8) | 14 (23.0) | 36 (25.7) | 34 (20.9) | 25 (23.8) | 59 (22.0) |       |
| Advanced ABL              | 21 (26.6) | 11 (18.0) | 32 (22.9) | 21 (12.9) | 5 (4.8) | 26 (9.7) |       |
| Calculus                  | 16 (20.3)b | 15 (24.6) | 31 (22.1) | 54 (33.1) | 21 (20.0) | 75 (28.0) | .235 |
| No of pockets, mean (SD)  | 1.9 (3.5)b | 1.0 (2.3) | 1.5 (3.1) | 1.0 (2.0) | 0.6 (1.6) | 0.8 (1.9) | .006 |
| Number of teeth, mean (SD) | 23.2 (5.8) | 19.7 (7.1) | 21.6 (6.6) | 24.4 (4.4) | 21.4 (6.2) | 23.2 (5.4) | .009 |
| **Smoking and general health** |     |     |       |     |     |       |         |
| Smoking                   | 18 (21.7)b | 2 (3.2) | 20 (13.8) | 19 (11.7) | 0 (0) | 19 (7.1) | .025 |
| Three or more medicines daily | 26 (31.0) | 28 (44.4) | 54 (36.7) | 41 (25.2) | 42 (38.5) | 83 (30.5) | .230 |
| Perceived good general health | 73 (88.0) | 56 (90.3) | 129 (89.0) | 143 (88.3) | 97 (90.7) | 240 (89.2) | .937 |

aData are expressed as number of individuals (percentages) for categorical variables and means (SD) for continuous variables.
bP-value < .05 within age group (comparison between those lost to follow-up and examined).
cAlveolar bone loss.

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mean number of teeth with PPD ≥6 mm were higher and proportionately fewer made regular dental visits. Those lost to follow-up also reported smoking to a higher degree.

Clinical variables are presented in Table 2. In 2008, 1.8% (n = 5) of the respondents were edentulous; by 2018 this had increased to 2.5% (n = 7), as one dentate individual with advanced ABL and another with moderate ABL had become edentulous. Among all examined participants, the mean number of teeth per individual decreased, regardless of ABL status, and the tooth loss over this ten-year period was the same in both age groups. The proportion of participants with moderate ABL increased as well as calculus visible on bitewing radiographs.

No differences were found between female and male participants in mean number of teeth, ABL or calculus visible on radiographs, or PPD ≥6 mm.

In 2018, the mean number of sites bleeding on probing was 20.0% in the total group; it was 18.7% among women, and 21.6% among men. Data for bleeding on probing in 2008 were not available.

Most respondents (98.8% in 2008 and 99.6% in 2018) brushed their teeth at least once a day. Interproximal cleaning was reported at least once a day by 67.4% of the participants in 2008 and 69.7% in 2018. In those with moderate or advanced bone loss, 71% used interproximal cleaning devices at least once a day. No differences were seen in oral hygiene habits between participants with or without bone loss. More women than men performed interproximal cleaning at least once a day (women: 59.6% in 2008 and 55.7% in 2018; men: 40.4% in 2008 and 44.3% in 2018; P < .001; data are not shown in Table).

Sociodemographic characteristics are presented in Table 3. Some 13% of participants reported an education level of college or higher learning (not shown in Table). Individuals living in nursing homes increased over this period of ten years, as well as those in need of home care (P < .001). Proportionately more participants reported single living, daily medication, irregular dental visits, worse general health and xerostomia in 2018. Most reported good chewing ability.

In 2008, current smoking was reported by 7% of the participants and former smoking by 36%; the corresponding figures in 2018 were 6% and 40%, respectively. The majority of the participants visited private dental clinics and 2% reported no permanent belonging to any dental clinic.

Table 4 presents the univariate and the adjusted multivariate analysis. In the univariate analysis, low level of education, irregular dental visits, mean number of teeth, and smoking were all associated with ABL. The proportion of participants with ABL was somewhat higher among those visiting public clinics (P = .069). The variables
**TABLE 2** Clinical characteristics of the study population<sup>a</sup>

|                     | 2018 65y | 2008 75y | 2018 65y | 2008 75y | Total 2008 | Total 2018 | p-value<sup>b</sup> |
|---------------------|----------|----------|----------|----------|------------|------------|---------------------|
| Calculus            | 54 (33)  | 78 (48)<sup>c</sup> | 21 (20)  | 44 (42)  | 75 (28)    | 122 (46)   | <.001               |
| ABL<sup>c</sup>     |          |          |          |          |            |            | <.001               |
| None                | 108 (67) | 63 (39)  | 75 (72)  | 49 (47)  | 183 (69)   | 112 (42)   | <.001               |
| Moderate            | 34 (21)  | 75 (46)  | 24 (23)  | 46 (44)  | 58 (22)    | 121 (46)   | <.001               |
| Advanced            | 20 (12)  | 24 (15)  | 5 (5)    | 9 (9)    | 25 (9)     | 33 (12)    | <.001               |
| No of teeth (mean, sd) | 24.4 (4.4) | 22.8 (5.6)<sup>d</sup> | 21.4 (6.2) | 19.8 (6.7)<sup>d</sup> | 23.2 (5.4) | 21.6 (6.2) | <.001               |
| No of pockets (mean, sd) | 1.0 (2.0) | 1.1 (2.2) | 0.6 (1.6) | 0.9 (1.9) | 0.8 (1.9)  | 1.0 (2.1)  | ns                  |

<sup>a</sup>Data are expressed as number of individuals (percentages) for categorical variables and means (SD) for continuous variables.

<sup>b</sup>Significant difference (in total) between 2008 and 2018.

<sup>c</sup>Alveolar bone loss.

<sup>d</sup>Significant between 2008 and 2018 within age group, *P* < .05.

**TABLE 3** Frequency distribution of socioeconomic and sociobehavioural variables in study years 2008 and 2018 (number of individuals, percentages in brackets)

|                     | 2018 65y | 2008 75y | 2018 75y | 2018 85y | Total 2018 | Total 2008 | P-value<sup>a</sup> |
|---------------------|----------|----------|----------|----------|------------|------------|---------------------|
| Marital status      |          |          |          |          |            |            | <.001               |
| Married/cohabitant  | 117 (76) | 105 (68) | 77 (78)  | 56 (57)  | 194 (77)   | 161 (64)   | <.001               |
| Living singly       | 37 (24)  | 49 (32)  | 22 (22)  | 43 (43)  | 59 (23)    | 92 (36)    | <.001               |
| Limited finances<sup>b</sup> |          |          |          |          |            |            | .052                |
| Yes                 | 19 (12)  | 14 (9)   | 8 (8)    | 2 (2)    | 27 (10)    | 16 (6)     |                     |
| No                  | 138 (88) | 143 (91) | 98 (92)  | 104 (98) | 236 (90)   | 247 (94)   |                     |
| Daily medication    |          |          |          |          |            |            | <.001               |
| Yes                 | 100 (63) | 130 (82) | 73 (71)  | 96 (93)  | 173 (66)   | 226 (87)   | <.001               |
| No                  | 58 (37)  | 28 (18)  | 30 (29)  | 7 (7)    | 88 (34)    | 35 (13)    | <.001               |
| Clinical belonging  |          |          |          |          |            |            | .725                |
| Private clinic      | 100 (63) | 101 (63) | 62 (58)  | 62 (58)  | 162 (61)   | 163 (61)   |                     |
| Public clinic       | 54 (34)  | 55 (35)  | 45 (42)  | 44 (41)  | 99 (37)    | 99 (37)    |                     |
| None permanent      | 5 (3)    | 3 (2)    | 0 (0)    | 1 (1)    | 5 (2)      | 4 (2)      | .725                |
| Dental visits       |          |          |          |          |            |            | .694                |
| Regular<sup>c</sup> | 124 (81) | 126 (82) | 86 (83)  | 80 (77)  | 210 (81)   | 206 (80)   |                     |
| Irregular           | 30 (19)  | 28 (18)  | 18 (17)  | 24 (23)  | 48 (19)    | 52 (20)    |                     |
| General health      |          |          |          |          |            |            | <.001               |
| Good                | 138 (88) | 123 (79) | 93 (90)  | 76 (74)  | 231 (89)   | 199 (77)   | <.001               |
| Bad                 | 18 (12)  | 33 (21)  | 10 (10)  | 27 (26)  | 28 (11)    | 60 (23)    | <.001               |
| Chewing ability     |          |          |          |          |            |            | .332                |
| Good                | 152 (97) | 150 (96) | 97 (95)  | 94 (92)  | 249 (96)   | 244 (94)   |                     |
| Bad                 | 5 (3)    | 7 (4)    | 5 (5)    | 8 (8)    | 10 (4)     | 15 (6)     | .332                |
| Living condition    |          |          |          |          |            |            | .901                |
| Independent<sup>d</sup> | 157 (97) | 151 (93) | 100 (94) | 71 (66)  | 257 (96)   | 222 (82)   | <.001               |
| Dependent           | 5 (3)    | 11 (7)   | 7 (6)    | 36 (34)  | 12 (4)     | 47 (18)    | <.001               |
| Self-perceived xerostomia |        |          |          |          |            |            |                     |
| No                  | 107 (68) | 63 (40)  | 75 (71)  | 39 (37)  | 182 (70)   | 102 (39)   |                     |
| Sometimes           | 41 (26)  | 70 (45)  | 26 (25)  | 51 (49)  | 67 (25)    | 121 (46)   |                     |
| Often               | 9 (6)    | 24 (15)  | 4 (4)    | 15 (14)  | 13 (5)     | 39 (15)    | <.001               |

<sup>a</sup>Difference between 2008 and 2018.

<sup>b</sup>Limited finances for dental care.

<sup>c</sup>At least every two years.

<sup>d</sup>Not in need of help from others.
significantly associated with alveolar bone loss from the univariate analysis were included in a multivariate analysis, adjusted for gender, and current/former smoking was the variable most strongly associated with ABL.

| TABLE 4 | Univariate, unadjusted and multiple adjusted analysis of the association between alveolar bone loss (moderate and advanced) and socioeconomic and sociobehavioural variables presented as odds ratio (95% CI in brackets) (n = 248) |
|-----------------|---------------------------------|-----------------|-----------------|
| Marital status  | Unadjusted or (95% CI) | Adjusted or (95% CI) | *P*- value |
| Married/cohabitant | 0.96 (0.57-1.61) | 0.46 (0.26-0.80) | .067 |
| Living singly    | 0.86 (0.57-1.35) | 0.83 (0.50-1.39) | .086 |
| Limited finances | No                  | 0.31 (0.15-0.66) | .017 |
|                     | Yes                 | 0.87 (0.50-1.53) | .556 |
| Daily medication  | No                  | 1.16 (0.56-2.40) | .687 |
|                     | Yes                 | 0.56 (0.25-1.21) | .220 |
| Clinical belonging| Private clinic      | 0.62 (0.37-1.04) | .069 |
|                     | Public clinic       | 0.68 (0.37-1.25) | .267 |
| Chewing ability   | Good                | 0.75 (0.25-2.19) | .595 |
|                     | Bad                 | 0.75 (0.25-2.19) | .595 |
| General health     | Good                | 1.31 (0.72-2.37) | .370 |
|                     | Bad                 | 1.31 (0.72-2.37) | .370 |
| Gender            | Female              | 1.06 (0.65-1.72) | .831 |
|                     | Male                | 1.06 (0.65-1.72) | .831 |
| Xerostomia        | Sometimes           | 0.73 (0.42-1.24) | .244 |
|                     | Often               | 1.21 (0.56-2.61) | .625 |
| Living condition  | Independent         | 1.21 (0.64-2.28) | .562 |
|                     | Dependent           | 1.21 (0.64-2.28) | .562 |
| Education         | High                | 0.41 (0.19-0.85) | .017 |
|                     | Low                 | 0.41 (0.19-0.85) | .017 |
|                     | ref                 | 2.15 (0.95-4.88) | .066 |
| Dental visits     | Regular             | 2.99 (1.17-7.65) | .022 |
|                     | Irregular           | 2.99 (1.17-7.65) | .022 |
|                     | ref                 | 2.85 (0.88-9.26) | .082 |

| Smoking habits     | Unadjusted or (95% CI) | *P*- value |
|--------------------|------------------------|------------|
| Never smoked       | ref                    |            |
| Current/former smoker | 2.00 (1.20-3.36) | .008 |
|                     | 2.01 (1.17-3.48) | .012 |
| Number of teeth    | 0.92 (0.88-0.96) | .001 |
|                     | 0.93 (0.89-0.98) | .005 |

*Limited finances for dental care.

*Not in need of help from others.

*University or college of higher learning.

*At least every two years.

*Adjusted for gender.

**DISCUSSION**

The principal findings of this longitudinal study were that the prevalence of moderate ABL and calculus visible on radiographs increased and approximately two teeth were lost during this period of ten years. Smoking was found to be the strongest risk factor for ABL.

The loss of participants from a cohort over time can lead to non-representativeness of the study sample in longitudinal epidemiological studies. In this study, those remaining after ten years were periodontally healthier, had a higher mean number of teeth, and were more likely to visit dental care regularly and the proportion of smokers was lower than among those lost to follow-up. Previous studies have shown that nonrespondents are generally less healthy than participants in health investigations. Participants lost to follow-up in the present study had more advanced ABL than those re-examined after ten years. The current study's findings should, therefore, be regarded as an underestimation of the periodontal disease progression in this cohort and generalizations from the present study may, therefore, be made with a certain degree of caution.

Some variables had very small numbers in response categories, making it hard to draw definitive conclusions. As a large number of professionals performed the clinical examinations, detailed written information and illustrations were provided for the different clinical variables to be recorded to ensure the best conformity. The classification of ABL was performed by one of the authors (KE, registered dental hygienist) and a periodontist, strengthening the clinical measures.

As a consequence of changes in health-related behaviours, such as reduced smoking and improved knowledge of the importance 
oral cleaning, adults are retaining more of their natural dentition as they get older. Although this outcome is desirable, many remaining teeth are heavily restored and most older adults have some degree of periodontal disease.\(^{26}\)

In this ten-year longitudinal study, each participant lost approximately two teeth and the prevalence of moderate bone loss doubled in both age groups, 65-75 and 75-85 years, respectively. Although periodontal disease is largely preventable, it remains the major cause of poor oral health and the primary cause of tooth loss in older adults.\(^{13-16}\)

Current smoking was rare in this high-aged population but still found to be a strong risk factor for ABL, further emphasizing the negative impact of smoking on periodontal health. Tobacco use is known to increase both the severity of periodontal disease\(^{19}\) and the risk of ABL.\(^{20}\) In contrast to other studies,\(^{23,27}\) low level of education and irregular dental visits became less evident in the regression model when adjusting for other risk factors. The reason might be that Sweden is a highly developed country, and most citizens visit dental care on a regular basis. The dental care system is designed to encourage adults to regularly visit their dentist for check-ups and preventative care.

In the present study, the need for help in daily living increased and dental attendance decreased. The majority of older people in Sweden live independently, but an increasing number of those living at home are frail and often dependent on daily help from others.\(^{28,29}\) This, together with barriers identified in other studies, such as transportation problems and limited finances,\(^{30}\) may contribute to decreased dental attendance.\(^{31}\) This lack of dental contact is likely to increase the risk for oral health problems along with deteriorating general health and increased intake of prescribed medication, all of which could contribute to the increasing prevalence of calculus and moderate periodontitis in the present study. However, the majority of participants reported toothbrushing at least once a day and also a fairly high degree of interproximal cleaning, which could be two of the reasons explaining why this study population had a relatively high mean number of remaining teeth. Although most of the participants reported daily medication and that their general health had deteriorated over the study period, the majority in our study were still living in their own homes. In addition, most participants continued to attend dental care on a regular basis and the economic conditions for dental care had slightly improved.

Investigating periodontal progression, this study includes a 10-year follow-up of individuals aged 65-85. There are few studies on this subject with individuals up to 85 years of age. It is important to identify older people before they lose their regular contact with dental care due to fragility and impaired cognitive function. An increasing number of older people live in their own homes, often with help from spouses or relatives due to reduced ability to attend daily activities in life and cognitive impairment. This is often the time when regular contact with dental care ceases and their oral health begins to deteriorate. Impaired oral health with increased tooth loss could lead to a change in chewing ability causing changes in dietary habits that could lead to increased risk for obesity and general diseases such as cardiovascular disease.\(^{32}\)

### 4.1 Strengths and limitations

As there were many individuals performing the dental examination, and no calibration was possible, and to ensure the best conformity, detailed written information and illustrations were provided for the clinical variables to be recorded. The categorization of ABL was performed by one of the authors (KE, registered dental hygienist) and one periodontist, which strengthens the analysis of the clinical measures. It is reasonable to expect that the nonrespondents did not have better general or oral health than the respondents, as other studies have shown that nonrespondents are generally less healthy than participants in health investigations.\(^{25}\) Those lost to follow-up were more periodontally unhealthy, more likely to be smokers and irregular dental visitors making it hard to generalize the study findings.

### 5 Conclusion

Despite an increasing progression of moderate alveolar bone loss, a fairly good dentition and chewing capacity was retained in this older population. However, age and fragility are important indicators to be considered when planning oral health care and availability of dental care.

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### Conflict of interest

The authors declare no conflicts of interest with respect to the authorship or publication of this article.

### Author contributions

All authors have made major contributions to data analysis and interpretation as well as writing the manuscript and revising it critically, and have given final approval of the version to be published. KE planned and performed the data collection.

### Data availability statement

Data available on request due to privacy/ethical restrictions.

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