

# 'Caries disease among an elderly population—A 10-year longitudinal study'

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## Abstract

**Objectives:** To investigate the prevalence of dental caries and to identify risk factors for dental caries in an elderly population between 2008 and 2018.

**Methods:** This longitudinal study used data from a questionnaire survey and a clinical examination administered on two occasions 10 years apart to 273 individuals who were 65 and 75 years of age in 2008. The variables included were prevalence of dental caries as well as socioeconomic and socio-behavioural factors.

**Results:** The number of teeth decreased in both age groups by a mean of 2 over the 10-year study period, but the prevalence of dental caries remained stable. Approximately, a quarter of the participants had caries lesions. Toothbrushing once a day or less was the factor most strongly correlated with dental caries lesions (OR: 3.82, 95% CI: 1.68–8.66,  $p = 0.001$ ), followed by need for homecare (OR: 3.50, 95% CI: 1.55–7.93,  $p = 0.003$ ) and interproximal cleaning less than once a day (OR: 2.65, 95% CI: 1.36–5.19,  $p = 0.004$ ).

**Conclusions:** This longitudinal study revealed no increase in the prevalence of dental caries lesions, indicating that good oral health can be preserved among elderly people. The highest risk for dental caries lesions was among participants with inadequate oral hygiene routines (toothbrushing once a day or less and seldom using interproximal devices) and in need of help in daily living, emphasizing the importance of oral hygiene and collaboration between dental services and community-based health care.

## KEYWORDS

dental caries, elderly, longitudinal, socioeconomic

## 1 | INTRODUCTION

The proportion of elderly people in the population is increasing. The number of individuals above 80 years of age is growing fast, and is globally estimated to nearly triple to 426 million in 2050.<sup>1</sup> In Sweden, the number of individuals aged 80 years and older is expected to increase from 500,000 to almost 755,000 in 2028.<sup>2</sup> Older adults

today tend to retain their natural teeth, and the proportion of edentulous individuals is decreasing.<sup>3,4</sup> This development is challenging for both dental and nursing personnel, as the need for help with dental care and daily oral hygiene increases. There is an increasing risk of oral diseases, including dental caries, which is one of the most common oral diseases and the most prevalent in older age groups. Dental caries is closely linked to socioeconomic status,<sup>5</sup> broader social

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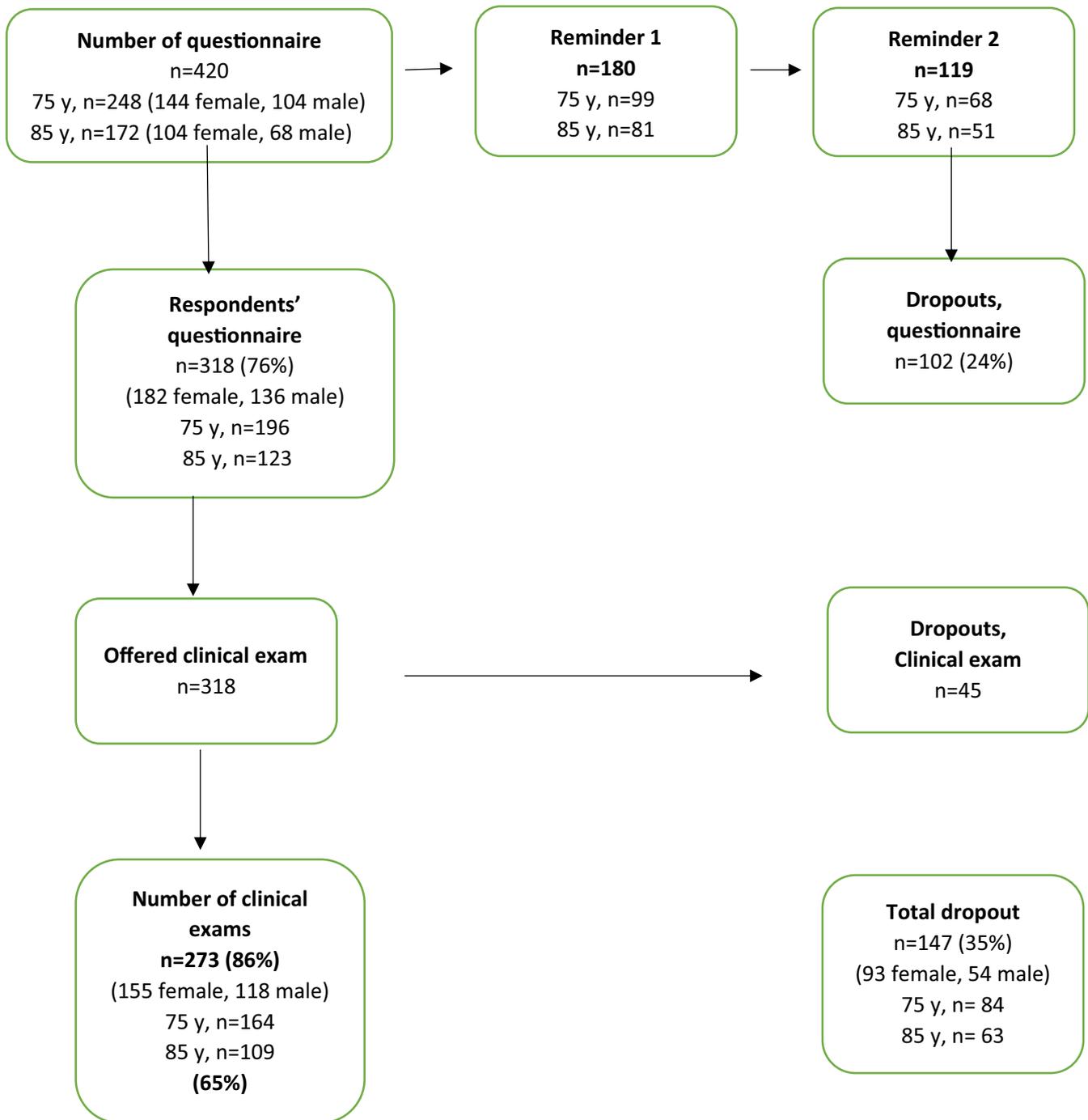


FIGURE 1 Recruitment of participants

determinants of health (high intake of prescribed medication),<sup>6</sup> and socio-behavioural risk factors (irregular dental visits, unfavourable dietary habits, tobacco habits, excessive alcohol use, low level of education and low quality of life measures), and hence disproportionately affects the poorer and more marginalized groups in society.<sup>7</sup>

Old and frail individuals, particularly those with reduced functional ability and cognitive impairment, tend to have more active caries than elderly people with no impairment.<sup>8</sup> Studies have reported wide ranges (25–100%) for the prevalence of root caries, but most conclude that the burden of root caries is high in the older

population.<sup>9</sup> However, in spite of socioeconomic differences, the prevalence and experience of dental caries have decreased in many regions over the last few decades.<sup>10</sup>

Dental caries lesions manifest as the localized destruction of dental hard tissues (enamel and dentine). The process is defined as the result of a chemical dissolution caused by acid production by a biofilm which is frequently exposed to sugars.<sup>11</sup> The caries process is dynamic, with alternating periods of demineralization and remineralization of dental hard tissues related to fluctuations in the pH of the plaque biofilm. Dental caries is preventable, above all in the early

stages, especially with exposure to fluoride.<sup>12</sup> A systematic review including studies with up to  $\geq 5$  years follow-up concluded that root caries is increasing even among healthy older adults.<sup>13</sup> In a Swedish study it was found that 95% of the participants had developed one or more carious lesions, mostly secondary caries and increasing with age, during a period of 10 years.<sup>6</sup>

Since 1983, cross-sectional epidemiological and clinical studies have been performed every 5th year in Dalarna County, Sweden, showing improved oral health in the population.<sup>14</sup> The latest in this series of cross-sectional studies was performed in 2018. A longitudinal study was added that included individuals who participated in the studies in 2008 and who were 65 years or 75 years of age at that time.

The aim of the present study was to investigate caries incidence and to identify factors influencing the risk of caries in an elderly population between 2008 and 2018.

## 2 | METHODS

### 2.1 | Study design

The study used a longitudinal design based on a questionnaire survey and clinical dental examination including radiographs.

### 2.2 | Study design and participants

In 2008, a random sample of 360 individuals in each of the age groups 65 years (born in 1943) and 75 years (born in 1933) was selected from the Dalarna population registry. Of the 720 individuals, 515 responded to both the questionnaire and the clinical examination in 2008. In 2018, according to the Dalarna population registry, 420 of these 515 individuals were eligible and thus invited to participate in the 2018 study (Figure 1). All individuals received an invitation by mail, and written informed consent was obtained from all participants at the beginning of 2018. Those returning the questionnaire were invited to a clinical examination. The study was performed in agreement with the guidelines of the Helsinki Declaration and was registered at ClinicalTrials.gov (NCT04081025). Further details are given elsewhere.<sup>3</sup>

### 2.3 | Measures

The clinical examination, including 2–6 bitewing radiographs, was conducted by each participant's regular dental practitioner and was free of charge. Individuals without regular dental contact were offered a referral to a dental practitioner of their choice. The prevalence of dental caries lesions was based on the clinical examination and radiographs. In addition to the dentist and dental hygienist who performed the clinical examination, two calibrated reviewers (one of the authors, KE, who is a registered dental hygienist, and one

dentist) reviewed all radiographs, confirming caries lesions on interproximal sites. A standardized examination protocol with comprehensive written instructions was used. Before data processing, all documents and radiographs were coded and personal identification details were deleted.

### 2.4 | Questionnaire variables

The questionnaire was the same as used in earlier cross-sectional studies in Dalarna County, Sweden. The number of questions increased from 29 questions in 2008 to 63 in 2018. Each question had between 2 and 10 response alternatives, depending on the question. The questions focused on demographics, socioeconomic factors, perceived general health and medication, oral hygiene, tobacco use, additional fluoride products (tablets, chewing gum and mouth rinse) and dental care habits. In 2018, questions regarding dietary habits were added, asking about 'principal meals' (breakfast, lunch, and dinner) and 'snacks' (fruit, coffee/tea, sweets, sandwiches and biscuits).

### 2.5 | Clinical examination

The same variables normally used in regular clinical examinations, such as number of existing teeth (third molars included) and number of intact teeth (teeth without restorations or dental caries lesions) were registered in the clinical examination as part of the study. The presence of primary and secondary caries was registered according to the criteria used by Gröndahl et al.<sup>15</sup> and only lesions extending into the dentine were registered. Decayed missing filled teeth (DMFT), decayed filled teeth (DFT), filled teeth (FT), decayed filled surfaces (DFS) and decayed filled interproximal surfaces (DFSa) were registered. Active root caries lesions were registered according to the criteria used by Nyvad and Fejerskov.<sup>16</sup> A standardized protocol with comprehensive written instructions on how to perform the examination was used. The examiner recorded the reason for tooth extraction using the diagnosis code documented in the participant's dental record.

### 2.6 | Dropouts

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, unwillingness to participate and death.

### 2.7 | Data analysis

*Marital status* was dichotomized into 'married/cohabiting' and 'living as a single adult'. *Dental care* was dichotomized into 'regular' (at least every 2 years) and 'irregular'. *Financial limitations* were dichotomized

into 'fewer dental visits due to limited financial resources' and 'no changes in dental visits'. *Daily medication* was dichotomized into 'no medication', '<3 prescribed daily medications' and '≥3 prescribed daily medications'. *Self-perceived xerostomia* was dichotomized as 'yes' (every day or almost every day) and 'no' (seldom/never), *self-perceived general health* as 'good' (feel healthy most or all of the time) and 'bad' (feel unhealthy most or all of the time), and *educational level* as 'high' (university or college of higher learning) and 'low' (up to secondary school). Need for homecare was defined as needing help from a relative or from the municipal homecare at least twice a day, a personal alarm, or night-time visits from the municipal homecare. In the logistic regression analysis, toothbrushing was dichotomized into 'twice a day or more' and 'once a day or less', interproximal cleaning was dichotomized into 'once a day or more' and 'seldom/never', and additional fluoride use was dichotomized into 'once a day or more' and 'seldom/never'.

The data were analysed using version 26.0 of IBM SPSS (SPSS Inc.). Mean values (Tables 1, 2 and 3), frequencies, and distributions (Tables 1 and 4) were calculated. Non-parametric tests (McNemar's test and the Wilcoxon signed-rank test) were used when calculating differences over time (Table 2), and logistic regression and 95% confidence intervals (CIs) were calculated to analyse factors that

might influence dental caries (Table 5). For pairwise comparisons, the Bonferroni correction was used (Table 4). The significance level was set at  $p \leq 0.05$ .

### 3 | RESULTS

Of the 420 individuals who answered the questionnaire and were examined at baseline, 273 (65.2%) were re-examined after 10 years. Those who had been lost to follow-up ( $n = 147$ ) had more missing teeth and proportionately fewer regular dental visits, and also reported smoking to a higher degree (Table 1).

The 273 individuals who participated in the present study comprised 164 (95 women and 69 men) in the 75 years age group and 109 (60 women and 49 men) in the 85 years age group.

The mean number of teeth in all examined participants decreased from 23.2 (SD: 5.4) at baseline in 2008 to 21.6 (SD: 6.2) at follow-up in 2018. At baseline, 1.8% ( $n = 5$ ) of the respondents were edentulous; at follow-up this had increased to 2.5% ( $n = 7$ ). The most common reason for extraction of teeth, as assessed by the dental examiner, was a mix of periodontal disease and dental caries.

TABLE 1 Baseline characteristics of dentate individuals who were examined at 10 years compared with those who were lost to follow-up

	Lost to follow-up ( $n = 147$ )			Examined ( $n = 273$ )			p-value
	65 years	75 years	Total	65 years	75 years	Total	
Socio-demographic characteristics, n (%)							
Female	49 (58.3)	44 (69.8)	93 (63.3)	95 (57.9)	60 (55.0)	155 (56.8)	0.197
Financial limitation on dental care	13 (15.7)	9 (15.0)	22 (15.4)	19 (11.7)	8 (7.3)	27 (10.0)	0.104
Living alone	21 (25.0)	25 (39.7)	46 (31.3)	39 (23.9)	25 (22.9) <sup>†</sup>	64 (23.5)	0.085
Dental characteristics, n (%)							
Regular dental visitors	61 (72.6) <sup>†</sup>	44 (69.8)	105 (71.4)	133 (81.6)	89 (81.7)	222 (81.6)	0.001
Brush teeth at least once/day	81 (96.4)	59 (96.7)	140 (96.6)	160 (98.2)	109 (100)	269 (98.9)	0.096
Interproximal cleaning at least once/day	78 (92.9)	53 (88.3)	131 (91.0)	147 (91.9)	101 (92.7)	248 (92.2)	0.709
Use of extra fluoride at least once a day, n (%)							
Tablets	4 (5.4)	5 (8.8)	9 (6.9)	15 (9.4)	9 (8.7)	24 (9.1)	0.563
Mouth rinse	6 (8.0)	6 (10.5)	12 (9.1)	19 (12.1)	22 (21.2)	41 (15.7)	0.085
Chewing gum	5 (6.8)	0 (0.0)	5 (3.8)	14 (8.9)	6 (5.8)	20 (7.7)	0.189
Mean 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)	0.009
Dental decay, mean (SD)							
Decayed filled teeth	15.8 (5.4)	14.2 (5.8)	15.1 (5.6)	16.2 (5.6)	15.2 (5.6)	15.8 (5.6)	0.249
Decayed teeth	0.6 (1.1)	0.6 (0.9)	0.6 (1.0)	0.4 (1.1)	0.6 (1.1)	0.5 (1.1)	0.351
Smoking n (%)	18 (21.7) <sup>†</sup>	2 (3.2)	20 (13.8)	19 (11.7)	0 (0)	19 (7.1)	0.025
Three or more medicines daily n (%)	26 (31.0)	28 (44.4)	54 (36.7)	41 (25.2)	42 (38.5)	83 (30.5)	0.230
Perceived good general health n (%)	73 (88.0)	56 (90.3)	129 (89.0)	143 (88.3)	97 (90.7)	240 (89.2)	0.937

<sup>†</sup> $p < 0.05$  within age group (comparison between those lost to follow-up and examined).

**TABLE 2** Mean (SD) numbers of teeth at baseline (2008) and follow-up (2018). Total teeth, intact teeth, decayed filled teeth (DFT), decayed missing filled teeth (DMFT), decayed filled surfaces (DFS), decayed filled interproximal surfaces (DFSa), root caries, decayed teeth (DT), decayed surfaces (DS), filled teeth (FT) and filled surfaces (FS)

	75 years		85 years		Total		p-value
	Baseline	Follow-up	Baseline	Follow-up	Baseline	Follow-up	
Total teeth	24.4 (4.4)	22.8 (5.6) <sup>†</sup>	20.4 (6.2)	19.8 (6.7) <sup>†</sup>	23.2 (5.4)	21.6 (6.2)	<0.001
Intact teeth	7.3 (4.8)	6.6 (4.7) <sup>†</sup>	5.0 (4.4)	4.6 (4.4) <sup>†</sup>	6.4 (4.8)	5.8 (4.7)	<0.001
DFT	17.1 (4.8)	16.2 (5.6) <sup>†</sup>	16.3 (5.6)	15.2 (5.6) <sup>†</sup>	16.8 (5.1)	15.8 (5.6)	<0.001
DMFT	24.7 (4.7)	25.4 (4.8) <sup>†</sup>	26.9 (4.4)	27.4 (4.4) <sup>†</sup>	25.6 (4.7)	26.2 (4.7)	<0.001
DFS	51.6 (17.9)	49.2 (19.4)	53.0 (19.7)	50.5 (20.4)	52.1 (18.6)	49.7 (19.8)	0.068
DFSa	24.9 (9.6)	23.7 (9.9) <sup>†</sup>	25.8 (9.8)	24.0 (9.7) <sup>†</sup>	25.3 (9.7)	23.8 (9.8)	<0.001
Root caries	0.04 (0.19)	0.07 (0.37)	0.19 (1.02)	0.13 (0.77)	0.10 (0.66)	0.09 (0.56)	0.979
DT	0.50 (0.92)	0.41 (1.12)	0.52 (0.87)	0.60 (1.08)	0.51 (0.90)	0.48 (1.10)	0.320
DS	0.61 (1.27)	0.44 (1.18)	0.75 (1.63)	0.82 (2.00)	0.67 (1.42)	0.59 (1.56)	0.198
FT	17.1 (4.8)	16.1 (5.4) <sup>†</sup>	16.3 (5.6)	15.2 (5.6) <sup>†</sup>	16.8 (5.1)	15.7 (5.5)	<0.001
FS	51.4 (17.9)	48.7 (19.5)	52.8 (19.7)	50.4 (20.4)	51.9 (18.6)	49.4 (19.9)	0.058

<sup>†</sup> $p < 0.05$  between 2008 and 2018 within participants.

**TABLE 3** Mean number (SD) of primary, secondary and root surface caries lesions at baseline (2008) and follow-up (2018)

	Baseline	Follow-up	p-value
Primary caries	0.15 (0.81)	0.09 (0.44)	0.540
Secondary caries	0.42 (0.98)	0.42 (1.26)	0.514
Primary root surface caries	0.02 (0.15)	0.06 (0.50)	0.164
Secondary root surface caries	0.08 (0.64)	0.03 (0.27)	0.142

The mean numbers of intact teeth, FT, DFT and DFSa were lower at follow-up, while the number of DMFT was higher. All clinical variables are presented in Table 2. Caries lesions were mostly secondary caries; primary dental caries and root surface caries were rare (Table 3).

At follow-up, 25% had at least one decayed tooth compared with 34% at baseline. The proportion of participants with caries lesions was higher in the 85 years group (33%) than in the 75 years group (20%,  $p = 0.030$ ). A total of 25 participants had dental caries lesions both at baseline and at follow-up (same individuals). At follow-up, men had a higher mean number of root surface lesions than women (0.21 [SD: 0.84] vs. 0.01 [SD: 0.08],  $p = 0.004$ ). The mean number of teeth with primary root surface caries was 0.14 (SD: 0.75) for men and 0.01 (SD: 0.08) for women ( $p = 0.032$ ). The corresponding mean number of secondary root caries surfaces was 0.07 (SD: 0.4) for men and 0.00 for women ( $p = 0.039$ ; not shown in table).

The majority of the participants continued with acceptable toothbrushing routines and brushed their teeth at least once a day. Interproximal cleaning decreased in the 85 years age group (Table 4). At follow-up, women were more likely than men to brush their teeth

twice a day or more (95% vs. 74%,  $p < 0.001$ ) and also more likely to use extra fluoride products every day (35% vs. 22%,  $p = 0.028$ ).

The proportion of participants in need of homecare increased in both age groups, with the increase being most pronounced among 85-year-old participants. Irregular dental visits also increased (Table 4).

Self-perceived xerostomia, living alone, poor general health and use of medication all became more common in both age groups over this period of 10 years (Table 4).

Self-perceived xerostomia was more common among women than men (75 years: 71% vs. 45%,  $p = 0.001$ ; 85 years: 74% vs. 50%,  $p = 0.015$ ), as was living alone (75 years: 40% vs. 21%,  $p = 0.015$ ; 85 years: 67% vs. 16%,  $p < 0.001$ ).

In 2018, 35% of the 75-year-olds and 26% of the 85-year-olds reported three principal meals per day (breakfast, lunch and dinner) (Table 4). More men (43%) ate only one principal meal per day compared with women (30%,  $p = 0.002$ ). The majority of participants reported intake of snacks 1–3 times a day (Table 4). No difference between women and men was found regarding snacking. In 2018, education to college or higher level was reported by 13% overall ( $n = 34$ ), 15% of 75-year-olds, and 8% of 85-year-olds (not shown in table).

### 3.1 | Dental caries lesions and oral hygiene and dietary habits

Model 1, using a logistic regression analysis with caries lesion as dependent variable and adjusting only for age and gender, showed that participants who brushed their teeth once a day or less and seldom-used interproximal devices or extra fluoride products were more likely to have caries lesions than those brushing their teeth twice a day or more and using interproximal devices and extra fluoride

**TABLE 4** Oral hygiene habits, need of homecare, dental visits, marital status, medication, perceived general health, self-perceived xerostomia, dietary habits and financial limitations among participants at baseline and at follow-up

	75 years			85 years		
	Baseline n (%)	Follow-up n (%)	<i>p</i> -value	Baseline n (%)	Follow-up n (%)	<i>p</i> -value
<b>Toothbrushing</b>						
More than once a day	127 (83)	129 (85)	0.329	83 (79)	91 (87)	0.096
Once a day	22 (15)	22 (15)		22 (21)	14 (13)	
A couple of times a week	3 (2)	1 (1)		-	-	
Seldom/never	-	-		-	-	
<b>Interproximal cleaning</b>						
More than once a day	44 (28)	52 (33)	0.474	57 (54)	37 (35)	0.006
Once a day	47 (30)	54 (35)		28 (27)	39 (37)	
A couple of times a week	51 (33)	41 (26)		12 (11)	18 (17)	
Seldom/never	14 (9)	9 (6)		8 (8)	11 (11)	
<b>Additional fluoride use</b>						
More than once a day	17 (11)	19 (12)	0.277	12 (12)	7 (7)	0.064
Once a day	22 (14)	25 (16)		18 (18)	25 (24)	
A couple of times a week	20 (13)	33 (22)		6 (6)	14 (14)	
Seldom/never	94 (62)	76 (50)		66 (64)	56 (55)	
<b>Need of homecare</b>						
No	157 (97)	151 (93)	0.07	100 (94)	71 (66)	<0.001
Yes	5 (3)	11 (7)		7 (6)	36 (34)	
<b>Dental visits</b>						
Regular	158 (96)	149 (91)	0.064	104 (95)	95 (87)	0.022
Irregular	6 (4)	15 (9)		5 (5)	14 (13)	
<b>Marital status</b>						
Married/cohabiting	117 (76)	105 (68)	0.004	77 (78)	56 (57)	<0.001
Living alone	37 (24)	49 (32)		22 (22)	43 (43)	
<b>Medication</b>						
No medication	59 (36)	33 (20)	<0.001	33 (30)	13 (12)	<0.001
1–2 medicines per day	64 (39)	41 (25)		34 (31)	25 (23)	
≥3 medicines per day	41 (25)	90 (55)		42 (39)	71 (65)	
<b>Perceived general health</b>						
Good	138 (88)	123 (79)	0.008	93 (90)	76 (74)	<0.001
Bad	18 (12)	33 (21)		10 (10)	27 (26)	
<b>Self-perceived xerostomia</b>						
No	107 (68)	63 (40)	<0.001	75 (71)	39 (37)	<0.001
Yes	50 (32)	94 (60)		30 (29)	66 (63)	
<b>Financial limitations on dental care</b>						
No	138 (88)	143 (91)	0.359	98 (92)	104 (98)	0.07
Yes	19 (12)	14 (9)		8 (8)	2 (2)	
<b>Principal meal</b>						
3 times a day		54 (35)			27 (26)	0.259 <sup>†</sup>
>3 times a day		1 (1)			-	
Twice a day		55 (35)			47 (46)	
Once a day		45 (29)			28 (28)	

(Continues)

TABLE 4 (Continued)

	75 years			85 years		
	Baseline n (%)	Follow-up n (%)	p-value	Baseline n (%)	Follow-up n (%)	p-value
Intake of snacks						
1–3 times a day		139 (88)		89 (90)		0.232 <sup>†</sup>
4–5 times a day		-		2 (2)		
≥6 times a day		1 (1)		-		
No snacks		17 (11)		8 (8)		

<sup>†</sup>Data not available in 2008, comparisons made between age groups 75 years and 85 years in 2018.

products once a day or more. Participants in need of homecare were more likely to have caries lesions than those with no need for homecare (Table 5).

Model 2 was a fully adjusted model with the parameters associated with caries included as covariates alongside adjustment for gender and age. Toothbrushing once a day or less was the factor that most strongly correlated with dental caries lesions (OR: 3.82, 95% CI: 1.68–8.66,  $p = 0.001$ ), followed by need for homecare (OR: 3.50, 95% CI: 1.55–7.93,  $p = 0.003$ ), and interproximal cleaning less than once a day (OR: 2.65, 95% CI: 1.36–5.19,  $p = 0.004$ , Table 5).

## 4 | DISCUSSION

This longitudinal study reveals the incidence of dental caries lesions and risk factors for caries among older people. In this elderly population, the mean number of teeth decreased over a period of 10 years, but the mean number of decayed teeth and surfaces did not increase. Particularly among the oldest participants, we found that regular dental visits decreased, the frequency of toothbrushing decreased, and the need for help in daily living increased. Inadequate oral hygiene routines and need of help in daily living were found to be risk factors for dental caries lesions.

In longitudinal studies including older individuals, there is a risk of losing participants for natural reasons such as sickness and death. The individuals who were not available for follow-up in the present study had at baseline a lower mean number of teeth, were less likely to visit dental care regularly, and were more likely to smoke. However, with respect to other clinical variables such as dental caries lesions, those lost to follow-up did not seem to differ from the other participants. As some variables had very small numbers in the response categories, it is difficult to draw definitive conclusions and so the results must be interpreted with caution.

Despite the increase in the number of older people and number of retained teeth, relatively few studies have reported on the dental status of older non-institutionalized persons. There is a particular lack of recent longitudinal studies. A review including data from six studies performed from 1988 to 1997, with a follow-up of 3–5 years, found that older people (age 50+) constitute a caries-active group.<sup>17</sup>

In the present study population, the incidence of dental caries lesions did not increase over a period of 10 years. Approximately, a

quarter of the participants had dental caries lesions, which is comparable with other studies.<sup>18</sup> Although the number of DFT decreased, the number of DMFT increased because of decreased mean number of teeth. The participants had on average lost approximately two teeth due to periodontal disease and dental caries, and now had an average of 21.6 teeth, thus meeting the WHO goal of at least 20 remaining teeth at the age of 80 years.<sup>19</sup> Globally, the prevalence of root caries has been reported to vary widely (25–100%).<sup>9,13,20</sup> The prevalence and incidence of root caries in the present study was very low. However, it is a challenge to compare different studies investigating root caries, as findings are reported in a variety of ways with different indices.<sup>9</sup> It seems that dental caries in this elderly population could be only a minor problem, as also shown by Henriksen et al.<sup>21</sup> Although around 80% of the Swedish population is enrolled in a dental recall system,<sup>22</sup> a considerable number of older individuals, living independently in their own homes or in need of homecare, lose contact with dental care.<sup>23</sup> Despite the decline in dental visits over the study period, the majority of the participants had regular dental visits and reported relatively good oral hygiene routines and use of fluoride toothpaste. This, together with adequate dietary habits, may have contributed to the lack of caries increment over the study period in this cohort. Fluoride toothpaste is considered to be the main factor responsible for the caries decline that has been observed in industrialized countries over the past four decades. Women in this study used extra fluoride products to a higher degree than men, which might explain why men had more caries.

Unlike many other studies, low level of education was not a risk for having caries in the present study.<sup>5,7,24,25</sup> Living alone, having limited finances for dental care, and having poor self-perceived general health were also shown not to be risk factors. The availability of dental care and dental insurance systems varies between countries, which makes it difficult to compare the impact of socioeconomic status on oral health. Socioeconomic inequalities tend to be higher in countries where there is no public dental care coverage than in countries with some degree of public dental-care coverage.<sup>26</sup> In Sweden, the dental-care system is supposed to benefit and encourage individuals aged 65 years and older by providing a yearly contribution of around €60 as well as high-cost protection when dental costs exceed €300. In addition, individuals with certain medical conditions or disabilities requiring high levels of health care can qualify for additional financial support from the regions. This, together with the fact that Sweden is a highly

TABLE 5 Multiple logistic regression analysis with dental caries as dependent variable

	Model 1 <sup>†</sup>		Model 2 <sup>‡</sup>	
	OR (95% CI)	<i>p</i> -value	OR (95% CI)	<i>p</i> -value
<b>Toothbrushing</b>				
Twice a day or more	Ref		Ref	
Once a day or less	3.52 (1.63–7.61)	0.001	3.82 (1.68–8.66)	0.001
<b>Interproximal cleaning</b>				
Once a day or more	Ref		Ref	
Seldom/never	2.53 (1.38–4.63)	0.003	2.65 (1.36–5.19)	0.004
<b>Additional fluoride use</b>				
Once a day or more	Ref		Ref	
Seldom/never	2.13 (1.04–4.36)	0.038	2.17 (0.98–4.83)	0.057
<b>Need of homecare</b>				
No	Ref		Ref	
Yes	2.28 (1.11–4.68)	0.025	3.50 (1.55–7.93)	0.003
<b>Education</b>				
High	Ref			
Low	0.81 (0.35–1.86)	0.615		
<b>Dental visits</b>				
Regular	Ref			
Irregular	1.71 (0.74–3.95)	0.213		
<b>Marital status</b>				
Married/cohabiting	Ref			
Living alone	1.74 (0.90–3.34)	0.099		
<b>Medication</b>				
1–2 medicines per day	Ref			
≥3 medicines per day	0.56 (0.22–1.38)	0.205		
No medicines	0.81 (0.39–1.73)	0.602		
<b>Self-perceived general health</b>				
Good	Ref			
Bad	1.88 (0.99–3.56)	0.052		
<b>Self-perceived xerostomia</b>				
No	Ref			
Yes	1.57 (0.84–2.94)	0.162		
<b>Financial limitations</b>				
No	Ref			
Yes	0.94 (0.25–3.55)	0.931		
<b>Principal meal</b>				
3 times a day	Ref			
>3 times a day	-			
Twice a day	1.09 (0.51–2.35)	0.828		
Once a day	1.05 (0.52–2.14)	0.886		
<b>Intake of snacks</b>				
1–3 times a day	Ref			
4–5 times a day	-			
≥6 times a day	-			
No snacks	0.59 (0.19–1.82)	0.358		

<sup>†</sup>Adjusted for age and gender.<sup>‡</sup>Variables include toothbrushing, interproximal cleaning, extra fluoride use and need of home care; results adjusted for age and gender.

developed country, makes it easier for citizens to benefit from and take part in dental care, thus promoting oral health.

There are several studies describing poorer oral health status among elderly people living in special accommodation.<sup>27,28</sup> In the present study, the majority of participants in need of help in daily living lived in their own homes with support from the municipality or relatives. These participants were more affected by dental caries lesions than those who were independent, which has been shown before.<sup>29</sup> This group of elderly people has not been sufficiently investigated, probably because they are less likely to be among those who agree to participate in studies. It can therefore be expected that oral health is deteriorating in home-dwelling elderly individuals in line with ageing and cognitive impairment. This highlights the importance of encouraging and supporting ageing individuals to continue with their dental contacts when entering the stage of life in which frailty and reduced cognitive functions occur. It is essential that health services and dental services collaborate to improve oral health routines in these individuals. In the future, we will see increased numbers of elderly people in the population, and it is, therefore, positive to see that elderly people can maintain acceptable oral health by using preventive measures and maintaining contact with dental health care.

#### 4.1 | Strengths and limitations

As the clinical examinations were performed by a large number of individuals, comprehensive written instructions and illustrations were provided for recording the different clinical variables in order to ensure the best conformity possible. The same diagnostic criteria were used in both study years. Dental caries lesions on interproximal sites were confirmed by one of the authors (KE, a registered dental hygienist) and a dentist, using bitewing radiographs, which strengthens the clinical measures. From the original study sample of 515 individuals participating in 2008, 420 were available in 2018 according to the Dalarna population registry. The majority of those not available had died, and a few had moved out of the country. Of the 420 invited, 273 individuals agreed and participated in both the questionnaire and the clinical examination. The most common reasons for not wanting to participate were illness, cognitive impairment and hospitalization. This indicates worse oral health, as studies have shown that non-respondents and elderly people living in special accommodation are generally less healthy than participants in health investigations.<sup>27,28,30,31</sup> This may have influenced our results, as oral health is suspected to be worse in an elderly population. The region studied comprised both rural and urban areas, and studies from other parts of Sweden show similar results in an adult population.<sup>32</sup>

## 5 | CONCLUSIONS

This longitudinal study revealed only a limited increase in tooth loss and no increase in dental caries lesions, indicating that good

oral health can be preserved among elderly individuals as long as adequate preventive routines are maintained. Inadequate oral hygiene routines and need for help in daily living were found to be the strongest risks for dental caries lesions, showing the importance of continuous dental health care and of collaboration between dental health services and community-based health care.

## 6 | CLINICAL RELEVANCE

### 6.1 | Scientific rationale for study

Previous research has revealed several factors associated with dental caries in older people. This study contributes further knowledge regarding dental caries and related factors among home-dwelling older people.

### 6.2 | Principal findings

Good oral health can be preserved among elderly individuals as long as adequate preventive routines are maintained. However, oral health can be expected to deteriorate in home-dwelling elderly individuals in need of help in daily living.

### 6.3 | Practical implications

To improve dependent older people's oral health and promote healthy ageing, interprofessional collaboration between health and dental professionals needs to be improved.

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## CONFLICT OF INTEREST

The authors declare no conflict of interests.

## AUTHORS' CONTRIBUTIONS

All authors contributed to the 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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