



ORIGINAL ARTICLE

Elderly with remaining teeth report less frailty and better quality of life than edentulous elderly: a cross-sectional study

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OBJECTIVE: To assess oral status and self-reported oral health in community-living elderly and to determine differences between relevant subgroups of oral status (remaining teeth, edentulous, implant-retained overdentures) and case complexity (robust, frail, complex care needs).

SUBJECTS AND METHODS: In this cross-sectional descriptive study, 1325 Dutch community-living elderly (≥ 75 years of age) were asked to complete validated questionnaires on frailty, activities of daily living (ADL), complexity of care needs, and QoL. Data on oral status, self-reported oral health, dental care, general health, and medication use were assessed. Differences between relevant subgroups were determined.

RESULTS: Data of 1026 (77%) elderly (median 80 years, IQR 77–84) were analyzed: 39% had remaining teeth, 51% were edentulous, and 10% had implant-supported overdentures. Elderly with complex care needs ($n = 225$, 22%) and frail elderly ($n = 217$, 21%) were more often edentulous and reported more oral problems than robust elderly ($n = 584$, 57%). Elderly persons with remaining teeth were less frail, had better QoL and ADL, and used fewer medicines than edentulous elderly. Elderly with implant-supported overdentures performed better on frailty and QoL than edentulous elderly with conventional dentures.

CONCLUSION: Community-living elderly commonly suffer from oral health problems, in particular elderly with complex care needs. QoL, ADL, and general health are higher among community-living elderly with remaining teeth and implant-supported overdentures than in edentulous elderly.

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Introduction

Worldwide life expectancy has increased and birth rates have declined resulting in aging of the society, especially in the Western countries (Branca *et al*, 2008). In 2060, 30% of the people living in the European Union will be 65 years and older compared to 17% in 2008 (Eurostat 2010). In the north of the Netherlands, the area where this study was performed, in 2020, already around 30% of the people will be 65 years of age or older (CBS (Dutch central agency for statistic) and Garssen, 2011).

When elderly become frail, care-dependent, and homebound, self-care often declines, including less attention for oral care (Lee *et al*, 2016). For example, when sarcopenia or mobility problems occur, daily activities such as brushing teeth or dentures, or periodic visits to the dentist can become difficult. Poor oral hygiene increases the risk of developing progressive periodontal disease and dental decay. Moreover, polypharmacy, which is commonly seen in the elderly (Maher *et al*, 2014), can lead to an even higher risk of developing oral problems as polypharmacy is associated with oral dryness and increased risk of developing oral infections and rampant caries (Aliquo *et al*, 2015). Dental and periodontal diseases have been associated with severe health problems including diabetes (Teeuw *et al*, 2010), cardiovascular disease (Janket *et al*, 2003), atherosclerosis (Friedlander *et al*, 2010), rheumatoid arthritis (de Smit *et al*, 2012), decreased kidney function (Iwasaki *et al*, 2012), pneumonia (Tada and Miura, 2012), multiple sclerosis, and other systemic immune problems (Somma *et al*, 2010). Moreover, poor oral health

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has been linked to greater cognitive dysfunction in patients with Alzheimer's disease (Cerajewska *et al*, 2015; Olsen and Singhrai, 2015).

Previous research has substantiated that good oral health is important, especially in care-dependent elderly. However, poor oral health is commonly seen in elderly in nursing homes (Zuluaga *et al* 2012; Lindqvist *et al*, 2013). Hoeksema *et al* (2014, 2016) even stated that oral health of elderly is usually already poor at admission to the nursing home. Strikingly, in contrast to the multiple publications on oral health, in nursing homes, little is known regarding the oral status and oral health problems of community-living elderly (elderly who live at their own home). Poor oral health might be a hidden health hazard with an increasing, not yet fully understood, impact on frailty, activities of daily living (ADL), quality of life (QoL), and general health. The few studies published on oral health of community-living elderly suggest that many elderly face oral health problems (Castrejón-Pérez *et al*, 2016), but did not report specifically on their oral status (own teeth, implant-supported overdentures, or edentulous) or the association of oral status and oral health with frailty, ADL, QoL, and general health. Recently, Törres *et al* (2015) systematically reviewed the relationship between components of frailty and poor oral health. They concluded that none of the eligible studies showed whether or not poor oral health increases the likelihood of developing signs of frailty, although the reviewed studies did suggest an association between frailty and oral health. Thus, there is a need for well-designed studies that give better insight in the oral status and oral health of community-living elderly and also focus on the possible relationship between frailty, ADL, QoL, general health, and oral status. Therefore, the aim of this study was to assess oral status and self-reported oral health in community-living elderly and to determine differences between relevant subgroups of oral status (remaining teeth, edentulous, implant-retained overdentures) and case complexity (robust, frail, complex care needs).

Methods

Participants and study design

This cross-sectional descriptive study took place between June 2015 and November 2015. Eligible elderly ($n = 1325$) for this study were community-living elderly aged 75 years and older and residing in the north of the Netherlands (the province of Drenthe) who participated in Embrace ('SamenOud' [aging together] in Dutch). Embrace is a person-centered and integrated care service whose primary aim is to prolong the ability of older adults to age at home for as long as possible by providing comprehensive, coherent, person-centered, proactive, and preventive care and support (Spoorenberg *et al*, 2013). Recruitment of the participants in Embrace was performed in two steps. First, general practitioners (GPs) working in the municipality Emmen, a representative region for the northern part of the Netherlands, were informed about the Embrace study and their consent to participate in the study was requested. Second, all patients ($n = 2752$), either healthy or unhealthy, from the participating GPs aged 75 years and older and living at home or in a home for the elderly were eligible for inclusion in Embrace. These eligible elderly were invited to participate. There were no exclusion criteria. Eligible patients finally received a letter from their GP with general information about participating in Embrace. One week later, these patients received a written informed consent form accompanied by validated questionnaires for baseline measurements such as frailty, QoL, ADL (see below for

further information on the questionnaires). Patients were free to ask for support in filling out the questionnaire, either from family, friends, or from a staff member of the Embrace study available via the project's helpdesk. In case of missing data, elderly were interviewed via the telephone to complete the questionnaire. For more details about Embrace, the person-centered, and integrated care service, see the studies of Spoorenberg *et al* (2013, 2015) and Uittenbroek *et al* (2016a,b). Informed consent was obtained from all participants, and the study was performed in accordance with the Declaration of Helsinki. The Medical Ethical Committee of the University Medical Center Groningen, Groningen, the Netherlands, assessed the study proposal and concluded that approval was not required (reference METc2011.108).

Procedure and assessments

At baseline, all eligible elderly for participating in Embrace received questionnaires on demographic characteristics such as age, gender, marital status, living situation, education level, income and health (underlying diseases, use of drugs), and a battery of health-related validated questionnaires:

1 Frailty was assessed with the Groningen Frailty Indicator (GFI). This instrument comprises 15 items and measures losses of functions and resources in four domains: physical, cognitive, social, and psychological (Peters *et al*, 2012). Theoretical range is 0–15, whereas a higher score indicates a higher level of frailty. Score >4 is considered frail (Peters *et al*, 2012).

2 Complexity of care needs was assessed with the INTERMED for the Elderly Self-Assessment (IM-E-SA) (Peters *et al*, 2013). IM-E-SA assesses the needs as perceived by elderly themselves by completing 20 questions in four domains: biological, psychological, and social needs, and healthcare. These domains cover three different time perspectives: history, current state, and prognosis. The total score of IM-E-SA ranges from 0 to 60, with a higher score indicating a more complex care needs.

3 Dependency in ADL was assessed with the modified Katz ADL index (Weinberger *et al*, 1992); this index includes six ADL items and four instrumental ADL activities. Theoretical range is 0–10, with a higher score indicating more dependency in performing daily activities.

4 Health-related QoL was assessed with the EuroQol-5D (EQ-5D) (Brooks, 1996). This instrument comprises five domains: mobility, self-care, pain, usual activities and psychological status. An index score is calculated for each participant, ranging from 0 to 1. A higher score indicates a better perceived QoL.

Case complexity

Participants in Embrace were classified into three subgroups (Robust, Frail, and Complex care needs) reflecting their case complexity based on their scores on the IM-E-SA and GFI. The subgroup 'Robust' consisted of participants without complex care needs and relatively low levels of frailty (IM-E-SA < 16 and GFI < 5). These elderly experienced none or a few consequences of aging. The subgroup 'Frail' consisted of participants at risk for developing complex care needs and had higher levels of frailty (IM-E-SA < 16 and GFI ≥ 5). These elderly suffered increasingly from the consequences of aging and experience growing dependency on others. The subgroup 'Complex care needs' consisted of participants with comprehensive care dependency (IM-E-SA ≥ 16 and GFI ≥ 5). These elderly were subjected to professional support for several aspects due to the consequences of aging and are at risk for assignment to a hospital or nursing home.

Oral status and oral health

After assessing baseline data and case complexity as mentioned above, all participating elderly in Embrace received an additional simple questionnaire with 13 questions on oral status (e.g., whether they have remaining teeth, dental implants, or dentures), oral health (e.g., complaints related to pain or dry mouth, difficulties with chewing), and oral self-care (e.g., oral cleaning habits, dental visits) (Figure 1). Participants were also asked to mark their oral health on a 10-point scale, ranging from 0 (very poor) to 10 (very good). A higher score indicates higher satisfaction with their oral status. Before application in this study, this oral health questionnaire was field-tested on feasibility and reliability among 25 elderly who were screened for formal home care. Elderly reported no difficulties with filling in the questionnaire. Next, we checked the oral status with the self-reported oral status and found no differences between the self-reported information on the oral status and assessment by a

1. Do you have own teeth or a full denture in the upper jaw?
 - a. I have my own teeth in the upper jaw.
 - b. I have my own teeth in the upper jaw and I wear a removable partial denture in the upper jaw.
 - c. I have a full denture in the upper jaw.
 - d. I have a full denture in the upper jaw which is retained on dental implants.
 - e. I do not have my own teeth anymore, but also do not wear a full denture in the upper jaw.

2. Do you have own teeth or a full denture in the lower jaw?
 - a. I have my own teeth in the lower jaw.
 - b. I have my own teeth in the lower jaw and I wear a removable partial denture in the lower jaw.
 - c. I have a full denture in the lower jaw.
 - d. I have a full denture in the lower jaw which is retained on dental implants.
 - e. I do not have my own teeth anymore, but also do not wear a full denture in the lower jaw.

3. How often do you brush your teeth or dentures?
 - a. I brush them once in a while, but not daily
 - b. I brush them once a day.
 - c. I brush them twice a day.
 - d. I brush them 3 or more times a day.

4. Can you brush your teeth or dentures yourself or do you need help?
 - a. I can brush my teeth or dentures myself.
 - b. No I cannot brush my teeth or dentures myself.

5. When did you visit the dentist for the last time?
 - a. I visited the dentist within the last 12 months.
 - b. It was between 1 and 2 years that I last visited the dentist.
 - c. I have not been at the dentist for more than 2 years.
 - d. I cannot remember when was the last time that I visited the dentist.

6. When was the last time that you had pain in your mouth (toothache, denture sore spots etc)?
 - a. I recently had pain in my mouth (less than 6 month ago)
 - b. I was between 6 and 12 months that I had pain in my mouth
 - c. It has been more than a year that I had pain in my mouth.

7. What did you do when you had pain in your mouth?
 - a. I have no pain anymore, I did not do anything, the pain disappeared by itself.
 - b. I do not have pain anymore, but I had to take painkillers for a while. The pain disappeared by itself.
 - c. I do not have pain anymore since I visited the dentist because of that pain complaint.
 - d. I still have pain (regularly), but I do not do anything to solve the pain.
 - e. I still have pain (regularly) and I take pain killers.
 - f. I still have pain and I am going to the dentist soon.

8. Are you able to chew properly?
 - a. Yes, I can chew very well.
 - b. Yes, I can chew, but it is not easy.
 - c. No, chewing is hard.

Figure 1 Questionnaire on oral health and oral status as presented to the participants

dentist. Elderly in the frail and complex care needs groups were helped by their case manager to fill in the oral health questionnaire. Robust elderly could ask for help if desired. In case a questionnaire was

incomplete, elderly were telephoned and interviewed to complete the questionnaire. If completion of a questionnaire was not possible, the participant was excluded for this study on oral status and oral health.

9. Do face difficulties when talking to others or when you have to pronounce certain words?
- No, I never have problems talking or pronouncing certain words.
 - No, normally I do not have problems with talking to others, but in some rare occasions I do have problems pronouncing certain words.
 - Yes, I do have difficulties pronouncing certain words on regularly basis.
 - Yes, I have very often problems with pronouncing words.
10. Do you have problems to chew certain food due problems with your teeth or dentures?
- No, never.
 - Yes, once in a while.
 - Yes, on regularly basis.
 - Yes, it happens very often.
11. Do you suffer from a dry mouth at day time?
- Never.
 - Once in a while.
 - Regularly.
 - Very often.
- 12 Do you suffer from a dry mouth at night time?
- Never.
 - Once in a while.
 - Regularly.
 - Very often.
13. Did you felt insecure due to problems with your teeth or dentures lately?
- No, I never feel insecure due to problems in my mouth.
 - Yes, once in a while.
 - Yes, on regularly basis.
 - Yes, it happens very often.
14. On a scale from 1 to 10, in which 10 is very good and 1 very bad, can you please state your overall oral situation

Figure 1 Continued.

Statistical analyses

Differences in baseline characteristics between the respondents and non-respondents were calculated with the chi-square tests and Mann–Whitney *U*-tests. A *P*-value <0.05 was defined as significant. Descriptive statistics were used to provide an overview of demographic characteristics, health, and oral health for the total population as well as for subgroups of elderly who differed regarding oral status (elderly with remaining teeth, implants, or prosthesis) or case complexity (Complex care needs, Frail, or Robust). For all variables that were not normally distributed, median scores and interquartile ranges (IQR) were reported. Chi-square tests and Mann–Whitney *U*-tests were used to asses differences between subgroups that differed regarding oral status or case complexity (Tables 2 and 3). In addition, subgroups based on case complexity were likewise compared per oral status subgroup (Table 4). For these analyses, a *P*-value of ≤ 0.0167 (0.05/3) was defined as significant according to the Bonferroni principle. All statistical analyses were performed with SPSS Statistics 22.0 (SPSS Inc., Chicago, IL, USA).

Results

Respondents

In total, 1325 of the 2752 eligible elderly (48% response rate) of the 13 participating GP practices

decided to participate in Embrace. With regard to the Embrace participants, non-respondents differed from respondents regarding gender (more women declined to participate, $P < 0.05$) and age (older participants consented less often, $P = 0.01$). For details, see Spoorenberg *et al* (2013, 2015) and Uittenbroek *et al* (2016a,b). Of the oral health status questionnaires sent to the 1325 participants in Embrace, 1041 questionnaires were returned (response rate of 79%). Due to missing values, 15 questionnaires were excluded from analysis. As a result, finally, 1026 (77%) respondents were included in the analysis (Figure 2). Respondents had a median age of 80 years (IQR 77–84) years and 59% ($n = 602$) was female (Table 1). Non-respondents of the oral status questionnaires (these elderly were interviewed at baseline by co-workers of Embrace) were older, lower educated, lived more often in a sheltered accommodation for the elderly, had a lower monthly income, and used more medicines when compared to respondents (all $P < 0.05$).

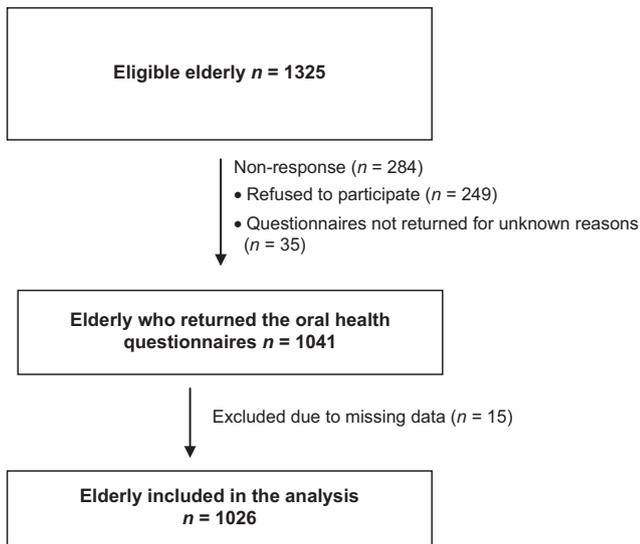


Figure 2 Flowchart of subjects invited to participate and those who completed the questionnaires

Oral status and self-reported oral health

Table 2 shows the results for the whole sample and oral status subgroups (for significance levels, see the various Tables). Thirty-nine percent of the respondents had remaining teeth, 10% had implant-supported overdentures, and 51% were edentulous. Elderly with remaining teeth were significantly higher educated and had better incomes when compared to edentulous elderly and those with implant-supported overdentures. Overall, 12% of the

elderly revealed to have chewing problems and 22% reported to have oral pain complaints. These pain complaints were most reported by elderly with remaining teeth (33% reported pain) and elderly with implants (23%), and significantly less reported by edentulous elderly (12%). The reported chewing complaints were comparable for the three oral status subgroups. More than 90% of the elderly with remaining teeth continued to visit their dentist for periodic visits, which was significantly higher when compared to elderly with implants (69%) and edentulous elderly (20%). Notwithstanding the more frequent pain complaints of elderly with remaining teeth, they were significantly less frail, had higher QoL, and better ADL functioning compared to edentulous elderly. Furthermore, elderly with remaining teeth used significantly fewer medicines (50% vs 62%). The overall results, of the oral status questionnaires, for elderly with implant-supported overdentures resembled, to a large extent, those of elderly with remaining teeth rather than those of edentulous elderly with conventional dentures.

Case complexity

Table 3 shows the results per subgroup based on case complexity. Robust elderly were significantly younger, more often male, and had a higher income and educational level than frail elderly or elderly with complex care needs. Furthermore, frail elderly and elderly with complex care needs were significantly more often edentulous than robust elderly. Frail elderly and elderly with complex care needs also reported significantly more oral health-related problems than robust elderly, such as dry mouth during the night (30% and 25% vs 14%) and chewing problems

Table 1 Characteristics of respondents and non-respondents

	Respondents n = 1026	Non-respondents n = 299	Differences between subgroups P-value
Demographic characteristics			
Age (median, IQR)	80 (77–84)	81 (78–85)	0.04
Female, n (%)	602 (59)	189 (63)	0.07
Widowed/divorced/single, n (%)	463 (45)	147 (49)	0.13
In sheltered accommodation/home for the elderly, n (%)	103 (10)	43 (14)	0.03
Low education level, n (%) ^a	418 (41)	176 (59)	≤0.001
Low income, n (%) ^b	321 (31)	112 (38)	0.03
Measures (median, IQR)			
Frailty (GFI) ^c	4 (2–6)	4 (2–7)	≤0.001
Complexity of care needs (IM-E-SA) ^d	10 (6–15)	11 (7–18)	≤0.001
Activities of daily living (Katz-15) ^e	1 (0–3)	2 (0–5)	≤0.001
Quality of life (EQ-5D) ^f	0.81 (0.69–0.86)	0.78 (0.65–0.84)	≤0.001
Case complexity, n (%)			
Complex care needs	217 (21)	93 (32)	≤0.001
Frail	225 (22)	62 (21)	0.85
Robust	584 (57)	144 (48)	0.003
General health, n (%)			
Number of chronic conditions ^g	2 (1–3)	2 (1–4)	0.06
Polypharmacy ^h	583 (57)	194 (65)	0.004

^aLow: (less than) primary school or low vocational training.

^bLow: <€1450 per month.

^cGFI (Groningen Frailty Indicator).

^dIM-E-SA (INTERMED for the Elderly Self-assessment).

^eKatz extended.

^fEQ-5D (EuroQoL-5D).

^gPresence or absence of 18 chronic diseases (e.g., diabetes mellitus, pulmonary emphysema, osteoporosis, hearing disabilities).

^hMore than four medications.

Table 2 Overview of demographic characteristics, measures, health, oral health, and case complexity for the total population and subgroups of oral status

	Oral status				Differences between subgroups P-value
	Total n = 1026 100%	Remaining teeth n = 401 39%	Implants n = 104 10%	Edentulous n = 521 51%	
Demographics					
Age (median, IQR)	80 (77–84)	79 (77–83) ^b	80 (76–85) ^c	81 (78–85)	≤0.001
Female, n (%)	602 (59)	229 (57)	60 (58)	313 (60)	0.65
Widowed/divorced/single, n (%)	463 (45)	160 (40) ^b	38 (37) ^c	265 (51)	≤0.001
In sheltered accommodation/home for the elderly, n (%)	103 (10)	17 (4) ^{a,b}	11 (11)	75 (14)	≤0.001
Low education level, n (%) ^d	418 (41)	103 (26) ^{a,b}	44 (42)	271 (52)	≤0.001
Low income, n (%) ^e	321 (31)	78 (20) ^{a,b}	34 (33)	209 (40)	≤0.001
Measures, median (IQR)					
Frailty (GFI) ^f	4 (2–6)	3 (1–5) ^b	3 (1–5) ^c	4 (2–6)	≤0.001
Complexity of care needs (IM-E-SA) ^g	10 (6–15)	9 (5–14) ^b	11 (6–14)	11 (7–15)	0.01
Activities of daily living (Katz-15) ^h	1 (0–3)	1 (0–2) ^b	1 (0–3)	1 (0–3)	≤0.001
Quality of life (EQ-5D) ⁱ	0.81 (0.69–0.86)	0.81 (0.77–0.89) ^b	0.81 (0.78–0.89) ^c	0.81 (0.69–0.85)	0.004
General health					
Number of chronic conditions (median, IQR) ^j	2 (1–3)	2 (1–3) ^b	2 (1–4)	2 (1–4)	0.06
Polypharmacy, n (%) ^k	583 (57)	200 (50) ^b	60 (58)	323 (62)	≤0.001
Oral health, n (%)					
Regular dentist visit (<2 years)	540 (53)	363 (91) ^{a,b}	72 (69) ^c	105 (20)	≤0.001
Chewing complaints (fair to poor)	118 (12)	54 (14)	11 (11)	53 (10)	0.29
Pain complaints (<2 years)	221 (22)	131 (33) ^b	24 (23) ^c	66 (12)	≤0.001
Dry mouth during the day	78 (8)	25 (6)	8 (8)	45 (9)	0.39
Dry mouth at night	201 (20)	69 (17) ^a	30 (29) ^c	102 (20)	0.03
Insecurity related to oral status	17 (2)	8 (2)	3 (3)	6 (1)	0.36
Self-rated oral condition, median (IQR)	8 (7–8)	8 (7–8) ^{a,b}	8 (7–9) ^c	8 (7–8)	≤0.001
Case complexity					
Complex care needs	217 (21)	76 (19) ^b	17 (16) ^c	124 (24)	0.002
Frail	225 (22)	72 (18) ^b	20 (19) ^c	133 (26)	0.002
Robust	584 (57)	253 (63) ^b	67 (64) ^c	264 (50)	0.002

^aStatistical difference ($P \leq 0.0167$) between elderly with remaining teeth and those with implants.

^bStatistical difference ($P \leq 0.0167$) between elderly with remaining teeth and edentulous elderly.

^cStatistical difference ($P \leq 0.0167$) between elderly with implants and edentulous elderly.

^dLow: (less than) primary school or low vocational training.

^eLow: <€1450 per month.

^fGFI (Groningen Frailty Indicator).

^gIM-E-SA (INTERMED for the Elderly Self-assessment).

^hKatz extended.

ⁱEQ-5D (EuroQoL-5D).

^jPresence or absence of 18 chronic diseases (e.g., diabetes mellitus, pulmonary emphysema, osteoporosis, hearing disabilities).

^kMore than four medications.

(20% and 14% vs 7%). Furthermore, significantly more elderly with complex care needs had pain complaints than robust elderly (30% vs 19%). Also, the percentage elderly with complex care needs experiencing a dry mouth during the day was higher compared to frail and robust elderly (17% vs 8% and 4%). No substantial differences were found between the subgroups with respect to dental visits (overall, 53% had visited a dentist in the last 2 years) and the self-reported mark for oral health status (overall, median 8).

Case complexity and oral status

Table 4 gives a total overview of the demographics and outcomes per risk profile for each oral status subgroup, applied measures, health and oral health related to oral status, and case complexity. Elderly with remaining teeth succeeded to visit their dentist in more than 90% of the cases, which is significantly different when compared to edentulous elderly (22% regular dental visits). Whether

elderly visited their dentist was independent of their case complexity. Chewing problems seem to extend when case complexity rises indifferent of oral status. Furthermore, subgroup analysis revealed that oral pain is reported significantly more in respondents with remaining teeth than in edentulous patients. Overall, the group of robust elderly with implant-supported overdentures and the group of robust elderly with remaining teeth both reported significant more pain (respectively 25% and 29%) than robust edentulous elderly (7%). Finally, elderly with remaining teeth and implant-supported overdentures reported less frailty, better general health, better ADL, better QoL, and used fewer medicines compared to edentulous elderly with conventional dentures.

Discussion

In this cross-sectional descriptive study, oral status and self-reported oral health in community-living elderly were

Table 3 Overview of demographic characteristics, measures, health, oral health, and oral status for the total population and case complexity subgroups

	Case complexity				Differences between subgroups P-value
	Total N = 1026 100%	Complex care needs N = 217 21%	Frail N = 225 22%	Robust N = 584 57%	
Demographics					
Age (median, IQR)	80 (77–84)	81 (78–85) ^b	82 (79–87) ^c	80 (77–83)	≤0.001
Female, <i>n</i> (%)	602 (59)	151 (70) ^b	154 (68) ^c	297 (51)	≤0.001
Widowed/divorced/single, <i>n</i> (%)	463 (45)	115 (53) ^b	138 (61) ^c	210 (36)	≤0.001
In sheltered accommodation/home for the elderly, <i>n</i> (%)	103 (10)	39 (18) ^b	32 (14) ^c	32 (6)	≤0.001
Low education level, <i>n</i> (%) ^d	418 (41)	107 (49) ^b	106 (47) ^c	205 (35)	≤0.001
Low income, <i>n</i> (%) ^e	321 (31)	89 (41) ^b	85 (38) ^c	147 (25)	≤0.001
Measures, median (IQR)					
Frailty (GFI) ^f	4 (2–6)	7 (5–8) ^{a,b}	6 (5–7) ^c	2 (1–3)	≤0.001
Complexity of care needs (IM-E-SA) ^g	10 (6–15)	19 (17–22) ^{a,b}	12 (10–14) ^c	7 (5–10)	≤0.001
Activities of daily living (Katz-15) ^h	1 (0–3)	4 (2–6) ^{a,b}	2 (1–3) ^c	0 (0–1)	≤0.001
Quality of life (EQ-5D) ⁱ	0.81 (0.69–0.86)	0.65 (0.57–0.78) ^{a,b}	0.78 (0.68–0.81) ^c	0.84 (0.81–1.00)	≤0.001
General health					
Number of chronic conditions (median, IQR) ^j	2 (1–3)	4 (2–5) ^b	3 (1–4) ^c	1 (1–2)	≤0.001
Polypharmacy, <i>n</i> (%) ^k	583 (57)	168 (77) ^b	163 (72) ^c	252 (43)	
Oral health, <i>n</i> (%)					
Regular dentist visit (<2 years)	540 (53)	109 (50)	109 (48)	322 (55)	0.17
Chewing complaints (fair to poor)	118 (12)	43 (20) ^b	32 (14) ^c	43 (7)	≤0.001
Pain complaints (<2 years)	221 (22)	65 (30) ^{a,b}	47 (21)	109 (19)	0.002
Dry mouth during the day	78 (8)	36 (17) ^{a,b}	17 (8)	25 (4)	≤0.001
Dry mouth at night	201 (20)	66 (30) ^b	56 (25) ^c	79 (14)	≤0.001
Insecurity related to oral health	17 (2)	9 (4) ^b	3 (1)	5 (1)	0.01
Self-rated oral condition, median (IQR)	8 (7–8)	8 (6–8) ^{b,c}	8 (7–8)	8 (7–8)	0.02
Oral status					
Remaining teeth	401 (39)	76 (35) ^b	72 (32) ^c	253 (43)	0.002
Implants	104 (10)	17 (8) ^b	20 (9) ^c	67 (12)	0.002
Edentulous	521 (51)	124 (57) ^b	133 (59) ^c	264 (45)	0.002

^aStatistical difference ($P \leq 0.0167$) between elderly with complex care and frail elderly.

^bStatistical difference ($P \leq 0.0167$) between elderly with complex care and robust elderly.

^cStatistical difference ($P \leq 0.0167$) between frail and robust elderly.

^dLow: (less than) primary school or low vocational training.

^eLow: <€1450 per month.

^fGFI (Groningen Frailty Indicator).

^gIM-E-SA (INTERMED for the Elderly Self-assessment).

^hKatz extended.

ⁱEQ-5D (EuroQoL-5D).

^jPresence or absence of 18 chronic diseases (e.g., diabetes mellitus, pulmonary emphysema, osteoporosis, hearing disabilities).

^kMore than four medications.

assessed and differences between relevant subgroups of oral status and case complexity were determined. The results suggest that oral status and (self-reported) oral health point toward a positive impact of oral health on healthy aging as edentulous elderly when compared with elderly with remaining teeth reported more frailty, used more medicines, and had a lower QoL and worse ADL. These observations are comparable with those of Watanabe *et al* (2017) who concluded that frail older individuals had significantly poorer oral function than prefrail and robust individuals and De Visschere *et al* (2016) who stated that care dependency was influenced by oral health parameters. In line with this observation, elderly with implant-supported overdentures performed better too. It has to be mentioned, however, that social-economic status (SES) might in part underlie these observations as the SES in our study is overall higher in elderly with remaining teeth when compared with edentulous elderly as well

as that oral health in adults with a higher SES is generally better. As the SES of the non-responders is significantly lower than the responders, the results of our study may underscore the impact that a poorer oral health status may have on frailty, use of medicines, QoL, and ADL. This presumption is in line with the observations of Vettore *et al* (2016) in their 13-year cohort study. They showed that a poor social position and weak social ties are important predictors for tooth loss and self-rated poor oral health like in our study that elderly with complex care needs had a lower SES and were more often edentulous than robust elderly.

Oral health problems and oral pain

Frail elderly and particular elderly with complex care needs suffered the most from oral dryness, a condition that is very uncomfortable and is known to have a negative impact on oral health, QoL, and oral health-related QoL

Table 4 Overview of demographic characteristics, measures, health, and oral health for elderly with remaining teeth, implants, or prosthesis for each of the case complexity subgroups

	Remaining teeth (n = 401)			Implants (n = 104)			Edentulous (n = 521)		
	Complex care needs N = 76 19%	Frail N = 72 18%	Robust N = 253 63%	Complex care needs N = 17 16%	Frail N = 20 19%	Robust N = 67 64%	Complex care needs N = 124 24%	Frail N = 133 26%	Robust N = 264 50%
			P-value						P-value
Demographics									
Age, median (IQR)	81 (78–85) ^b	80 (78–84) ^c	79 (76–82)	81 (75–86)	83 (76–88)	80 (77–82)	81 (78–85) ^{ab}	83 (80–87) ^c	80 (78–83)
Female, n (%)	56 (74) ^b	49 (68) ^c	124 (49)	12 (71)	12 (60)	36 (54)	83 (67) ^b	93 (70) ^c	137 (52)
Widowed/divorced/single, n (%)	37 (49) ^b	38 (53) ^c	85 (34)	8 (47)	13 (65) ^c	17 (25)	70 (57) ^b	87 (65) ^c	108 (41)
In sheltered accommodation/ home for the elderly, n (%)	6 (8)	2 (3)	9 (4)	2 (12)	4 (20)	5 (8)	31 (25) ^b	26 (20) ^c	18 (7)
Low education level, n (%) ^d	29 (38) ^b	23 (32) ^c	51 (20)	9 (53)	7 (35)	28 (42)	69 (56)	76 (57) ^c	126 (48)
Low income, n (%) ^e	23 (30) ^b	15 (21)	40 (16)	9 (53) ^b	10 (50) ^c	15 (22)	57 (46) ^b	60 (45) ^c	92 (35)
Measures, median (IQR)									
Frailty (GFI) ^f	7 (5–8) ^{ab}	6 (5–7) ^c	2 (1–3)	7 (6–9) ^{ab}	5 (5–6) ^c	2 (1–3)	7 (5–9) ^{ab}	6 (5–7) ^c	2 (1–3)
Case complexity (IM-E-SA) ^g	18 (17–22) ^{ab}	12 (9–14) ^c	7 (4–10)	20 (17–24) ^{ab}	12 (9–13) ^c	8 (5–12)	19 (17–23) ^{ab}	12 (10–14) ^c	7 (5–10)
Activities of daily living (Katz-15) ^h	3 (2–5) ^{ab}	1 (0–2) ^c	0 (0–1)	4 (1–5) ^{ab}	1 (0–3)	0 (0–1)	4 (2–6) ^{ab}	2 (1–4) ^c	1 (0–2)
Quality of life (EQ-5D) ⁱ	0.65 (0.57–0.78) ^{ab}	0.78 (0.69–0.81) ^c	0.84 (0.81–1.00)	0.65 (0.57–0.78) ^{ab}	0.78 (0.74–0.81) ^c	0.84 (0.81–1.00)	0.65 (0.57–0.78) ^{ab}	0.77 (0.68–0.81) ^c	0.84 (0.81–1.00)
General health									
Number of chronic conditions (median, IQR) ^j	4 (2–5) ^{ab}	3 (1–4) ^c	1 (1–2)	4 (3–6) ^{ab}	3 (1–4) ^c	2 (1–3)	4 (2–5) ^{ab}	3 (1–4) ^c	1 (1–2)
Polypharma, n (%) ^k	54 (71) ^b	51 (71) ^c	95 (38)	12 (71)	15 (75) ^c	33 (49)	102 (82) ^b	97 (73) ^c	124 (47)
Oral health, n (%)									
Regular dentist visit (<2 years)	68 (90)	66 (92)	229 (91)	9 (53) ^b	11 (55) ^c	52 (78)	32 (26) ^b	32 (24) ^c	41 (16)
Chewing complaints (fair to poor)	21 (28) ^b	14 (19) ^c	19 (8)	1 (6)	4 (20)	6 (9)	21 (17) ^b	14 (11)	18 (7)
Pain complaints (<2 years)	32 (42) ^b	26 (36)	73 (29)	3 (18)	4 (20)	17 (25)	30 (24) ^{ab}	17 (13)	19 (7)
Dry mouth during the day	10 (13) ^b	3 (4)	12 (5)	2 (12)	1 (5)	5 (8)	24 (19) ^{ab}	13 (10) ^c	8 (3)
Dry mouth at night	21 (28) ^{ab}	10 (14)	38 (15)	9 (53) ^b	11 (55) ^c	10 (15)	36 (29) ^{ab}	35 (26) ^c	31 (12)
Insecurity related to oral status	5 (7) ^b	2 (3)	1 (0)	0 (0)	1 (5)	2 (3)	4 (3) ^b	0 (0)	2 (1)
Self-rated oral condition (median, IQR)	7 (6–8) ^b	7 (7–8) ^c	8 (7–8)	8 (7–9)	8 (7–8)	8 (8–9)	8 (6–8) ^b	8 (7–8) ^c	8 (8–9)

^aStatistical difference ($P \leq 0.0167$) between elderly with complex care and frail elderly.^bStatistical difference ($P \leq 0.0167$) between elderly with complex care and robust elderly.^cStatistical difference ($P \leq 0.0167$) between frail and robust elderly.^dLow: (less than) primary school or low vocational training.^eLow: <€1450 per month.^fGFI (Groningen Frailty Indicator).^gIE-SA (INTERMED for the Elderly Self-assessment).^hKatz extended.ⁱEQ-5D (EuroQoL-5D).^jPresence or absence of 18 chronic diseases (e.g., diabetes mellitus, pulmonary emphysema, osteoporosis, hearing disabilities).^kMore than four medications.

(Turner and Ship, 2007; Anil *et al*, 2016; Ouanounou, 2016). As frail elderly and elderly with complex care needs often use more medicines than robust elderly, these elderly also suffered most from oral dryness (Table 4) as the usage of multiple medicines (polypharmacy) and especially the combination of several medicines often cause oral dryness (Maher *et al*, 2014; Aliko *et al*, 2015; Thomson, 2015; Anil *et al*, 2016). In case of oral dryness, the risk of denture-related problems (e.g., sore spots or retention problems), oral infections (due to accumulation of debris), and rapidly progressing dental decay (due to lack of good functioning saliva) increases significantly (Turner and Ship, 2007; Aliko *et al*, 2015; Anil *et al*, 2016). Thus, the side effects of polypharmacy may, at least in part, explain the observation that elderly with complex care needs and remaining teeth reported pain and oral health problems as their oral health is more at risk.

As mentioned above, lower SES seems to be related to general health and oral health (Vettore *et al*, 2016), so participants with a lower SES probably had a higher risk of becoming frail and/or ending up with oral health problems. This points toward the need to urge elderly to continue to visit their dentists and to maintain an adequate level of oral care, either by themselves or, when they are not able to self-maintain their oral health, by caregivers (Gerritsen *et al*, 2014). Unfortunately, this need to safeguard a proper level of oral care was not common in our community-living participants, especially in edentulous elderly of whom only 20% visited the dentist, oral hygienist, or dental technician the last two years. Not visiting the dentist by many elderly was also reported by Dolan *et al* (2005). The latter authors noted that many elderly are not regular users of dental services and that they may experience significant barriers to receive necessary dental care, although maintaining oral health is essential to an older adult's general health and well-being. Furthermore, in the study of Donaldson *et al* (2008) who reported on the effects of social class and dental attendance on oral health, it was stated that the number of sound teeth in adults was partially explained by dental attendance, which in turn was determined by the effect of SES on barriers to regular dental attendance. Donaldson *et al* (2008) stated that overcoming barriers to regular dental attendance for low socioeconomic groups may reduce oral health inequalities.

Dental implants

In this study, edentulous elderly with implant-supported overdentures generally performed better than edentulous patients with conventional dentures. This better performance is not limited to their oral health status, but is also reflected in less frailty and higher QoL. This observation is in line with the many studies showing that patients provided with implant-supported overdentures in general perform significantly better than edentulous patients with conventional dentures with regard to their oral function and oral health-related QoL (Stellingsma *et al*, 2005; Pan *et al*, 2014). Our study indicates that general health status and general QoL are also better in these patients which is also in line with our previous observation that care-dependent community-living elderly with remaining teeth reported less frailty, better general health, and better physical function than edentulous

elderly with conventional prostheses (A.R. Hoeksema, L.L. Peters, G.M. Raghoobar, H.J.A. Meijer, A. Vissink, A. Visser, 2016, unpublished data).

Limitations of the study

Strengths of this study are the large and varied sample of community-living older persons who participated and the broad range of variables that were assessed with validated self-assessment tools. However, limitations apply as well. Limitations of the study include the hazard of incorporation bias, the use of self-assessments to rate case complexity and oral health, and studying just one time point instead of following up the participants. With regard to the hazard of incorporation bias, there are indeed differences between respondents and non-respondents participating in the assessment of the oral status as in general non-respondents were older and less healthy compared to respondents. Presumably, oral health might be even worse in non-responders. This issue has been discussed in detail before. Second, self-assessments were applied. However, we feel that such an approach, as mentioned, is a strength of this study as we used validated self-assessment questionnaires (GFI, INTERMED, IM-E-SA, modified Katz ADL, EQ-5D) that were specifically developed for such assessments. Also, the oral health questionnaire was specifically designed for self-assessment and tested for application in older persons as described in the materials and methods. Third, we did not follow-up oral health and oral status. So, like for case complexity, changes may occur with time. However, when taking into account the large number of participants, we feel that time-dependent changes will have a negligible effect on the study results. Our analysis just reflects the connection between case complexity and oral health at a group level not at the individual level.

Conclusion

Elderly with complex care needs experience significantly more oral health problems and are more often edentulous than robust elderly. Moreover, elderly with remaining teeth and elderly with implant-supported overdentures reported less frailty and better QoL. Care givers should be aware of this phenomenon and should safeguard adequate oral health maintenance in case the patients are unable to maintain their desired level of oral independently.

Ethical aspects

The institutional review board of our institution provided a waiver (file number METc2011.108), as this observational study was not an experimental study with test subjects as defined in the Medical Research Involving Human Subjects Act.

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Declaration of conflict of interests

The authors declare no conflict of interest.

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Author contributions

A.R. Hoeksema contributed to data collection, concept/design, statistics, data analysis/interpretation, drafting article, final approval, and accountable for all aspects of the work. S.L.W. Spooenberg MSc contributed to data collection, concept/design, critical revision of article, and final approval. Dr. L.L. Peters contributed to concept/design, statistics, data analysis/interpretation, drafting the article, and final approval. Prof. H.J.A. Meijer, Prof. G.M. Raghoobar and Dr. K. Wynia contributed to concept/design, critical revision of article, and final approval. Prof. A. Vissink contributed to concept/design, data analysis/interpretation, drafting the article, critical revision of article, and final approval. Dr. A. Visser contributed to concept/design, data analysis/interpretation, drafting the article, final approval, and accountable for all aspects of the work.

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