

# **Oral health, taste and nutrition in hospitalized older people**

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To my mother Mia Hammer Solemdal



“ De gustibus non est disputandum”

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*A good statement may be written in many ways, but not in all ways simultaneously!*

*Don't read to swallow, but choose what to follow!*

*The best must never become the enemy of the good!*

Kirsten Solemdal

August 2012



# Abbreviations

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BCM	Body cell mass
BIS	Bio-impedance spectroscopy
BMI	Body mass index (weight / height <sup>2</sup> )
CIRS	Cumulative Illness Rating Scale
DT	Decayed teeth
HGS	Hand grip strength
MNA-SF	Mini nutritional assessment-short form
MPS	Mucosal-Plaque Score
MS	Mucosal Score
PS	Plaque Score
TTS	Total taste score

# List of papers

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**I** Solemdal K, Sandvik L, Willumsen T, Mowe M. Taste ability in hospitalised older people compared with healthy, age-matched controls. *Gerodontology* 2012; doi: 10.1111/ger. 12001

**II** Solemdal K, Sandvik L, Willumsen T, Mowe M, Hummel T. The Impact of Oral health on Taste Ability in Acutely Hospitalized Elderly. *PloS One*. 2012; 7(5): e36557. Epub 2012 May 3

**III** Solemdal K, Sandvik L, Møinichen-Berstad C, Skog K, Willumsen T, Mowe M. Association between oral health and body cell mass in hospitalised elderly. *Gerodontology*. 2012 Jun; 29(2): e1038-1044

**IV** Solemdal K, Møinichen-Berstad C, Mowe M, Hummel T, Sandvik L. Taste impairment, a predictor of mortality in acutely hospitalized older people. Submitted.

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# Introduction

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## 1.1. Oral health

“Oral health is an essential element for general health and quality of life throughout an individual’s life course”, as written in a WHO report from 2006 about oral health in elderly. Good oral health is a state of being free from oral diseases, infections and pain that restricts normal function and quality of life. The world’s population is ageing. National societies will face an economical challenge in treating oral and general diseases in older individuals being able to live longer despite high degree of morbidity.

Oral health among older people in Norway and Western societies has improved in recent years (1-3). During the last decades, good oral health has become a high priority for most people, and the proportion of elder adults keeping their own teeth even in advancing years is increasing (3). Most people in Norway have a tradition of seeing their dentist regularly (4). Especially in urban districts, where the number of patients per dentist is low, and where the transport facilities are good, we observe a high and increasing number of own teeth in older people (5). However, when the elderly become frail and burdened with diseases, this pattern changes. Frailty has been described as a condition where the capacity to withstand environmental stress is reduced (6;7). Frailty is often accompanied with problems performing daily routines including maintenance of proper oral hygiene. This may be due to muscle weakness, poor vision, nutrient deficiency, and dementia (8). In spite of improved oral health among healthy elderly, it is common to find elderly in nursing homes with heavy plaque accumulation, severe gingivitis, high caries activity and dry mouth (3;9-11). Often the teeth are so deteriorated that repair is not possible. The only solution may be extractions and prosthetic

replacement. Unfortunately, in many cases the elderly are so weak and frail that treatment and replacement of lost teeth are no longer possible.

Oral health and general health are closely related and may influence each other (12;13). It has been reported in review articles that oral diseases and chronic systemic diseases seem to have several risk factors in common (14;15). Oral infections and atherosclerosis appear to be associated (16;17). Diabetes is a known risk factor for developing periodontitis, and treating periodontitis may improve the metabolic glucose balance in diabetic patients (18). Further, oral micro-organisms and candida species have been aspirated and found to cause pneumonia in immune compromised older patients (19;20).

Oral health and nutrition are also associated (21;22). Anderson et al. (23) found that elderly with poor oral health were undernourished. Marshal et al. (24) concluded that persons with well-functioning dentures and functional natural dentition ate more healthy food compared to those with poor dentition. People with dentures consume more fat and sugar-containing food and less fibre compared to dentate individuals (25;26). Elderly with more than 20 functional teeth are more likely to have normal body mass index (BMI) than those with fewer teeth (27). However, most of these studies are cross-sectional, and it is therefore impossible to conclude whether oral health has impact on nutritional status or vice versa. Improvement of nutritional status due to rehabilitation of dentition status has been difficult to document (28). Intervention studies are few and mostly concerned with implant rehabilitation of oral function. Other factors such as selection of food, dietary habits, taste ability, and appetite may also be of importance for nutritional status in frail and diseased elderly.

## **1.2. Nutrition**

Under-nutrition is increasing with age and is affected by endocrine factors involved in decreased appetite control (29). Diseased elderly are especially vulnerable to nutritional deficiency, and many elderly are under-nourished and lack essential nutrients when admitted to hospital (30-32). Medications prescribed for common diseases in elderly may induce nausea, loss of appetite and taste disorders leading to weight loss and wasting (33). This situation is often aggravated during hospital stay (34). Chronic diseases such as heart disease and obstructive pulmonary disease are frequent among hospitalized elderly (35) and cause increased energy use and expenditure. An acute disease may lead to severe depletion of fat and protein stores (36). This loss should be restored to make the patient able to fight disease and regain a more healthy constitution. Reduced caloric intake, weight loss and nutrient deficiency may have negative impact on general health as well as oral health.

Nutritional status in elderly may be measured with a wide range of methods. Among these are different screening tools, dietary assessments, weight measurements, anthropometric assessments, and various body composition methods, as well as albumin and vitamin analysis (37-39).

Assessing body composition with bio-impedance spectroscopy (BIS) has been used since 1990 (40). The methods and mathematical calculations involved in BIS have improved continuously (40). The technique is non-invasive, easy to use and fast (approximately 10 minutes) (41). Thus, the method is appropriate in a clinical setting. BIS uses physiological modeling and calculations to determine the electrical resistance of extra-cellular and intra-cellular fluid and to calculate the volumes of these compartments (40). The determination of the fluid volumes are based on the assumption that the electric current at low frequencies passes easily through the extra-cellular fluid, whereas high



frequencies are needed to penetrate the cell membrane. The fluid inside the cells is related to the body cell mass.

Body cell mass (BCM) is almost equivalent to the amount of intra-cellular fluid of metabolically active cells (primarily muscle cells) (42). BCM may be estimated with BIS as in our study or by counting intra-cellular radioactive potassium ions. BCM comprises all the reproductive cells of the body participating in the energy production. These cells use oxygen to burn glucose, producing carbon dioxide and water as the end products (43). The concentration of intra-cellular potassium is about 150mEq. pr. kilogram cell water and is similar in all cells of the body. This is in contrast to a very low concentration (4.5mEq. pr. liter) in the extra-cellular fluid. The total amount of potassium in the body is a linear function of BCM. Low BCM is associated with wasting and under-nutrition (44).

### **1.3. Taste**

People have since ancient times been interested in the sense of taste. To our knowledge, the Greek philosopher Aristotle was one of the first to discuss taste in his thesis "On the soul". As early as 1888 an interesting taste testing experiment was published in Science (45), where the detection thresholds for the four basic taste qualities were examined. They reported that the detection threshold for bitter taste was 1/2000 of the taste threshold of sugar. They also concluded that women had better taste perception than men. This finding is still agreed upon even to-day.

Proper taste function is important for appetite and sufficient food intake (46;47). In most animal species the sense of taste acts partly as a protection from poison and in a positive selection of nutrients to sustain life. From birth human beings have a positive response to sweet and a dislike for bitter (48). In

our modern affluent society there is a strong focus on the pleasures of eating. Magazines are filled with recipes, all kinds of food and wines, describing delicious and tasteful meals. The meal is often the daily event for the frail elderly, being otherwise deprived of most of the pleasures that younger people take for granted. However, to enjoy a meal, good taste perception is essential. The elderly's appetite is often questioned when their caloric intake is low, whereas their taste perception is often neglected. Although taste impairment is shown to be associated with reduced dietary intake, weight loss and low nutritional status (46;49;50), investigations of taste perception in elderly with eating problems and under-nutrition are limited.

***Taste physiology, transduction and innervation:*** The tongue is the main taste organ and has three different papillae containing taste buds. These papillae are papilla Foliatae, Fungiforme, and Circumvallatae. Each papilla contains from a few to more than thousand taste buds. Taste buds are also distributed in the palate and in the upper part of the esophagus, larynx and epiglottis (51).

The taste bud consists of several bipolar taste cells of epithelial origin (52). These cells have specific taste receptors, and the cells have a turnover of approximately 10 days (48). Sweet, sour, salty and bitter were for a long time accepted as the basic taste qualities. Umami was discovered as early as in 1909 (53), but has only in recent years been recognized as the fifth taste quality (54;55). Further, receptors for fatty acids have also been discovered (56;57). A single taste bud seems to have receptors for all the taste qualities, and a single taste cell has receptors for more than one taste quality (48;58).

Chemosensory perception depends on membrane protein receptors which have been identified for all of the taste qualities (59). The G protein-coupled receptors mediate transduction of sweet, bitter and umami taste stimuli, whereas sour and salty stimuli appear to be mediated through ion channels

(59;60). The activation of the taste receptors elicits the signal transduction cascades within the cells, leading to a depolarization of the cell membrane, thus transferring the stimuli along the nerve fibers.

The cranial nerves involved in the response to taste stimuli are the 7th (facialis), the 9th (glosso pharyngeal) and the 10th (vagus) (61). The chorda tympani branch of the facialis nerve innervates the anterior part of the tongue, and another branch of Facialis, the great Petrosal superficial nerve innervates the taste buds in the palate. The Glossopharyngeal nerve conveys taste impulses from the posterior part of the tongue, and the Vagus nerve transfers taste stimuli from the pharynx, larynx and epiglottis. The signals from these nerves go to the solitary tract where they make synapses with second order neurons, crossing the midline and make synapses in the thalamus. From there the impulses travel to the taste centre in the primary gustatory cortex (61).

***Taste evaluation:*** Taste impairment is classified as ageusia (no taste perception), hypogeusia (reduced taste perception), and dysgeusia (distorted taste perception). Different methods such as chemogustometry and electrogustometry have been used to assess taste perception (62;63). Liquid solutions of increasing concentrations, taste tablets and taste strips are frequently used chemogustometry methods (64-66). With these methods it is possible to assess taste threshold, ability to discriminate between taste qualities and also to investigate taste ability at different areas of the tongue (67;68).

***Factors associated with diminished taste perception:*** The perception of taste is influenced by many factors. Women have better taste perception than men, with variations across different taste qualities (64;69;70). Further, diminished taste perception in older people compared to young people has for long been accepted (67;71-73). However, the various taste qualities are not uniformly affected by age. The average taste threshold for sweet is shown to be 3 times

higher in elderly people than in young people, 12 times higher for sodium salts, 4 times higher for sour and 7 times higher for bitter (61). Whether this is due to reduced number of taste buds, the size of the papillae or other mechanisms is not yet clarified (74-76).

Different drugs are reported to cause taste disturbances (77). A common remedy used in dentistry and widely recommended to control plaque in frail elderly, is mouth-rinse with chlorhexidine. This plaque inhibitor has been shown to interact with taste and is reported to impair salty taste and bitter taste qualities (78;79). Furthermore, some drugs are xerogenic, and since saliva is essential for bringing taste stimuli to the taste buds, hypo-salivation may result in diminished taste perception (80).

Burning mouth has also been linked to taste loss. However, symptoms from burning mouth, sore mouth from hypo-salivation or vitamin deficiency may be difficult to distinguish from each other, indicating that observed associations between burning mouth and taste loss may be influenced by the other factors as well (81). Moreover, various oral health factors such as poor oral hygiene, wearing dentures, and tongue coating have been associated with taste loss (82-87). Several causes for decline in taste sensitivity in denture wearers have been postulated. Some have suggested reduced tactility of the oral mucosa and also possible taste interference due to the acrylic denture base.(88) Retronasal olfactory reduction by the denture has also been suggested (89). A more likely explanation is that dentures covering the palatal mucosa, also cover taste buds in that area, and thus prevent taste stimuli to reach the taste receptors.

Is taste loss a problem among elderly? In a study by Bergdahl et al. (90) the prevalence of perceived taste disturbance was 5 % in women between 60 and 69 years of age. However, in a Japanese study, 25% reported dissatisfaction with taste ability(83). In both studies dissatisfaction with taste perception was

related to various factors such as dry mouth, wearing dentures, drug use, illness and depression. However, few seek treatment for taste loss. It is possible that older people adapt to diminished taste gradually, and compensate for reduced taste often by adding more salt to the food.

#### **1.4. Intentions**

Ageing, diseases and medications are associated with taste loss (77;91). Thus, we raised the question whether acutely hospitalized elderly may have impaired taste compared to healthy elderly. This topic has not been thoroughly investigated, and comparisons with healthy elderly have not been performed. Further, it has been mentioned in the literature that oral micro-organisms and inflammation in the oral cavity may lead to taste loss, but referrals to such studies are lacking.

The consequences of poor oral health and reduced taste ability in older people and in acutely hospitalized older people in particular, may result in lack of appetite, reduced caloric intake and under-nutrition. Further, nutrition, oral health and diseases are associated (21). The associations between oral health, taste ability, nutrition, morbidity, and mortality are therefore the focus of this thesis.

## **2. Aims of the study**

The overall aim of the study was to investigate associations between oral health, taste ability, nutrition, morbidity and mortality in older people being hospitalized due to acute disease.

- To investigate to what extent taste ability and different taste qualities are impaired in acutely hospitalized older people compared to healthy, age-matched controls. (Paper I)
- To examine whether oral health variables are associated with taste ability and specific taste qualities in acutely hospitalized elderly. (Paper II)
- To examine possible association between oral health and body cell mass (BCM) measured with bio-impedance spectroscopy. (Paper III)
- To examine possible associations between taste ability, morbidity and mortality in acutely hospitalized older people. (Paper IV)

### **3. Material**

#### **3.1. Study population**

##### ***3.1.1. Hospitalized elderly (paper I, II, III IV)***

All patients hospitalized for acute medical problems at Oslo University Hospital, Aker from primo November 2009 to October 2010, were consecutively asked to participate in the study, if they fulfilled the inclusion criteria.

Inclusion criteria were acutely hospitalized elderly  $\geq 70$  years old living at home prior to hospital admission and with adequate cognitive function. The patients were evaluated for participation at least 48 hours after hospital admission by two experienced physicians in geriatric medicine. The physicians were trained to evaluate patients in clinical studies with similar guidelines and criteria. Evaluation of cognitive function was based on thorough interviews with the patients.

Exclusion criteria: Patients with reduced cognitive function, patients coming from nursing homes and patients with terminal disease were not eligible for participation.

##### ***3.1.2. The control group (paper I)***

The control group comprised 63 older individuals at least 70 years old, without cognitive impairment, living in their own homes and healthy according to their own judgment. These individuals participated as controls in a former study at the same hospital. Our analyses are based on these data, collected 4 years earlier by the same dentist. A randomized list of age-matched inhabitants from the same geographical area as the hospitalized group was provided by the

computer company IBM from a list of inhabitants, delivered by the Norwegian Population Register.

### **3.2. Response-non response**

***Hospitalized elderly:*** 234 acutely hospitalized elderly fulfilled the inclusion criteria and were invited to participate in the study. Thirty-four patients did not want to participate due to reasons such as: “I have my own dentist, I just had a dental check-up, I don’t like to participate in research studies, I am too tired, I feel too sick, I am not interested”. Thus, 200 patients were included in the study.

Taste assessments (paper I, II, IV) were performed after the oral examinations. Hospital logistics and routines resulted in 26 “drop outs”. Reasons for “drop out” were: having visitors, busy with laboratory tests and medical examinations, eating, discharged from the hospital, and moved to another ward. Thus, 174 hospitalized elderly participated in taste testing.

Bio impedance spectroscopy (BIS) measurements (paper III) were performed the same day as the other registrations, but some of the participants were not available for assessment due to other priorities such as medical examinations, x-rays, laboratory tests etc. Five patients were excluded due to pacemakers. However, the main reason for “drop out” was delivery problems by the sales company. Thus, 138 patients were included with BIS assessments.

***Controls:*** A letter of invitation was sent to 500 potential control subjects. Ninety-eight persons responded to the invitation. Sixty-three individuals fulfilled the inclusion criteria and were included in the study (paper I). The participation rate was 20 %. Most of the refusals were due to lack of interest, other priorities, feeling tired and long distance to the hospital. Recruiting



individuals to studies is difficult (92). Although the participation rate in our study seems to be low, it is in accordance with other studies (93).

## 4. Methods

The patients participating in this cross-sectional study were old, frail and severely ill. It was therefore mandatory to select methods that were not cumbersome and exhausting for these patients.

The oral registrations and taste testing were performed by one dentist with long experience in oral health registrations and calibration studies of similar study populations. Examinations of the hospitalized subjects were performed at the bedside. The control subjects were invited to the hospital for examination. Oral inspection was carried out with 2 mirrors, a dental probe, and a head lamp.

### 4.1. Dental status and oral hygiene assessments (paper II and III)

**Dental status:** was recorded in accordance with WHO's criteria (94). Number of functional teeth was recorded. Remaining roots  $\leq 2\text{mm}$  were registered as non-functional teeth. A tooth was registered as decayed if there was loss of tooth substance, and the surface was soft on probing. No distinction was made between root caries and coronal caries in this study. A posterior maxillary functional tooth with opposing contact of a mandibular functional tooth was recorded as one posterior occluding tooth pair. Fixed prosthetics were incorporated in occluding tooth pairs. 3<sup>rd</sup> molars were omitted unless 1<sup>st</sup> or 2<sup>nd</sup> molar was missing. The numbers of occluding tooth pairs were maximum 4 in the each lateral segment.

**Oral hygiene:** We used the Mucosal-Plaque Score (MPS) to evaluate oral hygiene (95) (see paper II for details). A criteria catalogue was presented for visual calibration (96).

#### **4.2. Dry mouth assessments (paper II)**

**Stimulated saliva collection:** Assessment of stimulated whole saliva was done with the “chewing and spitting” method (97). The method is described in detail in paper II. The recommended chewing time is 5 minutes, but due to the health condition of the patients we let the patients chew on the paraffin wax for only 3 minutes. Some of the patients had severe problems with chewing, owing to either dry mouth or poorly fitted dentures. Thus, stimulated saliva was collected in 158 patients.

**Mirror slide test:** The back of a dental mirror was moved across the buccal mucosa as soon as the patient had opened the mouth and before any other registrations were done. If the mirror encountered friction, this was noted (10;98).

**Dry tongue assessment:** was based on visual inspection. “Dry tongue” was registered if the tongue was devoid of moisture.

#### **4.3. Bacterial growth assessments (paper II).**

The amount of *Streptococcus Mutans* and *Lactobacilli* in stimulated whole saliva were assessed with the CRT<sup>®</sup> Bacteria Kit (Ivoclar Vivadent AG, FL-9494 Schaan, Lichtenstein) (99). This method is described in detail in paper II. Due to the problems with chewing paraffin wax, sufficient saliva for bacterial growth assessment was obtained in only 153 patients.

#### **4.4. Tongue changes (paper II)**

*Coated tongue* was defined as a thick layer of plaque on the anterior part of the tongue to be scraped off (100;101). The tiny layer of white coating from normal shedding of filiform papillae was not recorded as tongue coating.

*Tongue atrophy*: The tongue was classified as atrophic if at least 50 % of the tongue was devoid of papillae. The assessment was based on visual observation and clinical experience. Making mistakes in estimation of tongue atrophy is possible with this method. However, to minimize diagnostic variations from day to day and variations in registrations between patients, oral photos were taken. In this way the clinical diagnosis could be verified. A previous study at the same ward, using identical criteria, demonstrated a similar prevalence of atrophic tongue in acutely hospitalized elderly (102).

#### **4.5. Taste assessments (paper I, II, IV)**

Whole mouth gustatory function was assessed with the “Taste strips” method (66), (paper I, II, IV). The taste strips are made of filter paper and saturated with 4 different concentrations of sweet, sour, salty and bitter. The following concentrations are used: *Sweet*: 0.4, 0.2, 0.1, 0.05g/ml sucrose, *Sour*: 0.3, 0.165, 0.09, 0.05g/ml citric acid; *salty*: 0.25, 0.1, 0.04, 0.016g/ml sodium chloride; *bitter*: 0.006, 0.0024, 0.0009, 0.0004g/ml quinine-HCl. The strips were given to the participants in a random, but fixed pattern, starting with the weakest and ending with the strongest. Both participant and examiner were blinded as to which taste concentration or quality being tested. The individual taste strip was placed in the middle of the anterior part of the tongue. The participant was allowed to close the mouth and suck on the taste strip for maximum twenty seconds. A poster with the names *sweet, sour, salty, bitter,*

was placed on the table in front of the subject, who had to decide on one of the names without delay. Before starting and in between every tastant, the participant had to rinse with water to get rid of the former tastant. Not until the participant confirmed that the former tastant had disappeared, was another taste strip placed on the tongue. Correct answer was given score 1 and incorrect answer was given score 0. Maximum total taste score (TTS) was 16. Impaired taste (hypogeusia) in our study was defined as total taste score less than 8. Landis et al. (2009) (103), using the “taste strip” method, selected the 10<sup>th</sup> percentile (TTS below 9) to separate hypogeusic subjects from normogeusic subjects in a healthy population (mean age 44 years). Due to the high age of the participants in our study and the knowledge that taste perception is reduced with increasing age, we deliberately chose a lower cut-off value (TTS less than 8) to indicate hypogeusia.

#### **4.6. Nutritional assessments (paper III)**

***Hand grip strength:*** The physicians measured hand grip strength (HGS) with North Coast Hydraulic Dynamometer (North Coast <sup>TM</sup> Hydraulic Hand Dynamometer NC70142, Santa Rosa, Ca.,USA), with the patient sitting on the bed in an upright position (104;105). The arm was flexed in an angle of 90 degrees and kept close to the trunk. The patients were instructed to squeeze the handle 3 times with the non-dominant hand as forceful as possible. Three measurements in kg were registered, and the mean was calculated.

***MNA - short form:*** Mini Nutritional assessment- Short form (MNA-SF) is a short form of the 18-item Mini Nutritional Assessment questionnaire. Both have been properly validated (106;107). MNA-SF consists of 6 questions, comprising information about body mass index (BMI), weight change, loss of appetite, acute stress due to diseases, and depression. The scores are

summarized and maximum score is 13. MNA-SF score < 8 indicates poor nutritional status.

***Assessment of Body Cell Mass (BCM):*** BCM was measured with a portable "whole-body" bioimpedance spectroscopy device (Body composition monitor- ©Fresenius Medical care, Bad Homburg, Germany) according to the manufacturer's guidelines. The machine uses 50 frequencies from 5 kHz to 1000 kHz. Electrodes were attached to one foot and one hand on the same side of the body with the patient in a relaxed, supine position. The patients' weight and height were measured in advance, and BMI (defined as weight / height<sup>2</sup>) was calculated by the bio-impedance computer. The bio-impedance method for assessing BCM with Body Composition Monitor by Fresenius has been validated with magnetic resonance tomography and total body potassium counting (108). Counting total body potassium is the most recognized method for estimating BCM (43;109). However, this method is much more time consuming and more complicated than bio-impedance spectroscopy measurements, and would be too difficult and cumbersome to use in our study on sick elderly.

#### **4.7. Co-morbidity assessments (paper III and IV)**

Cumulative Illness Rating Scale (CIRS) was used to assess medical burden and severity of diseases. It was developed in 1968 by Linn et al. (110). Miller et al. (111) modified the index to be more suitable for reflecting morbidity in elderly and renamed the index CIRS-G (112). The guidelines for the scoring system were later updated and the usefulness tested on hospitalized elderly by Salvi et al. (113). This version has been used in our study. The index describes medical burden and co-morbidity in elderly. CIRS comprises 14 different organ systems, rating severity of illness from 0 through 4. The different levels are as follows: 0 = "no problem affecting that system or past problem without

clinical relevance”, 1 = “current mild problem or past significant problem”, 2 = “moderate disability or morbidity and / or requires first line therapy”, 3 = “severe / or constant and significantly disability and / or hard to control chronic problems (complex therapeutic regimen)” and 4 = “extremely severe problem and / or immediate treatment required and / or organ failure and / or severe functional impairment”. The scores are summarized and the highest possible CIRS score is 56.

#### **4.8. Statistics**

The statistical package PASW Statistics, version 18.0 (SPSS Inc. Chicago, IL, USA) was applied for statistical analysis. Quality assurance of data transfer from paper records was carried out by monitoring every 10th record. Significance level was set to 5%.

When comparing continuous variables in two groups, a two-sided independent samples t-test was used as long as the distribution of the variables was sufficiently close to normal distribution. If this was not the case, a two-sided Mann-Whitney test was used. Chi-square test was used when comparing dichotomous variables. Spearman’s rho was applied to test associations between two continuous variables. Multivariate linear regression analysis was used to adjust for confounders. When studying the relation between taste ability and mortality, Cox regression analysis was used. The assumption underlying these regression methods were checked and found to be adequately met.

#### **4.9. Ethical considerations**

The study was approved by the Norwegian National Committee for Medical and Health Research Ethics. The participants were given both written and verbal information about the procedures of the study. All gave written informed consent.



## 5. Summary of results

**Paper I. Taste ability in hospitalised older people compared with healthy, age-matched controls.** This paper elucidates the differences in taste ability between acutely hospitalized elderly and healthy controls. Mean age was similar in the study groups. No significant differences were found with regard to smoking and gender. The hospitalized group used significantly more drugs than the control group. The prevalence of hypogeusia and perceived taste loss in the hospitalized group were 33% and 24%, respectively, which were significantly higher than in the control group (18% and 6%, respectively). Total taste score (TTS), sour and bitter sum scores were significantly lower in the hospitalized group compared with the control group. Sweet and salty sum scores were similar. Both groups had severe problems in the identification of all four concentrations of salty and sour taste qualities. The ability to identify all four concentrations of bitter was moderate in the control group, showing a prevalence of 27% with correct identifications, and was significantly better compared with the hospitalized group (12%). The four sweet concentrations were identified by nearly 50% of the controls and 43 % of the hospitalized elderly, indicating that sweet was the best preserved taste quality. Further, when the taste scores were analyzed separately for men and women, we showed that the hospitalized females had significantly reduced sour and bitter sum scores compared with the females in the control group. Sour sum score was significantly reduced in hospitalized men compared with men in the control group. When all participants were analyzed, TTS was shown to be significantly lower in men compared to women.

**Paper II. The impact of oral health on taste ability in acutely hospitalized elderly.** In this paper we studied the association between taste ability and various oral health variables in acutely hospitalized elderly. The main oral

health parameters were decayed teeth, growth of oral bacteria (Lactobacilli and Streptococcus Mutans), oral hygiene (MPS), dry mouth and tongue changes. We used the “mirror test”, “dry tongue” and stimulated whole saliva flow to assess dry mouth. The oral health variables were tested against TTS and the individual taste qualities; sweet, sour, salty and bitter. Decayed teeth were present in 41% of the dentate participants. The proportion of patients with unacceptable oral hygiene ( $MPS \geq 5$ ) was 37%. The prevalence of Lactobacilli  $\geq 10^5$  and Streptococcus Mutans  $\geq 10^5$  were 84% and 80%, respectively. Dry tongue and friction with the dental mirror were observed in 13 % and 15 % of the patients, and hyposalivation (stimulated whole saliva  $\leq 0.6$  g /ml) in 44%. TTS was significantly reduced in patients with decayed teeth, un-acceptable /poor oral hygiene, Streptococcus Mutans  $\geq 10^5$  and Lactobacilli  $\geq 10^5$ . Further, reduced TTS, sweet sum score and salty sum score were significantly associated with dry tongue and friction with the mirror test. In addition, low salty score was associated with reduced saliva flow. Sour sum score was significantly reduced in patients with Lactobacilli  $\geq 10^5$  and high plaque score. We also found that patients with atrophic tongue had significantly lower score for sweet.

**Paper III. Association between oral health and body cell mass in hospitalised elderly.** In paper III we studied the association between various oral health variables and BCM. BCM, comprising all the metabolically active cells in the body, was expressed in kilograms and divided into quartiles when analyzed. Mean BCM ranged from 8.7kg in quartile 1 to 21.4 kg in quartile 4. Mean age was similar in the four quartiles. The prevalence of men increased significantly from 18% in quartile 1 to 58% in quartile 4. Patients with the lowest BCM (quartile 1) used significantly more medications than patients with the highest BCM (quartile 4). Patients in BCM quartile 1 had significantly lower MNA-SF score compared with patients in BCM quartile 4.

Hand grip strength (HGS) was significantly and positively associated with BCM. There was no significant difference in CIRS score (comorbidity index) or BMI between the quartiles. The significant association between BCM and dentition status as well as oral hygiene was our main finding. Mean number of teeth was 12.2 in BCM quartile 1 and increased to 19.1 teeth in BCM quartile 4, while mean number of posterior occluding tooth pairs increased from 1.9 to 3.8, respectively. Reduced oral hygiene assessed with MPS was significantly associated with low BCM. The mean MPS decreased from 4.9 in BCM quartile 1 to 3.8 in BCM quartile 4. None of the dentition status variables were significantly associated with any of the other nutritional indicators (BMI, HGS or MNA-SF). The three oral health variables, being significantly associated with BCM, remained significant after adjusting for confounders (age, gender, smoking, education level, BMI, HGS, CIRS, MNA-SF and drugs). These findings demonstrated that patients with reduced BCM had fewer teeth, fewer occluding tooth pairs and poor oral hygiene compared to patients with high BCM.

**Paper IV. Impaired taste, a predictor of mortality in acutely hospitalized elderly.** In paper IV we have investigated the association between impaired taste and mortality in acutely hospitalized elderly during a 12 months observation period. Fifty-six patients died during the observation period. Total taste score (TTS) was divided into quartiles. Mortality in TTS quartile 1 was compared with mortality in the other three quartiles. When comparing TTS quartile 1 with TTS quartile 4, mortality was reduced by 68% (hazard ratio 0.32, 95% CI 0.14-0.71,  $p = 0.005$ ) after adjusting for age, gender, education level, smoking status, and co-morbidity (CIRS). During the first year 30 % of the patients in TTS quartile 1 died, as opposed to 9 % in TTS quartile 4. Thus, impaired taste appears to be a strong predictor of mortality in acutely hospitalized elderly.

## **6. Discussion**

In this thesis we have examined associations between oral health, taste ability, nutrition, morbidity and mortality. We have shown that hospitalized elderly had impaired taste ability compared with age-matched healthy controls, and that sour and bitter taste qualities were particularly affected (paper I). Furthermore, taste ability measured as total taste score (TTS) was reduced in hospitalized elderly with decayed teeth, high growth of oral bacteria, poor oral hygiene and dry mouth. Interestingly, various taste qualities were affected differently, in that sweet and salty taste qualities were particularly affected in patients with dry mouth, whereas sour taste quality was impaired in patients with plaque accumulation and high growth of Lactobacilli (paper II).

Hospitalized elderly with reduced dentition status and poor oral hygiene had reduced BCM measured with bio-impedance spectroscopy. No such association was demonstrated between dentition status and the other nutritional indicators (paper III).

Surprisingly, reduced taste ability was associated with a significant increase in mortality in the hospitalized elderly (paper IV), even after adjusting for confounders such as age, gender, smoking status, education level, and diseaseburden (CIRS). As far as we know this finding represents entirely new information.

### **6.1. Oral health**

Assessments of dentition status and oral hygiene were essential in our study. A significantly larger proportion of the hospitalized elderly were without any teeth of their own compared with the healthy controls (18% vs. 6%,  $p = 0.020$ ),

unpublished data). Tooth loss in elderly is a result of previous experience of dental infections and periodontitis, and is associated with socioeconomic status (114).

In our study oral hygiene was measured with the MPS index (95). This index was chosen because it is easy to use and requires minimal cooperation from the patients. The 4 graded scores for mucosal inflammation and plaque accumulation give reliable information about the oral hygiene status of the patients when scored by an experienced clinician. An advantage is that plaques on dentures as well as the presence of ulcers, decubitus and denture stomatitis, are incorporated in the index. This makes the index useful for assessing oral hygiene status in older patients at the bedside in hospital. Considering the fact that the hospitalized elderly were acutely sick and probably had difficulties with daily oral hygiene, the high prevalence of unacceptable/poor oral hygiene (37%) in the hospitalized group was not unexpected. This finding is similar to findings in nursing homes where the same method for assessing oral hygiene has been used (115;116). It has also been reported better oral hygiene in elderly living at home compared with nursing home residents (10). This is in agreement with our findings showing that the controls in our study had lower prevalence of un-acceptable oral hygiene (6%, unpublished data) compared with the hospitalized group. Although the groups differed in health status, it could be suspected that the controls had paid special attention to their oral hygiene, since they were scheduled in advance to participate in an oral examination.

## **6.2. Taste ability in hospitalized elderly compared with healthy elderly**

The "taste strips" method was first introduced in 2004 (66), and has later been used in several taste studies (68;103;117). The method has been validated against the "three drop method" with positive results (65;66). Other well-established methods have used liquid solutions in taste testing (118;119). This is however a much more elaborate method, because the liquid solutions have to be freshly prepared at least every week. Those methods were therefore not suitable for assessing taste ability in our study with a high number of hospitalized older participants. In preparation and mixing of solutions errors can easily be introduced. Compared with other methods, the "taste strips" method has some advantages such as long shelf life and fewer problems with repeated mixing of liquid solutions.

Several studies have focused on taste perception in relation to age, diseases and drugs (120), but as far as we know, no study has examined and compared taste ability in acutely hospitalized elderly with healthy controls living at home. We showed that taste ability was impaired in the hospitalized group. Our finding showing that sour and bitter taste qualities is more reduced in the hospitalized group than in the control group are of importance and should be taken into consideration when preparing food for sick elderly.

Hypogeusia does not seem to be frequent (117). Landis et al. (103) found the prevalence of hypogeusia to be 6 % in a population of approximately 700 individuals with a mean age of 44 years. In our study, this prevalence was higher. We showed that 33 % of the hospitalized elderly and 18 % of the controls suffered from hypogeusia. These findings demonstrate a decline in

taste ability with age, indicating that many elderly even without diseases have problems with impaired taste compared with younger people.

It is known that specific diseases and drugs may cause taste disorders (120;121). To what extent the difference in taste ability between the acutely hospitalized group and the control group in our study was influenced by diseases and / or drugs, is difficult to confirm. The controls were considered healthy according to their own judgment, but since their health was not verified by any medical examination prior to inclusion, this statement might be questioned. However, the healthy appearance of the controls and the large difference in number of medications between the two groups, indicate that they differed markedly in health status.

Drugs may interfere with chemosensory perception by acting on the taste receptors, and /or the signal transduction pathway to the gustatory cortex. The mechanisms behind the interaction on taste is complex, and there are few evidence-based studies on this issue (91). It was surprising to note that number of drugs was not associated with TTS, despite the fact that the patients in our study on average used almost 3 times as many drugs as the controls. This finding is in agreement with Kettaneh et al. (122). However, they used electrogustometry for measuring taste function, which is a quite different taste testing method. It has been speculated that drugs containing sulfhydryl groups like some of the ACE inhibitors (e.g. Enalapril) may be associated with taste disturbances (91;120;121). Suliburska et al. (123), also using electrogustometry, found that taste sensitivity was reduced in individuals taking ACE inhibitors for hypertension. In our study we registered only number of drugs. To examine the potential interaction between taste and all the different drugs used by our participants, was not an issue in this study.

An interesting finding in our study was that being acutely sick seemed to affect sweet, sour, salty, and bitter taste qualities differently. Spitzer (124) reported that reduced sour taste perception in institutionalized men could be due to medications. This is in agreement with our findings, showing that sour score was negatively associated with increasing number of drugs (paper I).

It has also been claimed that olfactory loss may influence taste perception negatively (72;125). Deems et al (126) concluded that complaints of taste loss usually reflect loss of olfactory function, whereas Stinton et al. (127) did not find any association between olfactory loss and taste disturbance. Data on olfaction was not included in our study.

Oral candida growth is frequent in diseased elderly (128) and especially in elderly with dentures (129;130). Studies have shown a relationship between candida infection and taste loss (131). Considering that the prevalence of “dentures only” was 3 times higher in the hospitalized group than in the control group in our study, it is possible that candidosis has contributed to differences in taste ability between hospitalized and healthy elderly. The differences in oral hygiene between the study groups could also be an explaining factor (82;132).

Zinc deficiency has been linked to taste loss and taste disturbances (133;134). Zinc is secreted from the salivary glands and seems to act as a co-factor in the regeneration of the taste receptor cells (135). However, the mechanisms are not clarified. Reduced levels of Zinc have been reported in hospitalized elderly (136;137), but Zinc analysis was not obtained in our study.



### **6.3. Taste ability and oral health**

Diseases, drugs and dehydration may lead to xerostomia and hypo-salivation among hospitalized elderly. In our study 45% of the hospitalized elderly suffered from hypo-salivation, which is in accordance with Soini et al. (138), who examined chronically ill elderly living at home. The large proportion of hypo-salivation in the hospitalized group indicates that dry mouth was a serious problem among the hospitalized elderly in our study. The quality and flow of saliva are important for maintaining good oral health (139), because saliva contains several immune components that can fight bacteria and thus prevent mucosal inflammation and reduce caries activity (140). The list of xerogenic medications are long (141) and many of them are frequently used by frail elderly. A study by Lewis et al. (142) revealed that 56% of community-dwelling elderly used xerogenic drugs. Hypo-salivation and/or xerostomia have been reported even after an intake of 3-4 non-xerogenic medications daily (143;144). Diminished saliva may lead to impaired transport of taste stimuli to the taste buds (145). Hypo-salivation is a common and characteristic feature of Sjögrens syndrome. Reduced taste perception has been documented in such patients (146-148). Our results are in line with their findings.

Further, transport of taste stimuli to the taste cell receptors may also be blocked by plaque accumulation and debris covering the taste buds. Association between taste impairment and poor oral hygiene has once been demonstrated in a small study by Langan et al. (82). . This is in accordance with our results, showing clearly that patients with compromised oral hygiene had impaired taste.

It has been speculated that decayed teeth may have a negative influence on taste ability. In the present study we have shown, apparently for the first time, that number of decayed teeth and oral bacteria are associated with reduced taste ability. No x-rays were available for caries registrations. Many participants had a high number of teeth. Without x-rays, under-registration of approximal caries is most likely. Meticulous registration and long clinical experience in caries detection in frail elderly may have minimized the problem. All the same, these considerations should be kept in mind when interpreting our findings.

Approximately 80% of the hospitalized patients had high growth of *Streptococcus Mutans* and *Lactobacilli*, both bacteria being involved in caries development. The prevalence of increased bacterial growth in our study is high compared to some studies (149;150). The reason for this is unknown, but could be due to our patients' medical condition and the use of xerogenic medications. Our findings are in agreement with Emilson et al. (151) reporting similar prevalence of bacterial growth in elderly with compromised health.. The significant associations between impaired taste and decayed teeth as well as bacterial growth could be due to various toxins and decomposition products from bacteria and food particles which may interact with taste receptors and alter or reduce the response. Adaption of sour taste perception due to acid producing bacteria may also provide a plausible explanation.

Another interesting observation in our study was that both sweet and salty tastes were impaired in patients with oral dryness. The mechanism of signal transduction is however different for the two taste qualities. Sweet stimuli are mediated via G-coupled membrane receptors, whereas salty taste stimuli seem to be mediated through ion-channels (60).

When interpreting our findings in relation to hypo-salivation and dry mouth assessment, certain aspects regarding our methods have to be considered. The amount of collected stimulated saliva with the “chewing and spitting” method may be reduced if the individual is unable to keep up the recommended chewing pace, often due to poor dentition status (144). These problems were observed in a few cases. Further, the “mirror test” which has been used as a clinical reference when more sophisticated devices have been tested for assessing buccal dryness (98), has not been extensively validated. However, our unpublished data showed that friction with the dental mirror was significantly associated with dry mouth ( $p < 0.001$ ) and reduced stimulated saliva flow ( $p < 0.001$ ), indicating that the mirror test was useful in detecting buccal dryness in our patients.

#### **6.4. Oral health and nutrition**

The association between dentition status and nutritional status has for a long time been in focus (24;152-154). Different indicators for dentition status such as number of teeth, occluding tooth pairs, and dentures versus natural dentition have been used (21). Nutritional status has been assessed with body composition methods, vitamins and albumin analysis, functional test like hand grip strength (HGS) and different global nutritional questionnaires. To our knowledge, our study is the first using body cell mass (BCM) as a nutritional indicator with focus on association between oral health and nutrition. In our study BCM was estimated with bio impedance spectroscopy, and we demonstrated a significant association between BCM and dentition status as well as oral hygiene. We did not find any such association between dentition status and the other nutritional indicators.

Associations between compromised dentition status (no teeth / reduced number of teeth) and low BMI have been observed in several studies (138;153-155). On the other hand there are reports showing that being edentulous is associated with obesity and increased BMI (156;157). In contrast to these aforementioned studies, no significant association was found between dentition status and BMI in our study. This is in agreement with De Andrade et al. (158). Under-nutrition with depletion of BCM may lead to a relative increase in the extra cellular fluid volume, masking weight change, and thus leaving BMI unchanged. Loss of BCM has been shown to occur in symptom free HIV patients without observed changes in BMI (159). BMI does not discriminate between muscle mass and fat mass, whereas BCM primarily reflects muscle mass. It is possible that BCM may be a more relevant parameter in detecting under-nutrition and loss of muscle mass in frail elderly.

MNA-SF is a widely used questionnaire in detecting elderly at risk of under-nutrition (160-164). Soini et al. (165) concluded that dental status was associated with MNA, and De Marchi et al. (166) reported that being edentulous was associated with reduced MNA score. These results are in contrast to our study, where no association between dentition status and MNA-SF score was observed. However, the prevalence of edentulous individuals was much higher in these two studies compared with our study. This may be a possible explanation as to the discrepancies between their studies and our study.

HGS measurements are frequently used to evaluate muscular function in frail elderly (167-169). Decrease in HGS has been associated with increased morbidity and functional decline after hospitalization and also with reduced BCM (170-172). Hamelainen et al. (173) found HGS to be positively associated with number of teeth in men, but not in women. No such

relationship was found in our study. Our finding is in accordance with Takata et al. (174) examining HGS in elderly of similar age.

A few HGS measurements were performed with the patients lying in bed. This was not in accordance with the manual. However, we do not believe that this deviation from the correct procedure has influenced our results substantially. Measurements of weight and height were performed by trained nurses. In 5-6 cases it was impossible to obtain these measurements due to the medical condition of the patients. Instead the patients' own knowledge of height and weight was used. Furthermore, some elderly have vertebral compressions of the spine, resulting in loss of height with age. In those cases the patients' self-reported former height was obtained. This may have caused some inaccuracies in the calculation of BMI.

Various medical conditions such as obesity and fluid overload may influence BIS measurements (42). The bio-impedance technique has been criticized for not being able to control for these conditions. However, the method incorporated in the Body Composition Monitor by Fresenius has recently been improved with regard to these problems. Thus, body fluid volumes can now be determined with better accuracy in both healthy and diseased individuals (108).

## **6.5. Taste and mortality**

Several studies have reported associations between increased mortality and factors such as diseases, high blood pressure, smoking, obesity, and compromised dentition status (175-179). Our study revealed a significant association between reduced taste ability and increased mortality. This finding was surprising, and as far as we know represents entirely new information. To what extent this is a peripheral or central blunting of taste recognition is not

known. It is possible that chemosensory perception degenerates along with other functions when life approaches the end.

## **7. Conclusions**

In the present study we have examined associations between oral health, taste ability, nutrition, morbidity and mortality in acutely hospitalized elderly. Since our study was cross-sectional, conclusions about cause and effect are not possible.

Major conclusions:

1. Taste ability was impaired in acutely hospitalized older people compared with healthy, age-matched controls. Sour and bitter taste qualities were particularly affected.
2. Taste ability was reduced in acutely hospitalized elderly with decayed teeth, high growth of oral bacteria (Lactobacilli and Streptococcus Mutans), unacceptable oral hygiene, and dry mouth.
3. Various taste qualities were altered differently. Sweet and salty tastes were particularly impaired in patients with dry mouth, whereas sour taste was impaired in patients with plaque accumulation and high growth of Lactobacilli.
4. Acutely hospitalized elderly with compromised oral health had reduced BCM. No association was found between dentition status and the other nutritional indicators.
5. Reduced taste ability was associated with a significant increase in mortality in acutely hospitalized elderly.

## **8. Implications and future studies**

In this study we have examined associations between oral health, taste, nutrition, diseases and death. Investigations of taste ability in sick elderly are scares, even though taste function is especially important in these patients with regard to appetite and food intake. One of the few pleasures left in older people's life is the enjoyment of food. Hospital staff and nursing personnel should therefore be aware of impaired taste ability in acutely hospitalized elderly and frail elderly in general. Considering the fact that dry mouth and un-acceptable oral hygiene seem to be associated with impaired taste ability, our findings should enhance health workers focus on sick older people's oral health, increasing attention for proper oral hygiene and implementing better routines. Dry mouth should be prevented with sufficient and continuous water supply and other remedies against oral dryness. In addition, food should be seasoned in order to give elderly a tasteful meal and thus help increasing caloric intake and improving quality of life.

Under-nutrition, poor oral hygiene and hypo-salivation are serious problems, not only in hospitalized elderly but also among elderly living in nursing homes. Future studies should therefore evaluate taste ability in nursing home residents. Moreover, future research should test the usefulness of various bio-impedance parameters, and BCM in particular, in studies focusing on the association between oral health and under-nutrition.



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# The Impact of Oral Health on Taste Ability in Acutely Hospitalized Elderly

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## Abstract

**Objective:** To investigate to what extent various oral health variables are associated with taste ability in acutely hospitalized elderly.

**Background:** Impaired taste may contribute to weight loss in elderly. Many frail elderly have poor oral health characterized by caries, poor oral hygiene, and dry mouth. However, the possible influence of such factors on taste ability in acutely hospitalized elderly has not been investigated.

**Materials and Methods:** The study was cross-sectional. A total of 174 (55 men) acutely hospitalized elderly, coming from their own homes and with adequate cognitive function, were included. Dental status, decayed teeth, oral bacteria, oral hygiene, dry mouth and tongue changes were recorded. Growth of oral bacteria was assessed with CRT<sup>®</sup> Bacteria Kit. Taste ability was evaluated with 16 taste strips impregnated with sweet, sour, salty and bitter taste solutions in 4 concentrations each. Correct identification was given score 1, and maximum total taste score was 16.

**Results:** Mean age was 84 yrs. (range 70–103 yrs.). Total taste score was significantly and markedly reduced in patients with decayed teeth, poor oral hygiene, high growth of oral bacteria and dry mouth. Sweet and salty taste were particularly impaired in patients with dry mouth. Sour taste was impaired in patients with high growth of oral bacteria.

**Conclusion:** This study shows that taste ability was reduced in acutely hospitalized elderly with caries activity, high growth of oral bacteria, poor oral hygiene, and dry mouth. Our findings indicate that good oral health is important for adequate gustatory function. Maintaining proper oral hygiene in hospitalized elderly should therefore get high priority among hospital staff.

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## Introduction

Diminished taste perception and decreased ability to identify and discriminate basic taste qualities may deprive people of the pleasures of eating and of quality of life. Impaired taste may have serious consequences for sick elderly [1]. Poor appetite, weight loss and under-nutrition are frequently observed among elderly admitted to hospital [2–5]. In addition, acute disease often leads to depletion of proteins and essential nutrients which may further aggravate the patients' general health [6]. Taste loss may be one of several factors contributing to poor appetite, reduced dietary intake and weight loss in elderly patients. [7–10]. Adequate gustatory function is therefore important for these old patients in order to fight disease and regain a healthy constitution.

Reduced taste ability has been associated with gender [11,12], increasing age [13,14], diseases and drugs [15,16]. Further, it has been claimed that some oral conditions, such as wearing dentures [17], dry mouth [18] and coated tongue [19,20], may cause taste impairment. Many frail elderly have poor oral health, character-

ized by heavy plaque accumulation, mucosal inflammation, hyposalivation and high caries activity [21–24]. However, as far as we know, only one study has examined the association between oral hygiene and taste ability before and after professional oral care [25]. Further, the possible influence of specific conditions such as caries and oral bacteria on taste ability has not been studied. To what extent compromised oral health in general may interfere with taste ability in acutely hospitalized elderly also remains to be investigated.

The aim of the present study was therefore to examine whether various oral health variables, such as caries, oral bacteria, oral hygiene, oral dryness and tongue changes may influence taste ability in such patients.

## Materials and Methods

### Ethics statement

The present cross-sectional study was approved by The National Committee for Medical and Health Research Ethics in

Norway, and carried out at Oslo University Hospital, Aker, Norway between November 2009 and October 2010. Written informed consent was obtained from all participants.

### Study population

**Inclusion criteria.** Elderly at least 70 years old, living in their own homes prior to hospitalization for acute medical problems, and who met the inclusion criteria, were consecutively invited to participate. The patients were evaluated for participation at least 48 hours after hospital admission by two experienced physicians in geriatric medicine. The physicians were trained to evaluate patients for participation in clinical studies with similar guidelines and criteria. Evaluation of cognitive function was based on thorough interviews with the patients.

**Exclusion criteria.** Patients less than 70 years of age, patients with reduced cognitive function, patients coming from nursing homes, and patients with terminal diseases were not eligible for participation. Two hundred and thirty-four patients were asked to participate, and 200 accepted. Various reasons for non-attendance were as follows: “feeling too sick, too tired, just had my teeth checked, and I have only dentures, etc.”

Twenty-six patients did not have taste assessments. All twenty-six patients fulfilled the inclusion criteria. They had accepted to participate and had signed the letter of informed consent. However, when they were scheduled for taste testing, they were not available due to practical hospital logistics such as busy with laboratory tests, medical examinations or treatment, having visitors, eating, or dismissed from hospital. Drop out was not associated with the clinical condition of the patient, or any other underlying causes. They were not tested any time later. Thus, 174 patients were included in the study.

## Methods

### Examination of patients

The patients were instructed not to eat or drink one hour prior to the examination, because this could interfere with the taste testing and the registration of oral dryness. The oral examination was carried out at the bedside by a dentist, using two mirrors, a dental probe, and a head lamp. A predefined questionnaire was used to acquire information about age, education, and smoking as well as relevant clinical information. Information about the number of prescribed drugs was obtained from medical records in the hospital.

### Dental status

Dental status was registered according to WHO's Oral Health Surveys, Basic Methods 4th Edition [26]. The number of own teeth was noted. Teeth with crowns were counted as own teeth. A tooth was recorded as decayed if there was loss of tooth substance, and the tooth surface was soft on probing. In addition, “own teeth only”, “own teeth with dentures” or “dentures only” were recorded.

### Oral hygiene

Plaque on teeth and/or dentures (plaque score) and mucosal and/or gingival inflammation (mucosal score) were assessed with the Mucosal-Plaque Score (MPS) [27–32]. The index has been validated and tested for both intra- and inter-examiners agreement [27,33]. The index has 4 graded scores for mucosal and/or gingival inflammation and 4 graded scores for the amount of plaque accumulation on teeth and/or dentures. Denture stomatitis, ulcers and decubitus are included in the mucosal score. The recordings for the mucosal score (MS) were as follows; (1)

normal appearance of gingiva and oral mucosa, (2) mild inflammation, (3) moderate inflammation and (4) severe inflammation. The plaque score (PS) on teeth and/or dentures were as follows; (1) no easily visible plaque, (2) small amounts of hardly visible plaque, (3) moderate amounts of plaque, and (4) abundant amounts of confluent plaque. The MPS is the sum of mucosal score and plaque score, and the score range is from 2 to 8. Scores between 2 and 4 describe good or acceptable oral hygiene.  $MPS \geq 5$  reflects un-acceptable/poor oral hygiene, and this score has been selected by experienced clinicians in previous studies according to the severity of the recorded oral hygiene status [27,28,31]. A criteria catalog with photos, showing examples of all the various conditions according to the graded scores, was presented for visual calibration [34].

### Oral dryness

To express oral dryness, three different variables were selected. These variables were the “mirror test” [35], registration of dry tongue and measurements of stimulated whole saliva. To assess dry mouth with the mirror test, the back of a dental mirror was moved across the inside of the buccal mucosa immediately after opening the mouth when starting the oral inspection. If the dental mirror was sticking to the mucosa, friction was noted. Dry tongue was recorded if the tongue was completely devoid of moisture. Assessment of stimulated whole saliva was done with the “chewing and spitting method” [36]. The patients were asked to chew on paraffin wax for approximately 1 min. to soften the wax. After emptying the mouth of saliva, the timer was started. The patients were instructed to chew vigorously on the paraffin wax for 3 minutes while spitting into pre-weighted plastic container, whenever needed. The amount of saliva collected during paraffin wax chewing, was immediately weighted on a Precisa 2200C electronic scale (Precisa Gravimetrics AG, 8953 Dietikon, Switzerland), which was calibrated daily. Hypo-salivation was defined as stimulated whole saliva  $\leq 0.6$  g/min.

### Bacterial growth

The amount of *Streptococcus Mutans* and *Lactobacilli* in stimulated whole saliva were assessed with the CRT<sup>®</sup> Bacteria Kit (Ivoclar Vivadent AG, FL-9494 Schaan, Lichtenstein) [37]. The collected, stimulated whole saliva was dripped onto the growth medium and incubated for 48 hours at 37 °C. The CRT bacteria count was expressed as low colony forming units (CFU < 10<sup>3</sup>/ml saliva) and high colony forming units (CFU  $\geq 10^5$ /ml saliva). Some patients had severe problems with chewing paraffin wax due to either dry mouth or poorly fitted dentures. Thus, 158 patients had stimulated whole saliva collected, and 153 patients had valid assessments of oral bacteria.

### Tongue changes

Coated tongue was defined as a thick layer of plaque on the anterior dorsum of the tongue to be scraped off [38]. The tiny layer of white coating from normal shedding of filiform papillae was not recorded as tongue coating. The tongue was classified as atrophic if at least 50% of the tongue was devoid of papillae. In addition to visual inspection of the tongue, photos were taken for verification of the clinical diagnosis.

### Taste ability testing

Whole mouth gustatory function was assessed with the “taste strips” method [39]. The method has been validated and calibrated against the well-established “three-drop taste test” and shown to give a significant correlation with the “three-drop taste

test” [40]. The taste strips were prefabricated and impregnated with sweet, sour, salty, and bitter taste solutions in four different concentrations each. The concentrations were: *Sweet taste*; 0.05, 0.1, 0.2 and 0.4 g/ml sucrose, *sour taste*; 0.05, 0.09, 0.165 and 0.3 g/ml citric acid, *salty taste*; 0.016, 0.04, 0.1 and 0.25 g/ml NaCl and *bitter taste*; 0.0004, 0.0009, 0.0024, 0.006 g/ml quinine-HCl. The strips were given to the participants according to a predefined procedure, starting with the weakest concentration and ending with the strongest. Both participant and examiner were blinded as to which taste quality or taste concentration given to the participant. The individual taste strip was placed in the middle of the anterior region of the tongue. The patients were allowed to suck on the strip for maximum twenty seconds. A poster with the words; *sweet, sour, salty, bitter*, was placed on the table in front of the patients who had to decide on one of the taste qualities without delay. Before starting, and in between every taste strip, the patients were asked to rinse with water to cleanse the mouth. The patients confirmed that the former taste had disappeared before the next taste strip was placed on the tongue. Correct identification was given score 1 and incorrect identification, score 0. The correct scores were summarized, and maximum total taste score was 16. Each individual taste quality was also given a sum score, ranging from 0 to 4.

**Sample size determination**

Information about variability in taste ability, where taste was measured with the same “taste strip” method as in our study, was available from a pilot study, where the standard deviation of the total taste score was 2.5. We thus assumed that the corresponding standard deviation would be 2.5 in the planned study. We considered differences  $\geq 1$  in mean total taste score between two groups to be of clinical interest. It was shown that with 174 patients included in our study, we had at least 80% test power to detect a mean difference in total taste score of at least 1 between two subgroups, provided that the smallest subgroup contained at least 30 patients. Thus, our study appeared to have acceptable test power.

**Statistics**

When comparing continuous variables in two groups, a two-sided independent samples t-test was used as long as the distribution of the variables was sufficiently close to normal distribution. If not, a two-sided Mann-Whitney test was used. Spearman’s rho was applied to test associations between two continuous variables. Multivariate linear regression analysis was used to adjust for gender. The level of significance was set to 5%. PASW statistics, version 18.0 (SPSS INC. Chicago, IL 60611, USA) was applied for statistical analysis. Quality assurance of data transfer from paper records was carried out by monitoring every 10th record.

**Results**

**Demographic data and clinical variables**

The mean (SD) age of 174 patients (n = 55 men) with valid taste scores was 83.5±6.1 years. Age ranged from 70 to 103 years. The prevalence of current smoking was 12% and the proportion of patients with education level of at least 12 years was 24%. The mean (SD) number of daily medications was 6.9±3.3. The mean (SD) number of natural teeth was 14.5±10.0 (n = 174). Mean (SD) plaque score was 2.3±0.8, mean (SD) mucosal score was 1.9±0.6 and mean (SD) MPS was 4.2±1.1. Mean (SD) stimulated whole saliva (158 patients) was 0.9±0.7 g/min. Stimulated whole saliva

was significantly associated with the mirror test and dry tongue (r = -0.38, p<0.001, r = -0.41, p<0.001), respectively.

Table 1 presents various oral health variables such as dental status, oral hygiene, and oral bacteria. Further, table 1 shows the proportion of patients with oral dryness and tongue changes (coated tongue and atrophic tongue).

**Oral health variables and total taste score**

Table 2 shows that there was no significant difference in total taste score between patients with “dentures only” and “patients with own teeth only”. Patients with un-acceptable oral hygiene (MPS $\geq$ 5) had significantly lower total taste score than patients with acceptable oral hygiene (p = 0.009). Patients with high growth of *Streptococcus Mutans* and *Lactobacilli* had significantly lower total taste score than patients with low bacterial growth (p = 0.021 and p = 0.011), respectively. Patients with friction with the dental mirror and patients with dry tongue had significantly lower total taste score than patients without friction and normal moist tongue (p = 0.002 and p = 0.043), respectively. There was no significant difference in total taste score between patients with and without tongue coating or between patients with and without atrophic tongue.

**Oral health variables associated with total taste score, sour and salty score**

Table 3 shows that total taste score was reduced in patients with high number of decayed teeth (r = -0.22, p = 0.008), high plaque score (r = -0.16, p = 0.035), high mucosal score (r = -0.15, p = 0.048) as well as high mucosal-plaque sum score (r = -0.20, p = 0.010). Low sour sum score was associated with decayed teeth (r = -0.21, p = 0.015) and high plaque score (r = -0.17, p = 0.027), but not with the other oral health variables listed. Low sum score for “salty” was associated with increasing mucosal inflammation score (r = -0.20, p = 0.009) and mucosal-plaque

**Table 1.** The prevalence of various oral health variables in 174 hospitalized elderly with data presented as numbers (n) and proportions (%).

Dental status	Own teeth only, n (%)	98 (56.3)
	Own teeth with dentures, n (%)	44 (25.3)
	Dentures only, n (%)	32 (18.4)
	<sup>1</sup> Decayed teeth, n (%)	57 (40.8)
Oral hygiene status	<sup>2</sup> MPS $\geq$ 5, n (%)	65 (37.3)
Oral bacterial growth	<sup>3</sup> Lactobacilli $\geq$ 10 <sup>5</sup> CFU/ml saliva, n (%)	129 (84.3)
	<sup>3</sup> Streptococcus $\geq$ 10 <sup>5</sup> CFU/ml saliva, n (%)	123 (80.4)
Oral dryness	Dry tongue, n (%)	22 (12.6)
	Friction with mirror test, n (%)	26 (14.9)
	<sup>4</sup> Hyposalivation, n (%)	69 (43.7)
Coated tongue, n (%)		44 (25.3)
Atrophic tongue, n (%)		48 (27.6)

<sup>1</sup>Prevalence of participants with number of teeth >0 (n = 142).

<sup>2</sup>MPS (Mucosal -Plaque score) is the sum of the Mucosal score and the Plaque score with a sum score from 2 to 8. Un-acceptable/poor oral hygiene is defined as MPS $\geq$ 5.

<sup>3</sup>Number of patients with valid bacteria test was 153 patients.

<sup>4</sup>Hyposalivation is defined as stimulated whole saliva  $\leq$ 0.6 g/ml. The number of patients with collected stimulated whole saliva was 158 patients.

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**Table 2.** Associations between oral health variables and total taste score<sup>1</sup> in 174 hospitalized elderly.

Oral health variables	n	Total taste score, mean (SD)	p-value ( p-values (adjusted for gender)
Dentures only	32	8.5 (2.4)	0.70
Own teeth only	98	8.7 (2.6)	
<sup>2</sup> Acceptables oral hygiene, (MPS<5)	109	9.1 (2.4)	0.009*
Un-acceptable oral hygiene, (MPS≥5)	65	7.9(2.9)	(0.004*)
<sup>3</sup> Streptococcus M<10 <sup>5</sup> CFU/ml saliva	30	9.7(2.3)	0.021*
<sup>3</sup> Streptococcus M≥10 <sup>5</sup> CFU/ml saliva	123	8.5 (2.6)	(0.014*)
<sup>3</sup> Lactobacilli <10 <sup>5</sup> CFU/ml saliva	24	10.0 (2.5)	0.011*
<sup>3</sup> Lactobacilli ≥10 <sup>5</sup> CFU/ml saliva	129	8.5 (2.6)	(0.010*)
No friction with mirror test	148	8.9 (2.6)	0.002*
Friction with mirror test	26	7.2 (2.6)	(0.001*)
No dry tongue	152	8.8 (2.6)	0.043*
Dry tongue	22	7.6 (2.7)	(0.007*)
No coated tongue	130	8.9 (2.6)	0.09
Coated tongue	44	8.1( 2.9)	
No atrophic tongue	126	8.9 (2.6)	0.09
Atrophic tongue	48	8.1 (2.7)	

<sup>1</sup>Total taste score is the sum of correct identifications of taste strips (maximum score = 16).  
<sup>2</sup>MPS is the sum score of Mucosal inflammation score and Plaque score. The score is from 2 to 8. Acceptable oral hygiene is defined as MPS<5, and unacceptable/poor oral hygiene is defined as MPS≥5.  
<sup>3</sup>The oral bacteria *Streptococcus Mutans* and *Lactobacilli* were assessed in 153 patients.  
 \*p≤0.05.  
 In cases where significance was reached, p-values adjusted for gender are shown in parentheses below unadjusted p-values.  
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sum score (r = -0.15, p = 0.045). Further, the salty sum score was positively associated with stimulated whole saliva (r = 0.18, p = 0.023). Sweet and bitter sum scores were not significantly associated with any of the oral health variables presented in table 3 (data not shown).

**Dichotomous oral health variables and taste quality**

Table 4 shows the influence of various dichotomous oral health variables on the basic taste qualities sweet, sour and salty. Sweet sum score was significantly lower in patients with friction with the dental mirror, dry tongue and atrophic tongue (p = 0.007,

p = 0.001, and p = 0.009), respectively. Sour sum score was significantly lower in patients with high growth of Lactobacilli (p = 0.001). Salty sum score was significantly lower in patients with friction with the dental mirror and dry tongue (p = 0.009 and p = 0.030) respectively, both indicative of dry mouth. The possible influence of these oral health variables on bitter sum score is not presented in the table due to lack of significant differences.

**Confounding factors**

Potential confounding factors in this study might be age, gender, smoking, education, and number of medications. All were tested

**Table 3.** Total taste score, sour and salty sum scores associated with different oral health variables in 174 hospitalized elderly.

Oral health variables	Total taste score		Sour sum score		Salty sum score	
	r	p-value (adjusted)	r	p-value (adjusted)	r	p-value (adjusted)
<sup>1</sup> Decayed teeth	-0.22	0.008* (0.001*)	-0.21	0.015* (0.10)	-0.13	0.14
<sup>2</sup> Plaque score	-0.16	0.035* (0.032*)	-0.17	0.027* (0.031*)	-0.04	0.59
<sup>3</sup> Mucosal score	-0.15	0.048* (0.022*)	-0.012	0.89	-0.20	0.009* (0.009*)
<sup>4</sup> Mucosal-Plaque sum score	-0.20	0.010* (0.004*)	-0.13	0.09	-0.15	0.045* (0.037*)
<sup>5</sup> Stimulated saliva g/min	0.12	0.15	-0.10	0.23	0.18	0.023* (0.026*)

<sup>1</sup>The number of dentate patients were 142.  
<sup>2</sup>Plaque score is defined as plaque on teeth and/or dentures, (graded from 1-4).  
<sup>3</sup>Mucosal score is defined as mucosal and/or gingival inflammation, (graded from 1-4).  
<sup>4</sup>Mucosal-Plaque Score (MPS) is the sum of Plaque score and Mucosal score with sum score from 2 to 8.  
 Stimulated whole saliva was collected in 158 patients.  
 \*p≤0.05.  
 In those cases where significance was reached, the p-values adjusted for gender are shown in parentheses below the unadjusted p-values.  
 Sweet and bitter sum scores were not significantly associated with any of these variables, and are therefore not shown in the table.  
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**Table 4.** Impact of various oral health variables on sum scores of sweet, sour and salty taste qualities in mean (SD) in 174 hospitalized elderly.

Oral health variables	Sweet sum score (adjusted)	Sour sum score (adjusted)	Salty sum score (adjusted)
<sup>1</sup> Streptococcus M<10 <sup>5</sup> CFU ml/saliva	3.4 (0.8)	1.2 (0.9)	2.3 (1.2)
<sup>1</sup> Streptococcus M≥10 <sup>5</sup> CFU ml/saliva	3.0 (1.1)	0.9 (0.8)	2.0 (1.2)
	p=0.13	p=0.10	p=0.26
<sup>2</sup> Lactobacilli<10 <sup>5</sup> CFUml/saliva	3.4 (0.8)	1.5 (0.8)	2.0 (1.3)
<sup>2</sup> Lactobacilli≥10 <sup>5</sup> CFUml/saliva	3.0 (1.1)	0.9 (0.8)	2.1 (1.1)
	p=0.17	p=0.001* (0.001*)	p=0.84
No friction with mirror test	3.2 (1.0)	1.0 (0.9)	2.1 (1.1)
Friction with mirror test	2.4 (1.3)	0.9 (0.8)	1.5 (1.1)
	p=0.007* (0.001*)	p=0.78	p=0.009* (0.009*)
No dry tongue	3.2 (1.0)	0.9 (0.8)	2.1 (1.2)
Dry tongue	2.2 (1.3)	1.1(0.9)	1.6(1.0)
	p=0.001* (<0.001*)	p=0.31	p=0.030* (0.027*)
No atrophic tongue	3.2 (1.0)	1.0 (0.9)	2.1 (1.1)
Atrophic tongue	2.7 (1.2)	1.0 (0.8)	1.9 (1.2)
	p=0.009* (0.002*)	p=0.74	p=0.36

\*p≤0.05.

Significant p-values are adjusted for gender and shown in parentheses. None of the oral health variables had significant impact on bitter taste quality, and the results are therefore not presented in the table.

<sup>1,2</sup>Streptococcus Mutans and Lactobacilli were assessed in 153 patients.

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against the outcome variables. However, only gender was significantly associated with the taste scores. Thus, all the significant findings were adjusted for gender only. The majority of the oral health variables with significant associations with total taste score, sweet, sour and salty taste scores remained significant after adjusting for gender (table 2 and 3). However, the association between sour taste and decayed teeth was no longer significant after adjusting for gender.

## Discussion

In the present study we show that taste ability is significantly impaired in acutely hospitalized elderly with decayed teeth, high growth of oral bacteria associated with caries, poor oral hygiene and dry mouth. The majority of these findings remained significant after adjusting for gender.

Caries is associated with *Lactobacillus*, *Streptococcus Mutans* and poor oral hygiene [41,42]. It has been suggested that taste loss associated with poor oral health could be due to toxins and inflammatory products produced by the oral bacteria [43]. In our study, sour taste was particularly impaired in patients with high lactobacilli growth. These oral bacteria proliferate in an acidic environment, and they also produce acid themselves. Although the mechanisms involved in taste transduction are rather complex [44,45], an explanation could be that the acid produced by the bacteria may cause adaption in sour taste perception, and thus increasing the taste threshold for sour. Further, we found that poor oral hygiene was associated with reduced total taste score and salty taste. This is in agreement with Langan et al. [25], concluding, in a small study with 15 participants, that professional oral hygiene improved taste acuity for salty taste as well as sweet taste.

In our study, no difference in taste ability was found between patients with and without tongue coating. This is in contrast to a number of studies, e.g., Quirynen et al. [46], Ohno et al. [19], and

Kostka et al. [20], reporting that taste sensitivity improved after tongue cleaning. However, their study design and methods were quite different from those in our study. We examined taste ability in patients with and without coated tongue, while they tested taste sensitivity before and after removal of tongue coating with tongue brushing.

Hospitalized elderly frequently use a high number of drugs daily, which may induce xerostomia and hypo-salivation [47]. Saliva is essential for bringing food particles and taste stimuli to the taste buds in the oral cavity [48]. Reduced saliva flow is reported to be associated with taste loss [49,50]. In our study in acutely hospitalized elderly, dry mouth was associated with impaired taste. This is in accordance with both Kamel et al. [18] and Weiffenbach et al. [51], reporting that patients with Sjögren's syndrome, which is characterized by oral dryness, had reduced taste sensitivity compared with controls.

Some studies claim that people with dentures have higher taste threshold [17,52] and also elevated retronasal flavour threshold [53], than people without dentures. In our study there was no difference in taste scores between patients with full dentures and patients with natural dentition. Why our finding is not in line with those other studies is not known, but could be due to different methods used.

In our study, atrophic tongue was associated with reduced sweet score. It remains to be explained why atrophy of the tongue papillae affected the sweet taste quality more than the other taste qualities.

## Limitations and strengths

Our study has some limitations. The "mirror test" is a crude clinical method for estimation of buccal dryness. This test has not been properly validated. However, it has been used as a clinical reference when more sophisticated devices have been tested for possible use in assessing buccal dryness [35]. Furthermore, the

registrations of caries were not performed under optimal conditions, and no x-rays were taken to support the findings. This could cause underestimation of caries activity in these patients. Still we do not believe that this will change the main conclusions of our study. When assessing atrophic tongue based on visual inspection, there is always a risk of either over or underestimations. However, the prevalence of atrophic tongue in our study was similar to a previous study at the same hospital ward [54]. Although the study took place in a difficult setting, we managed to collect substantial information about several oral health parameters and their associations with gustatory function in a relatively large number of very old and severely ill acutely hospitalized elderly. This is an important strength of our study.

## Conclusion

The present study shows that taste ability was significantly reduced in acutely hospitalized elderly with caries activity, high growth of oral bacteria, poor oral hygiene, and dry mouth. Our findings suggest that good oral health is important for adequate

gustatory function in such patients. Maintaining proper oral hygiene in hospitalized elderly should therefore get high priority among hospital staff. Further, healthy oral conditions contributing to better taste perception, may stimulate appetite and enhance caloric intake. This may help to prevent nutritional deficiency in hospitalized elderly and improve the patients' general health and quality of life.

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## Author Contributions

Conceived and designed the experiments: KS LS TH TW MM. Performed the experiments: KS. Analyzed the data: KS LS TH TW MM. Contributed reagents/materials/analysis tools: KS LS TH. Wrote the paper: KS LS TH TW MM.

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# Short nutritional assessment

Vekt(kg):

Høyde(cm)

BMI:

Dato:

## 1. BMI

0: BMI < 19

1:  $19 \leq \text{BMI} \leq 21$

2:  $21 \leq \text{BMI} \leq 23$

3: BMI  $\geq$

Poeng:

## 2. Vekttap siste 3 måneder

0: > 3 kg;

1: Vet ikke

2: Mellom 1 - 3

3: Intet vekttap

## 3. Har pasienten hatt akutt sykdom eller psykologisk stress siste 3 måneder

0 = Ja

1 = Nei

## 4. Mobilitet

0= Seng/stol "bundet"

1=Er i stand til å komme seg ut av seng(/stol men går ikke

2=Går ut

## 5. Neuropsykologiske problemer

0= Uttalt demens/depresjon

1= Mild demens

2=Ingen psykologiske problemer

## 6. Har matlysten blitt redusert siste tiden?

0=Matlysten er redusert

1=Er usikker, vet ikke

2=Matlysten er ikke redusert

Sum:

Basert på Guigoz and Vellas, 1994.  
Svensk oversetting: Westergren  
Til norsk av Mowe



