Oral health status among 65-year-olds in Oslo, Norway: dental caries, apical periodontitis, and dry mouth

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Contents

“Adding more years to life can be a mixed blessing if it is not accompanied by adding more life to years.”

- *Dr Tedros Adhanom Ghebreyesus*

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My Tien Diep

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List of papers

This thesis is based on the following three papers, submitted in partial fulfilment of the requirements for the Degree of *Philosophiae Doctor* at the Faculty of Dentistry, University of Oslo, Norway. In the text, they will be referred to by their roman numerals. The papers (I-III) are based on the OsloMunn65 study, funded by and conducted at the Faculty of Dentistry, University of Oslo.

I. Diep MT, Skudutyte-Rysstad R, Sødal ATT, Young A, Hove LH. **Caries experience and risk indicators among 65-year-olds in Oslo, Norway.** *Submitted to Caries Research, January 2022.*

II. Diep MT, Hove LH, Ørstavik D, Skudutyte-Rysstad R, Sødal ATT, Sunde PT (2022) **Periapical and endodontic status among 65-year-old Oslo-citizens.** BMC Oral Health 22(1), 371.

III. Diep MT, Jensen JL, Skudutyte-Rysstad R, Young A, Sødal ATT, Petrovski BÉ, Hove LH (2021) **Xerostomia and hyposalivation among a 65-yr-old population living in Oslo, Norway.** European Journal of Oral Sciences 129(1), e12757.

Abbreviations

AP	Apical periodontitis
CI	Confidence interval
CODS	Clinical Oral Dryness Score
DMFT/S	Decayed, missing, filled teeth/surfaces
ICDAS	International Caries Detection and Assessment System
IQR	Interquartile range
ODC	Oral Data Collector
OECD	Organization for Economic Co-operation and Development
OM65	OsloMunn65
PAI	Periapical Index
SD	Standard deviation
SWS	Stimulated whole saliva
SXI-D	Shortened Xerostomia Index – Dutch Version
TSD	Tjenester for Sensitive Data
USIT	University Centre of Information Technology
UWS	Unstimulated whole saliva
WHO	World Health Organization

Background

Healthy oral ageing

"Healthy ageing" is defined by WHO as "the process of developing and maintaining the functional ability that enables wellbeing in older age" (World Health Organization 2020). During the last decades, a marked reduction of dental caries and periodontitis have been evident in many developed countries (Marthaler 2004, Skudutyte-Rysstad & Eriksen 2007, Skudutyte-Rysstad *et al.* 2007, Wahlin *et al.* 2018), especially in children and young adults. However, these oral diseases are still highly prevalent among older individuals, with the largest burden among the care-dependent elderly (Samson *et al.* 2008, Karki *et al.* 2015, Edman *et al.* 2021).

Oral diseases represent a substantial burden both for those affected and for the society (Zucoloto *et al.* 2016). Unfortunately, oral health has been given low priority on the global health agenda (Benzian 2021). However, in 2021, the World Health Assembly adopted a historic resolution on oral health (World Health Organization 2021), aiming to develop a global oral health strategy and action plan by 2023. The resolution recommends a shift from the traditional curative approach towards a more preventive approach, which requires insights into disease patterns and the identification of risk-indicators and factors. In this context, knowledge about the oral health status of the young-elderly age group will facilitate the planning of targeted preventive strategies required in this population, as well as the allocation of health-care resources in accordance with the specific population's needs.

Oral health in the young-elderly population

When setting the goals for future dental health services and developing related strategies, several characteristics about the current young-elderly population should be emphasised. Age 65 has been defined as the beginning of old age (OECD 2022), and some studies have categorised age 65-74 as 'young-old' (Jordan *et al.* 2014), age 75-84 as 'older old', and age ≥85+ as 'oldest old' (Lee *et al.* 2018, Mehraban-Far *et al.* 2021).

As many other countries, Norway experienced a baby boom after World War II, that lasted until the late 1960s (Tømmerås 2020). This baby boom generation is now entering old age. In addition, reduction in both mortality rates and birth rates have affected the demographic distribution of the populations in many countries, resulting in 'population ageing' (United Nations 2020). At the same time, the elderly are retaining more of their natural teeth (Petersen *et al.* 2004, Tonetti *et al.* 2017, Jordan *et al.* 2021). Due to all these trends, it may be speculated that the need for oral health care will increase.

The current young-elderly population has benefitted from the caries-preventive effect of fluoride toothpaste that was introduced in Norway in the late 1960´s (Rølla & Jonski 2014). In the following years, the restorative philosophy started to shift from a "extension for prevention" approach to a more minimally invasive treatment approach (Osborne & Summitt 1998). Whereas the previous philosophy had advocated extending the cavity preparation margins into buccal and lingual tooth surfaces for higher cleaning accessibility, the minimally invasive approach involved a caries lesion-orientated preparation technique that focuses on only removing the infected dentine (Tyas *et al.*

2000, Ericson 2007). The introduction of adhesive dental materials facilitated this transition due to less need for macro-mechanical prepared retention (Ericson 2007). The minimal invasive approach also emphasizes that caries lesions that are or could be arrested should be treated non-operatively. During the 1980s, the operative treatment criteria for caries lesions gradually shifted among the majority of dentists in Norway. The new approach involved not restoring enamel caries lesions, but rather waiting until the caries progressed into the dentine (Tveit *et al.* 1999). This modern treatment approach causes less removal of sound tooth substance, lowering the risk of tooth fractures and pulpal complications. However, since these major events in the history of dentistry did not occur until after the current young-elderly population had reached young adulthood, the lack of fluoride supplements and invasive treatment approach have resulted in irreversible loss of tooth substance.

Åstrøm and co-workers reported that older individuals are less emotionally affected by loss of teeth than younger individuals (Åstrøm *et al.* 2006). Age-related changes in values and expectations may explain this finding. However, an increased focus on appearance (Birkeland *et al.* 2005, Grabe *et al.* 2008), the 'staying young phenomenon' (Akın 2021), and the perception of the ideal smile (Dudea *et al.* 2012) in Western society is reflected in the growing market for aesthetic dentistry (Odaira *et al.* 2011, Al-Ansari *et al.* 2020). An increased self-awareness in the population, including the elderly population, may also increase the motivation for oral preventive measures. However, it may also increase the psychological burden for those who are unable to maintain satisfactory oral health (Newton & Minhas 2005).

In Norway, large geographical disparities in dental status among elderly have been reported (Henriksen *et al.* 2003). Recent studies on oral health status in adult populations, including the young-elderly, from central (Rødseth *et al.* 2022) and northern parts of Norway have been conducted (Holde *et al.* 2016, Holde *et al.* 2017, Oscarson *et al.* 2017, Mulic *et al.* 2020). However, information about the oral health status in the general young-elderly population in the southern parts of Norway is still lacking.

Organisation of dental health services in Norway

In Norway, dental health services are divided into a private and public sector (Grytten *et al.* 2009, Grytten & Skau 2009). The majority of adults receive oral care from private general dental practitioners, mainly paid by the patients. Dental treatment provided by the Public Dental Health Service is free of charge for patients aged 0-18 years, mentally disabled adults, and elderly living in an institution or receiving home nursing care. Due to the increasing number of elderly, the demand for dental health services is likely to increase in the coming years. However, this prognosis also depends on the oral health status of the future elderly population. Therefore, data on the oral health status of this population at the threshold of old age are required.

The OM65 project

In 2019, a cross-sectional study named OsloMunn65 (OM65) was conducted, with the aim to map the oral health status of 65-year-olds in Oslo. The OM65 study included assessments of:

- Caries experience

- Periodontal status
- Periapical- and endodontic status
- Salivary status
- Tooth wear
- Taste- and smell function

In addition, occlusion, temporomandibular joint osteoarthritis, and ocular dryness (Hynne *et al.* 2022) were investigated in sub-studies.

The present thesis reports on the caries experience (Paper I), periapical and endodontic status (Paper II), and salivary status (Paper III) of the participants in the OM65 study. Papers describing the periodontal status (Sødal *et al.* 2022), taste- and smell function (Sødal *et al.* 2021), and oral health-related quality of life (Sødal *et al.* 2022) have recently been published and are the subject of another PhD thesis.

Dental caries

A dental caries lesion is a localized chemical dissolution of the tooth surface caused by metabolic events in the biofilm covering the affected area (Fejerskov *et al.* 2015). Caries development is determined by a complex interplay between biological, behavioural, psychosocial, and environmental factors (Machiulskiene *et al.* 2020). Plaque control, dietary modification, fluoride supply, and salivary status are direct disease determinants (Selwitz *et al.* 2007). Moreover, these factors may be related to lifestyle (intermediate effects) and sociodemographic factors (distal effects) (Aleksejūnienė *et al.* 2009). The consequence of severe caries is tooth loss (Chan *et al.* 2021).

Caries lesions may be classified in several ways (Fejerskov *et al.* 2015). For instance, according to their anatomical site, caries lesions may be classified as coronal caries or root caries. Primary caries lesions are recorded on otherwise, intact tooth surfaces, while secondary caries refers to caries lesions that develop adjacent to an existing dental restoration. Root surfaces and restored teeth are at higher risk of plaque retention, and subsequently caries development (Kirkevang *et al.* 2011). Since gingival recessions and tooth restorations are accumulating conditions and events, their prevalence tends to increase with age, possibly making elderly individuals more susceptible to caries. One may also distinguish between non-cavitated and cavitated caries lesions, which will influence the management of the lesions.

“Caries experience is the number of teeth/surfaces that have caries lesions (at a specified threshold), restorations, and/or are missing due to caries, accumulated by an individual, up to a designated point in time” (Machiulskiene *et al.* 2020). The decayed, missing, and filled teeth/surfaces (DMFT/S) index is the predominant measure of caries experience (Petersen 2013).

According to a systematic review on caries prevalence in older adults reported from 2016 to 2020, the caries prevalence ranged from 25%-99% around the globe, with the highest levels in Asian and African countries (Chan *et al.* 2021). However, of the 39 studies included, only four studies (D'Avila *et al.* 2017, Oscarson *et al.* 2017, Głowacka & Konopka 2019, Varghese *et al.* 2019) investigated study samples from the general population.

Recent studies from the northern (Oscarson *et al.* 2017, Mulic *et al.* 2020) and central (Rødseth *et al.* 2022) parts of Norway showed a mean DMFT score of 21.0-22.5, and a caries prevalence of 35-39% (Oscarson *et al.* 2017, Mulic *et al.* 2020). However, data on caries experience and risk indicators of dentine caries in the young-elderly population in the southern part of Norway is scarce.

Apical periodontitis

Apical periodontitis (AP) is an inflammatory lesion in the periapical tissues that develops as a reaction to a root canal infection (Nair 2004). Bacteria invasion into the pulp space may be caused by deep caries lesions, clinical procedures, or dental trauma. The immune response includes destruction of periapical bone and dental hard tissues, which, after a certain point, may be detectable on radiographs as a radiolucent area. While the inflammatory process may be chronic and asymptomatic, it can also cause dental pain and apical abscess formation, which in rare cases might lead to severe complications and even mortality (Siqueira & Rôças 2013). Apical periodontitis has been associated with systemic diseases, such as diabetes type II (López-López *et al.* 2011, Marotta *et al.* 2012) and cardiovascular disease (Caplan *et al.* 2006, Petersen *et al.* 2014, Sebring *et al.* 2022), however, the evidence is controversial (Frisk *et al.* 2003, Cotti & Mercuro 2015). Nevertheless, the potential relationship between apical periodontitis and systemic diseases may affect older age groups more than younger, as multi-morbidity becomes more prevalent with age.

Periapical lesions may be classified as primary- or post-treatment AP, respectively referred to as 'untreated AP' and 'AP related to root-filled teeth' in Paper II. Periapical lesions may heal if an adequate amount of the causing bacteria are successfully removed through endodontic treatment. Post-treatment AP is a periapical lesion that 1) has persisted due to failed endodontic treatment, 2) was not present to begin with, but developed after endodontic treatment due to bacterial contamination during the treatment procedure, or 3) has developed after a former healed periapical lesion due to re-infection of the tooth (Siqueira & Rôças 2020).

Several individual- and tooth-related risk indicators for AP have been reported. Several of the risk indicators for AP are the same as for dental caries; increasing age (Kirkevang *et al.* 2001, Jakovljevic *et al.* 2020, Razdan *et al.* 2022), low socioeconomic status (Aleksejūnienė *et al.* 2000), smoking (Kirkevang & Wenzel 2003), and irregular dental attendance (Aleksejūnienė *et al.* 2000, Kirkevang & Wenzel 2003). Furthermore, poor technical quality of the root filing is a well-known risk indicator for AP in root-filled teeth (Kirkevang *et al.* 2004, Vengerfeldt *et al.* 2017, Meirinhos *et al.* 2020). In a 10-year longitudinal study, it was shown that unsatisfactory quality of the root filling increased the probability of persistent AP (Kirkevang *et al.* 2014).

During the last twenty years, only a few studies have reported the prevalence of AP and root-filled teeth in a general young-elderly population. The prevalence of AP in the age group 49-64 years in Finland (Huumonen *et al.* 2017), Sweden (Virtanen *et al.* 2017), and Denmark (Razdan *et al.* 2022) were found to range from 34-69%. However, data on the prevalence of root-filled teeth and apical periodontitis in the Norwegian young-elderly population is lacking.

Dry mouth

Saliva is a fluid produced in the salivary glands and secreted into the oral cavity, where it covers the teeth and oral mucosa (Edgar 1992). While saliva is composed of more than 99% water, it also contains a variety of substances, ensuring several functions such as: 1) lubrication of teeth and oral mucosa, 2) facilitation of remineralisation of the teeth by acting as a reservoir for tooth minerals and neutralising plaque and oral pH after eating, 3) clearance of food and bacteria, and 4) helping to control the oral microflora through antimicrobial actions. Thus, the most common complications with pathologically reduced salivary secretion rate (hyposalivation) include dental caries, gingivitis, fungal infection, impaired prosthesis retention, traumatic oral lesions, and difficulties with chewing and swallowing (Kaplan *et al.* 2008, Ichikawa *et al.* 2011, Navazesh 2012, Anil *et al.* 2016, Iwasaki *et al.* 2016).

Whole saliva is a mixture of saliva secreted from the major and minor salivary glands in the mouth, but also gingival crevicular fluid, desquamated epithelial cells, bacteria, leucocytes, and possibly food residues, blood, and viruses (Dawes 2012). While the normal range of unstimulated whole saliva secretion rate in healthy individuals is wide, the average range is about 0.3-0.4 mL/min (Dawes 2012). In addition, whole salivary secretion rate may be influenced by exogenous stimuli, such as tastants or chewing. On average, the stimulated salivary flow rate in elderly, stimulated by chewing on paraffin wax, has been reported to be between 1-2 mL/min (Österberg *et al.* 1984, Österberg *et al.* 1992, Iwasaki *et al.* 2016).

Dry mouth may refer to objectively measured reduced salivary flow rate or visual clinical signs of oral dryness, or to xerostomia, the subjective feeling of dry mouth. Dry mouth is more prevalent in females than males (Österberg *et al.* 1992, Ohara *et al.* 2016). It has also been shown that the prevalence of dry mouth increases with age (Nederfors *et al.* 1997, Hay *et al.* 1998, Johansson *et al.* 2012, Kongstad *et al.* 2013), not primarily due to the ageing process itself (Whelton 2012), but caused by various conditions, such as Sjögren’s syndrome (Tashbayev *et al.* 2017), diabetes type II (Sandberg *et al.* 2000, Chavez *et al.* 2001, Bernardi *et al.* 2007), and side-effects of radiation therapy to the head and neck region (Hey *et al.* 2009, Jensen *et al.* 2019). In addition, the use of multiple medications that may cause dry mouth (Nederfors *et al.* 1997, Bergdahl & Bergdahl 2000) increases with age (Berg 2018).

The knowledge on the prevalence and potential risk indicators of xerostomia in the Norwegian young-elderly population is scarce. In 2009, Ekback and co-workers reported that 29% of 65-year-olds in the three Norwegian counties Hordaland, Sogn and Fjordane, and Nordland occasionally had problems with dry mouth (Ekback *et al.* 2009). To my knowledge, no studies have reported on objectively measured salivary status and dry mouth in the general young-elderly population in Norway.

Aims

The overall aim of the present thesis was to gain more insight about three important oral health parameters in 65-year-old Oslo-citizens: caries experience, periapical and endodontic status, and salivary status. More specifically, the aims of the papers included in this thesis were as follows:

Paper I: To investigate the caries experience, and to explore possible associations to sociodemographic-, behavioural-, and biological risk indicators in this population

Paper II: To investigate the prevalence of apical periodontitis and root-filled teeth, and to investigate possible associations of periapical pathosis and endodontic treatment with selected individual risk indicators and the technical quality of the root fillings

Paper III: To determine the prevalence of xerostomia and hyposalivation, to explore the correlation between the two conditions, and to investigate the possible associations with medication use, medical conditions, gender, level of education, and smokingf in this population

Participants and methods

Study design and participants

The papers included in this thesis are based on an epidemiological cross-sectional study (the OM65 study). The inclusion criteria for the OM65 study were 1) being 65 years old (born in 1954), and 2) residing in Oslo, Norway. At the point of recruitment, there were no exclusion criteria. The sample size calculation resulted in 450 participants (see Statistical analyses). Accounting for the fact that there would be a certain proportion of non-responders, 1500 eligible individuals were randomly selected from the Norwegian National Population Register. Invitation letters were sent out (Appendix I), and after two weeks, the individuals were telephoned and asked if they were interested in participating in the study. This procedure was conducted consecutively until the sample size had been reached. Some participants had to be excluded from the studies due to missing data related to the questionnaire or to radiographic examinations, which resulted in a slightly different number of participants in the three papers. The recruitment process is shown in Figure 1.

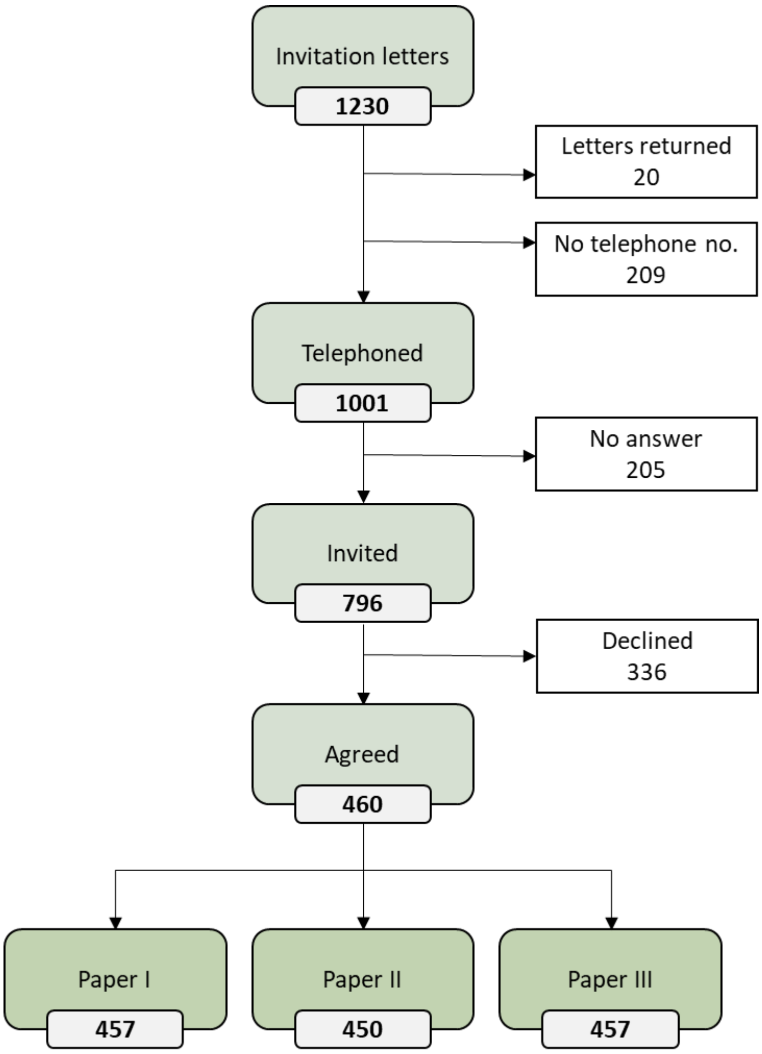

Figure 1. Flow chart of the recruitment process in the OM65 study

Non-responders

To indirectly explore the characteristics of the non-responders, the sociodemographic characteristics of the study sample were compared with those of the source population (Table 1).

Table 1. Sociodemographic characteristics in the study sample (N=460) and in the source population (65-year-olds in Oslo, N = 6014)

Sociodemographic factor	Study sample (%)	Source population* (%)
Gender		
Male	51.7	49.5
Female	48.3	50.5
Country of birth		
Western	91	82
Non-western	9	18
Education level		
Basic	33	53
Higher	67	47

*Data retrieved from Statistics Norway, microdata.no – own computations (Heldal 2019)

Data collection

The Oral Data Collector: Development of an electronic data capture system for oral health surveys

During the planning stage of the OM65 project, it became evident that suitable systems for collecting and storing research data from the clinical examinations were needed. The desired features of the data capture system were that it should be 1) electronic and available for direct data entry, with no use of handwritten data capture, 2) customized for the clinical parameters included in the project, 3) intuitive and user-friendly for the examiners, 4) easy to transform the captured data into datasets for statistical analyses, and 5) affordable. To achieve this, time was invested in developing the Oral Data Collector (ODC), an electronic data capture system.

ODC was designed using Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA). The user interface was based on traditional set-up for dental journal software, with an overview of the patient's dentition for direct data entry on tooth surface level (Figure 2). Separate data sheets were designed for assessment of the different oral health parameters (Appendix II). One excel-file was created for each study participant.

(a)

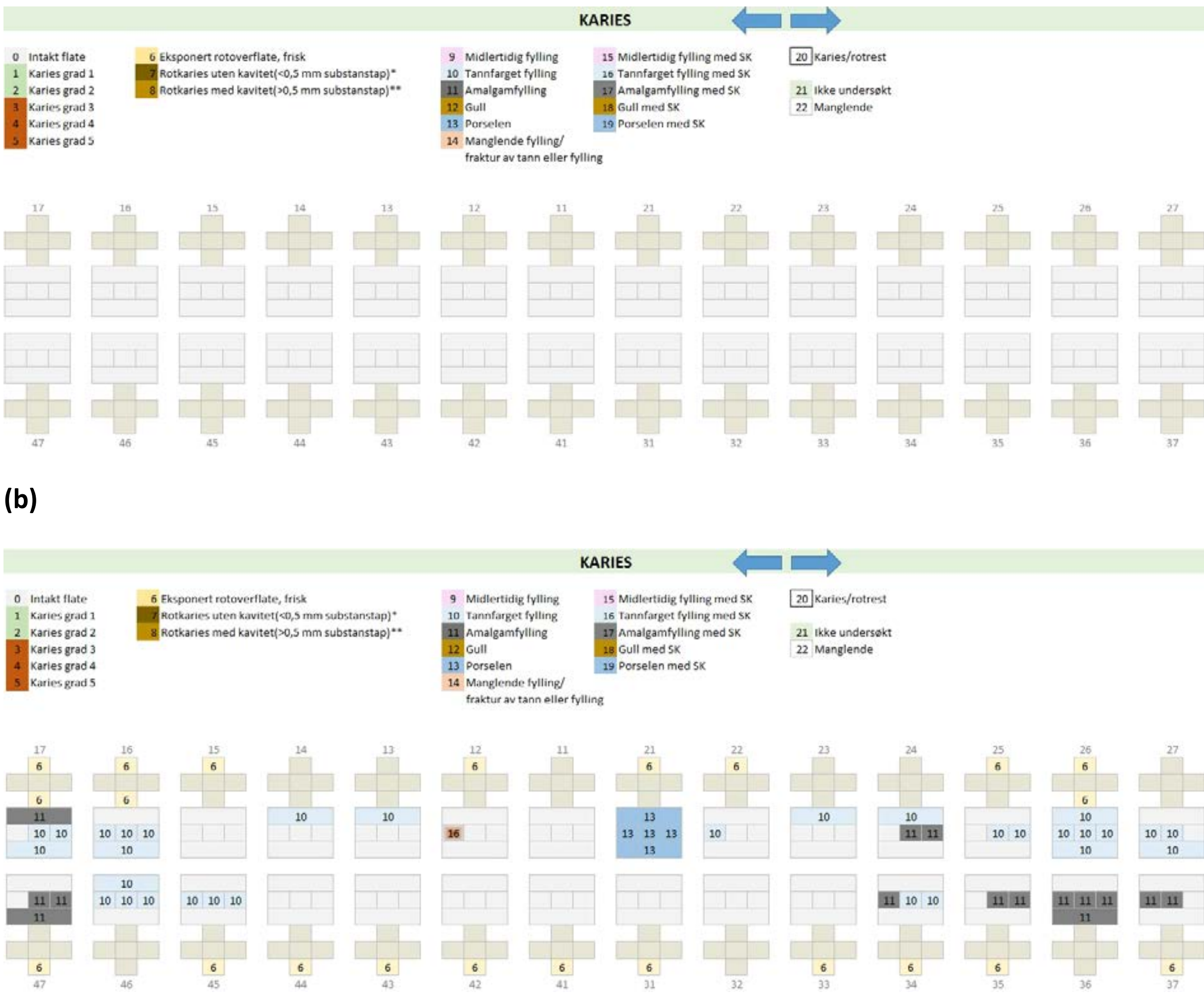

Figure 2. Images of the Oral Data Collector with the display for registrations of caries experience before data entry **(a)** and after **(b)** (text in Norwegian). Full-scale images are shown in Appendix II.

A program to combine the data from the multiple excel-files into a dataset for analysis was made using openpyxl 3.0.4 and pandas 1.1.0 in Python 3.8 (Python Software Foundation, https://www.python.org/). The program also processed the data according to the project, before presenting the dataset. For instance, analysing data on both individual level and tooth level required rearrangements of the dataset, which were performed by the Python program. The dataset was imported into STATA (Stata version 16.1; College Station, TX, USA) for statistical analysis. All data-files were created, stored, and analysed in the TSD (Tjenester for Sensitive Data) facilities, developed and maintained by University Centre of Information Technology (USIT) at the University of Oslo.

Questionnaire

All study participants answered a self-administered questionnaire that aimed to collect information related to sociodemographic-, general health-, and behavioural factors, as well as self-perceived oral dryness (Appendix III and IV). Prior to attending the clinical examination, an electronic link to an online questionnaire was sent to the participants (Nettskjema®, University of Oslo). Participants who were unable to answer the questionnaire at home, answered the questionnaire during the appointment.

Clinical and radiographic examinations

The participants were examined at the Research Clinic at the Institute of Clinical Dentistry, University of Oslo, between 26 February 2019 and 13 December 2019. Two calibrated dentists performed the clinical examinations relevant for the papers included in the present thesis. The radiographic examinations comprised bitewing radiographs, a panoramic radiograph, and, if there were indications, also periapical radiographs. Third molars were not included in the registrations.

Assessment of caries experience

Coronal primary- and secondary caries and root caries were recorded based on clinical- and radiographic examinations.

Coronal caries: A diagnostic five-grade scale was used to grade the coronal primary caries lesions' depth of penetration into the tissue, according to the diagnostic grading criteria described by Amarante and co-workers (Amarante et al. 1998) (Appendix V). Coronal primary enamel caries lesions were registered as grade 1 or 2, and dentine caries lesions as grades 3, 4 or 5. Secondary caries lesions in dentine were recorded without grading, and were all classified as dentine caries.

Root caries: Caries lesions on tooth roots were graded according to the International Caries Detection and Assessment System (ICDAS) for root caries (Mendieta et al. 2009). Three states of the exposed root surfaces were recorded: 1) sound root surface without discolouration, 2) clearly demarcated area on the root surface with zero to minimal cavitation (< 0.5 mm), and 3) root surface with discolouration and cavitation (≥ 0.5 mm).

DMFT/S: Caries experience was calculated using the DMFT/S index in accordance with the criteria by the World Health Organization (WHO 2013), combining the recordings from both the tooth crown- and root surfaces (Table 2).

Table 2. Components of the DMF-system as used in the OM65 study.

D-component	Coronal dentine caries Root caries with ≥ 0.5 mm cavitation Root remnants
M-component	All missing teeth
F-component	All restorations* on coronal- and root surfaces

*Direct fillings and crowns, but not fixed dental prosthesis abutments

Assessment of periapical and endodontic conditions

Periapical radiographs were taken of all root-filled teeth, and of teeth with apical radiolucency, based on screening of the panoramic radiographs. One calibrated dentist (MTD) evaluated all periapical radiographs, using the ImageJ software (Schneider *et al.* 2012).

Assessment of periapical status: Periapical status was evaluated for root-filled teeth and teeth with AP using the periapical index (PAI) (Ørstavik *et al.* 1986). In this scoring system, the observer uses five reference radiographs to assign a score from 1-5, in order of absence to presence and increasing severity of disease. In cases of multi-rooted teeth, the score of the root with the highest PAI score was used. Apical periodontitis was defined as a PAI score of 3-5.

Apex-to-filling distance: The distance from the radiographic apex to the root filling was measured. For multi-rooted teeth, the largest apex-to-filling distance among the roots (over- and under-filling treated equally) was used, independent of the PAI score and homogeneity. The registration categories were as defined by Kirkevang and co-workers (Kirkevang *et al.* 2000). Satisfactory apex-to-filling distance was defined as a root filling ending inside the root canal, 0-3 mm from the radiographic apex.

Homogeneity of the root filling: The homogeneity of the root filling was evaluated using the visual scoring system developed by Jordal and co-workers (Jordal *et al.* 2014). In this scoring system, the observer uses four reference radiographs to assign a score from 1-4, in order of absence to presence and increasing amount of voids in the root filling. For multi-rooted teeth, the highest homogeneity score among the roots was used, independent of the PAI score and apex-to-filling distance. Only homogeneous root filling (score 1) was defined as satisfactory.

Assessment of salivary status

The participants were instructed to refrain from eating, drinking, and smoking for at least 1 h before the clinical examination. Standardized sialometry and recording of clinical oral dryness score were performed on all participants between 8 am and 3 pm. The saliva collection cups were pre-weighed and chilled on ice, and saliva samples were weighed after sample collection.

Collection of unstimulated whole saliva (UWS): Participants were instructed to sit relaxed and swallow any saliva in their mouth. The participants were then asked to drool passively into a saliva collection cup for 5 min. Participants were instructed to spit into the saliva collection cup first in the event of their needing to swallow during collection. After 5 min, the participants were asked to spit any remaining saliva into the test cup. A density of 1 g/ml saliva was assumed when calculating the UWS secretion rate. Pathologically low salivary secretion rate, hyposalivation, was defined as a salivary secretion rate of ≤0.1 ml/min for UWS (Anttila *et al.* 1998, Vitali *et al.* 2002).

Collection of stimulated whole saliva (SWS): The participants were first instructed to chew on a paraffin wax tablet (Ivoclar Vivadent AG, Schaan, Liechtenstein) for 30 s, and to swallow the saliva that was produced. Participants were then instructed to continue chewing on the wax tablet for a further period of 5 min and to regularly spit out all saliva produced into a saliva collection cup. Pathologically low salivary secretion rate, hyposalivation, was defined as a salivary secretion rate of ≤ 0.7 ml/min for SWS (Anttila *et al.* 1998).

Clinical oral dryness: The Clinical Oral Dryness Score (CODS) was used to visually identify and quantify oral dryness (Osailan *et al.* 2012, Jager *et al.* 2018). Ten signs of oral dryness were evaluated (score range 0-10; higher scores represent more severe dryness), including mirror tests and visual signs of mucosal wetness, presence and frothiness of saliva, and presence of cervical caries and debris (Appendix VI). This examination was performed after UWS sampling and before SWS sampling.

Assessment of subjective oral dryness: The questionnaire included questions assessing subjective oral dryness; Xerostomia was assessed using the standardized question 'How often does your mouth feel dry?' (Thomson *et al.* 1999, Thomson *et al.* 2006) (Appendix IV). Symptoms of dry mouth were assessed further using the Summated Xerostomia Inventory-Dutch Version (SXI-D), which contains five questions related to dry mouth (Appendix IV). The SXI-D sum score ranges between 5 and 15, with a higher score representing an increased number of symptoms and/or an increased frequency of symptoms related to dry mouth (Thomson *et al.* 2011).

Statistical analysis

The statistical analyses were performed using STATA (Stata version 16.1; College Station, TX, USA). In order to detect and report oral conditions with a prevalence of 10%, and the possibility for longitudinal follow-up, the final sample size estimate was 450 individuals. The outcome- and explanatory variables and the statistical methods used in the present papers (I-III) are shown in Table 3.

Table 3. Overview of outcome- and explanatory variables, and statistical methods

Outcome variables	Explanatory variables	Statistical methods
Paper I		
• Mean/median DMFT/S (sum score and separate components) • Prevalence of having > 0 decayed teeth (DT)	• Gender • Country of birth • Education level • Financial capacity • Smoking • Dental attendance pattern • Toothbrushing • Sugar intake • Hyposalivation (UWS)	• Mann–Whitney U-test • Chi-square test • Logistic regression
Paper II		
• Prevalence of having ≥ 1 teeth with untreated (primary) AP • Prevalence of having ≥ 1 root-filled teeth • Prevalence of having ≥ 1 teeth root-filled teeth with AP • Prevalence of untreated AP (on tooth level) • Prevalence of root-filling (on tooth level) • Prevalence of root-filling with AP (on tooth level)	• Gender • Education level • Dental attendance pattern • Smoking • Number of remaining teeth • Tooth group and jaw • Quality of root filling (Apex-to-filling distance and homogeneity)	• Chi-square test • Logistic regression
Paper III		
• Salivary secretion rate (UWS and SWS) (mL/min) • Prevalence of hyposalivation (UWS and SWS) • Clinical Oral Dryness Score (CODS) • Prevalence of xerostomia (frequently/always) • Summated Xerostomia Index (SXI) score	• Gender • Education level • Smoking • Number of medications • Type II diabetes • Rheumatic disease • Radiation head/neck	• Kruskal-Wallis ANOVA and Mann-Whitney U-test • Spearman's rank-order correlation • Chi-square test and Fischer's exact test • Linear regression • Logistic regression

UWS = unstimulated whole saliva

SWS = stimulated whole saliva

Ethical considerations

The OM65 study was approved by the Norwegian Regional Committee for Medical and Health Research Ethics (REK 2018/1383) and was performed in compliance with the tenets of the Declaration of Helsinki.

Participation in the present study was voluntary, and the participants had the right to withdraw from the study at any stage. When individuals were telephoned and asked if they were interested in participating in the study, a pre-written invitation guide (Appendix VII) was used to prevent the person feeling pressured during the conversation. All participants signed a written informed consent form (Appendix VIII) prior to the examination, with information about the purpose, benefits, risks, and funding of the study. The main benefit for the participants was receiving a free, comprehensive oral examination and feedback. After the examination, the participants received written information (Appendix IX) about relevant findings from the examination, as well as a CD with the radiographic images.

Data confidentiality was ensured by storing personal data, the collected dental records, and the coupling key in separate files. Furthermore, all data-files were created, stored, and analysed in TSD. TSD is designed for storing and post-processing sensitive data in compliance with the Norwegian "Personal Data Act" and "Health Research Act". TSD provides virtual servers, backup-systems, storage-systems, high performance computing facility and databases all confined within in a highly secured environment.

It is an important ethical consideration that potential harm to the study participants should be kept to an absolute minimum. Panoramic and intraoral radiographs were taken of all participants, which exposed the participants to a certain amount of radiation. However, the radiographic examinations were necessary for the conduction of the present cross-sectional study. The bitewings radiographs were needed for the detection and grading of caries lesions, and the panoramic radiographs were necessary to identify all root-filled teeth and teeth with apical radiolucency, for further examinations using periapical radiographs. The radiographs were also used for other purposes in the OM65 project, such as the evaluation of periodontal conditions (Sødal *et al.* 2022). In Norway, panoramic radiographs are not taken regularly at dental routine check-ups. Thus, the radiographs taken could be beneficial for the study participants as they were given the radiographic images at the end of the examination (to bring to their dentist if needed). The participants were informed about any conditions detected during the clinical or radiographic examinations that needed follow-up or treatment. Considering these factors, we believe that the advantages of study participation were in proportion with the potential disadvantages (The Health Research Act, chapter 5).

Summary of results

This thesis describes caries experience (Paper I), periapical and endodontic status (Paper II), and salivary status (Paper III) in 65-year-old Oslo-citizens. The characteristics of the study sample are presented in Table 4. The prevalence estimates for enamel- and dentine caries, primary- and post-treatment AP, and xerostomia and hyposalivation are shown in Figure 2.

Table 4. Characteristics of the study sample

Variables	**n (%)**
All	457 (100)
Gender	
Male	236 (52)
Female	221 (48)
Country of birth	
Western	414 (91)
Non-western	43 (9)
Education level	
Higher education	305 (67)
Basic education	152 (33)
Postponed dental treatment due to expenses	
No	384 (84)
Yes	73 (16)
Number of medications	
0	124 (27)
1-3	216 (47)
≥4	117 (26)
Radiation therapy head/neck	
No	450 (98)
Yes	7 (2)
Diabetes type II	
No	426 (93)
Yes	31 (7)
Rheumatic disease	
No	401 (88)
Yes	56 (12)
Smoking	
Never	197 (43)
Former	210 (46)

Current	50 (11)
Dental visits	
Regular	405 (89)
Irregular	52 (11)
Toothbrushing	
≥ twice daily	386 (84)
< twice daily	71 (16)
Sugar intake	
≤ twice a week	239 (52)
< twice a week	218 (48)

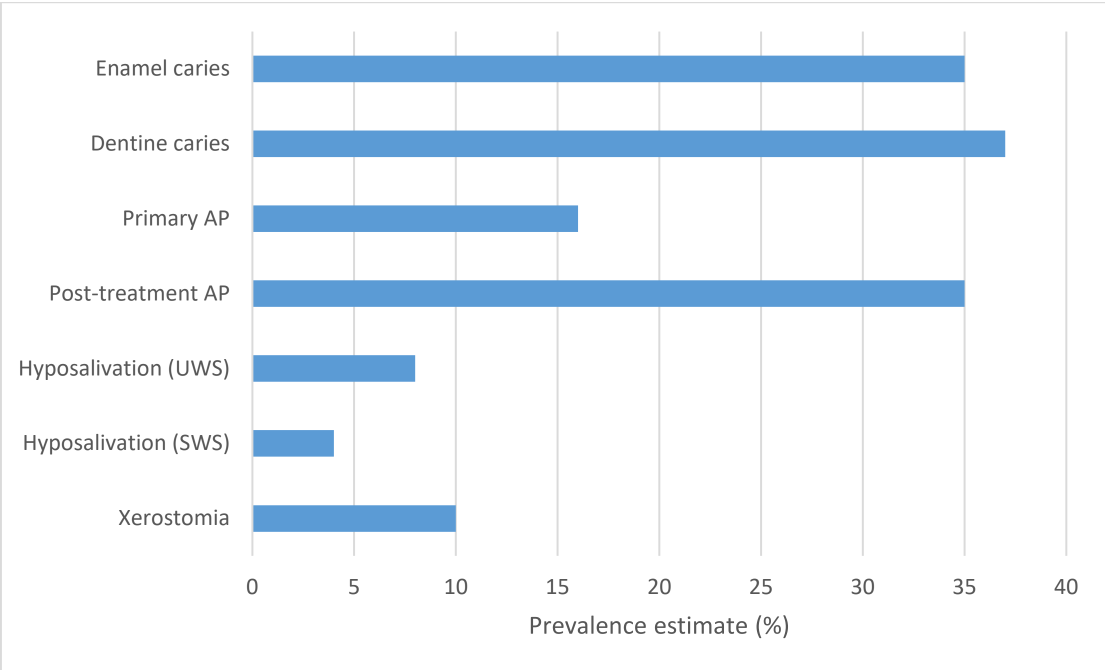

Figure 2. Prevalence estimates for a selection of oral conditions in a sample of 65-year-olds Oslo-citizens. AP = apical periodontitis. UWS = unstimulated whole saliva. SWS = stimulated whole saliva.

Paper I

Caries experience and risk indicators among 65-year-olds in Oslo, Norway

Overall, the mean number of teeth was 25 (SD: 4), the mean number of exposed root surfaces was 25 (SD: 18), and the mean DMFT was 19.4 (SD: 4.7). Thirty-seven percent of the individuals had at least one decayed tooth (DT > 0), and the mean number of filled teeth (FT) was 16.1 (SD: 5.4). The prevalence of enamel caries was 35%, and the prevalence of the other caries classifications was as follows: primary coronal dentine caries 12%, secondary coronal caries in dentine 33%, root caries without cavitation 17%, and root caries with cavitation 7%. Bivariate analyses showed that male gender, non-western country of birth, basic education level, irregular dental visiting pattern, toothbrushing less than twice daily, and hyposalivation (UWS) were risk indicators of having decayed teeth ($DT > 0$) (Chi-square test, $p < 0.05$). Multivariable logistic regression analysis showed that when all the explanatory variables were included into one model, male gender (OR: 1.8, 95% CI: 1.2-2.7), basic education (OR: 1.9, 95% CI: 1.2-2.9), dental attendance pattern (OR: 2.2, 95% CI: 1.0-4.8), and hyposalivation (OR: 2.2, 95% CI: 1.1-4.5) were significant risk indicators for having decayed teeth ($p < 0.05$).

Paper II

Periapical and endodontic status among 65-year-old Oslo-citizens

AP was present in 45% of the individuals. Sixteen percent of the individuals had untreated AP and 38% had at least one root-filled tooth with AP. Ten percent of the individuals had three or more teeth with AP. Sixty-six percent of the individuals had one or more root-filled teeth, and 25% of the individuals had three or more root-filled teeth. The presence of untreated AP was associated with a decreasing number of remaining teeth (logistic regression, $p < 0.05$). The presence of untreated AP was associated with basic educational level, irregular dental attendance, and being a current smoker (Chi-square test, $p < 0.05$). However, only current smoking was significant in the multivariable logistic regression analysis ($p < 0.05$). In the present study, 48% of root-fillings had satisfactory apex-to-filling distance and homogeneity. Thirty-five percent of the root-filled teeth had AP, and AP was more prevalent in teeth with too short apex-to-filling distance (53%) or unsatisfactory root filling homogeneity (46%) (logistic regression, $p < 0.05$). Having root-filled teeth with AP was not associated with any of the sociodemographic or behavioural variables.

Paper III

Xerostomia and hyposalivation among a 65-yr-old population living in Oslo, Norway

Ten percent of respondents reported xerostomia (Figure 2). The median Summated Xerostomia Index (SXI) score was 6 (interquartile range (IQR): 5–7) and the median Clinical Oral Dryness Score (CODS) was 2 (IQR: 1–3). The median unstimulated whole saliva (UWS) secretion rate was 0.34 ml/min (IQR: 0.20–0.53) and the median stimulated whole saliva (SWS) secretion rate was 1.74 ml/min (IQR: 1.24–2.38). Eight percent of the participants had pathologically low UWS secretion rate, and 4% had pathologically low SWS secretion rate. Three percent of the study participants had both xerostomia and hyposalivation with respect to UWS. Xerostomia was significantly associated with the use of ≥4 medications, having rheumatic disease, and having received radiation therapy to the head/neck region (multivariable logistic regression, $p < 0.05$). Hyposalivation, with respect to both UWS and SWS, was significantly associated with the use of ≥4 medications and type II diabetes (Chi-square/Fischer's exact test, $p < 0.05$).

Discussion

General methodological considerations

Target population, source population and study sample

To discuss the representativeness of the study results, I would like to define some of the relevant concepts. The target population is the population to which conclusions are to be generalized (Benestad & Laake 2015). The target population in the current thesis was “the young-elderly”, or in other words, individuals at the beginning of old age, with common features, some of which are presented in the ‘Background’ section. Thus, in this case, although the present target population did not have strictly defined criteria, we sought to target a group from which oral data will be valuable when planning geriatric oral care for the next decades. The source population is defined as a subset of the target population, obtained by applying certain selection criteria. It will in most cases differ somewhat from the target population for practical reasons. The present source population was 65-year-olds in Oslo, Norway, from which we randomly drew the study sample and finally obtained 460 study participants.

Internal validity

Internal validity refers to the generalization of results to the source population (Benestad & Laake 2015) and may be compromised by several factors which are discussed below.

The cross-sectional study design
The present thesis is based on an epidemiological cross-sectional study (the OM65 study), that aimed to describe the prevalence of several oral health parameters, as well as identify risk indicators for disease. Risk factors may increase the likelihood that a certain outcome will occur. Since cross-sectional studies, by definition, have no dimension in time, the associations identified cannot support conclusions on causal relationships (Benestad & Laake 2015). However, the associations found between the outcomes and explanatory variables represent risk indicators for disease. In principle, a bivariate analysis is “adequate” to identity a risk indicator. However, in this work, multivariable analyses were also performed in order to explore the interrelation of the risk indicators.

Selection bias
The source population for the OM65 study was the general population of 65-year-olds living in Oslo. The response rate of 58% is comparable to previous studies with similar recruitment procedures (51-64%) (Kirkevang *et al.* 2001, Skudutyte-Rysstad & Eriksen 2006). Due to restrictions from the ethics committee, we were not permitted to ask non-responders why they declined to participate. Therefore, to explore potential selection bias, the gender distribution, education level, and country of birth in the study sample were compared with the reported data on 65-year-olds living in Oslo, retrieved from Statistics Norway. Although the gender distribution was similar, the proportion of participants with higher education and who had a Western country of birth in the present study sample was higher than in the source population (Table 1). Furthermore, it was found that oral diseases were more prevalent in individuals with only basic education and non-Western country of birth (Paper I and II). These population subgroups are also reported to have poorer general health (Abebe 2010, Syse *et al.* 2022). Thus, overrepresentation of individuals with higher education and

Western country of birth may have resulted in underestimation of the measured prevalence of oral diseases in the present study.

Self-reported data

A self-administered questionnaire was used to assess sociodemographic-, general health- and behavioural factors, and symptoms of oral dryness. Therefore, the validity of these data is dependent on the responder's interpretation of the questions, and their ability to recall or identify the requested information. If this possible data inaccuracy is different for "cases" and "non-cases", the recall is considered biased (Coughlin 1990). For instance, if individuals with dry mouth symptoms are better at recalling their medications than their counterparts, this may result in a falsely strong association between xerostomia and number of medications taken. Furthermore, socially undesirable habits, such as smoking or eating unhealthy food, tend to be underreported (Coughlin 1990).

Reliability of the data

The internal validity of the results can also be influenced by the consistency of the data collectors (McHugh 2012). Two calibrated dentists performed the clinical and radiographic bitewing examinations in the present project (OM65), and both were present during all examinations. For calibration of the recording of caries experience (Paper I), seven of the patient examinations (840 tooth surfaces) were performed by both examiners. The kappa value was 0.95 (95% CI: 0.94-0.96) for inter-observer agreement on decayed, missing and filled surfaces, indicating almost perfect agreement (McHugh 2012). Testing of intra-observer reliability was not performed because this would have required an additional visit for the participants. For Paper II, one observer evaluated all periapical radiographs and was prepared for using the PAI system by calibration against a reference set of 100 radiographic images of teeth. The weighted kappa value was 0.73 (95% CI 0.71–0.77) for reproducibility compared to the reference set and 0.72 (95% CI 0.69-0.75) for intra-observer reproducibility, indicating good agreement (Landis & Koch 1977).

Statistical confounding

The internal validity may also be compromised by statistical confounding (Benestad & Laake 2015). The sample size obtained was adequate according to the sample size calculation. However, some of the conditions studied, such as hyposalivation (Paper III), turned out to be less prevalent than 10%. Moreover, the small sample size of some of the subgroups of interest weakened the power of the analysis. For instance, only seven individuals had undergone radiotherapy to the head/neck region (Paper III), and even though that group had the highest prevalence of hyposalivation compared to the other subgroups analysed, the results were not statistically significant.

In the present papers (I-III), the level of significance was set to $p < 0.05$, and it was decided to base the discussion on this chosen level of significance, and not to present and discuss other p-values. However, it may be discussed if associations with p-values slightly above 5% could also have been highlighted in the result- and discussion sections in the papers.

Data caption

The development of the Oral Data Collector brought several benefits to the project. It had an interactive interface which allowed the "tooth surfaces" to change colours according to the data registrations (e.g., typing 11 for amalgam filling changed the colour to dark grey). This, together with no need for manual transfer of data from handwritten paper forms, minimized the risk of errors when entering data (Carvalho *et al.* 2011). Moreover, avoiding handwritten data capture was a huge time-saver, considering the large sample size and high number of oral health parameters in the OM65 study. If there were corrections that had to be made to the individual records (excel-files), the dataset could easily be updated by running the Python program again after the corrections had been made. Thus, although the development of the Oral Data Collector required a high initial time investment, it almost certainly increased the reliability of the data in the present study.

External validity

External validity relates to the generalization of conclusions from the source population to the wider target population. The fact that "the young-elderly" is not a strictly defined term, makes this discussion somewhat challenging.

A national study indicated that there are considerable geographical differences in Norway with respect to dental status in the population aged 67 years and older, with a marked better dental status in the south of the country compared with the north (Henriksen *et al.* 2003). This difference was confirmed when comparing the mean number of missing teeth in the present study compared to the corresponding figures reported from the central (Rødseth *et al.* 2022), and northern (Oscarson *et al.* 2017) parts of Norway, although the mean number of decayed teeth in Oslo compared to the more northern regions was similar.

Ettinger and co-workers described three different patterns of dental treatment need where they distinguished between rural, urbanising, and industrialised societies (Ettinger 1993). Norway belongs to the latter group, and the present results can therefore be considered relatively comparable with other industrialised nations in Europe, North America, Australia, and Japan.

As mentioned previously, several studies define the young-elderly (or the young-old) as the age group ranging from 65-74 (Jordan *et al.* 2014, Koyama *et al.* 2016, Komiya *et al.* 2022). To what extent the present results also can be generalized to the population of 66 to 74-year-olds in Oslo depends on the level of heterogeneity in oral health status within this age group. Considering that dental caries and its sequels accumulate with age, and that the persistence of xerostomia from 65 to 75 years of age has been reported to be high (Johansson *et al.* 2022), one can assume that the prevalence estimates of oral diseases in the present study would have been higher if the source population of 65-74 years had been chosen to represent "the young elderly". This assumption is supported by a cross-sectional study from Norway that reported a difference of 5.3 surfaces in the DMFS score between age groups 65-69 years and 70-74 years, however, only a 0.4 tooth difference in the DMFT score (Mulic *et al.* 2020).

Specific methodological considerations

Paper I

Caries experience and risk indicators among 65-year-olds in Oslo, Norway

Diagnostic methods

Based on both clinical and radiographic examinations, a diagnostic five-grade scale was used to grade the coronal primary caries lesions, according to the Espelid & Tveit diagnostic criteria described by

Amarante and co-workers (Amarante *et al.* 1998). Other similar Norwegian studies published recently (Oscarson *et al.* 2017, Mulic *et al.* 2020, Rødseth *et al.* 2022) have used the same caries diagnostic criteria. The WHO criteria (Petersen 2013) are the most frequently used in previous epidemiological surveys (Carvalho & Schiffner 2019). In contrast to the diagnostic criteria used in the present study, caries detection according to the WHO criteria are performed at the cavitation level. However, the International Caries Detection and Assessment System (ICDAS-II) (Ismail *et al.* 2007), like the Espelid & Tveit criteria, also includes non-cavitated lesions. On the other hand, unlike the diagnostic criteria used in the present work, the WHO criteria and the ICDAS criteria are solely based on visual inspection. It has been argued that ICDAS-II is suitable as caries registration method in populations with high caries prevalence and progression rate, whereas methods including radiography are preferable when the caries prevalence is low, due to a higher specificity and negative predictive value of radiographic methods (Mitropoulos *et al.* 2010). Given that the mean DT was 0.8 in the present study sample, it can be considered a low-risk population, where use of radiographic methods provide additional diagnostic value.

The DMF index was used for measuring caries experience according to the description by WHO (Petersen 2013). All missing teeth were included in the DMF score. However, this may have resulted in an overestimation of caries experience, since some of the teeth may have been missing due to other reasons, e.g., periodontitis or orthodontic treatment. On the other hand, excluding bridge abutments from the DMF score may have resulted in an underestimation of caries experience, as it is likely that a proportion of the bridge abutments were 'filled' or 'decayed' before serving as a bridge abutment.

Cut-off value for number of caries lesions

One of the main outcomes was caries prevalence, i.e., having at least one caries lesion. Studying the prevalence of caries at this threshold facilitated the comparison with other studies that have used the same threshold. However, it may be discussed if this cut-off was suitable for identifying high-risk groups that need more attention from the health authorities, and if the subsamples with a higher number of caries lesions also should have been in focus.

Paper II

Periapical and endodontic status among 65-year-old Oslo-citizens

Radiographic examination

The prevalence estimate of AP may have been affected by the radiographic method used. In the present study, panoramic imaging was used to detect root-filled teeth and non-root filled teeth with periapical radiolucencies, and periapical radiographs were then taken to further assess these teeth using PAI, in accordance with a similar study on 35-olds in Oslo (Skudutyte-Rysstad & Eriksen 2006). However, cone beam computed tomography (CBCT) may have higher diagnostic accuracy in detecting AP than periapical radiography (Kanagasingam *et al.* 2017). Nevertheless, periapical radiography holds an effective validity (Lo Giudice *et al.* 2018, Ramis-Alario *et al.* 2021), inflicts less radiation to the study participants, and is less time consuming, all beneficial factors in larger cross-sectional studies. The use of periapical radiographs also facilitates the assessment of periapical status using PAI, since the reference radiographs used in this scoring system are periapical radiographs.

The PAI score and technical quality of root filling

The PAI score was used to assess periapical status as a means of facilitating comparison with the numerous studies that have used this scoring system (Skudutyte-Rysstad & Eriksen 2006, Frisk *et al.* 2008, López-López *et al.* 2012, Kirkevang *et al.* 2014). Estimation of the endodontic treatment needs based on the PAI score registrations in a cross-sectional study may be inaccurate because one cannot distinguish between healing and progressing cases. On the other hand, one study showed that the baseline PAI score had a significant predictive value for periapical status including tooth extraction over a 10-year period (Kirkevang *et al.* 2017). Hence, the scoring of PAI may provide valuable information about the prognosis of root-filled teeth that may, when analysed, influence inferences about the future treatment needs.

The technical quality of root fillings was measured by apex-to-filling distance and homogeneity score of the root filling, which may be subjected to inaccuracies in measurement. Unlike for the PAI score system, a structured calibration course does not exist for the scoring of homogeneity (Jordal *et al.* 2014).

Separate analyses for primary and post-treatment AP

Primary and post-treatment AP were treated as separate outcomes in the present study. Previous studies, that mainly have analysed the overall prevalence of AP, have come to different conclusions regarding the relationship between socioeconomic status and having AP (Aleksejūnienė *et al.* 2000, Kirkevang & Wenzel 2003, Frisk & Hakeberg 2006). In the present study, having only basic education was found to be a risk indicator for having primary apical periodontitis, but not for having post-treatment apical periodontitis. In the majority of the studies on prevalence and risk indicators of AP, primary and post-treatment AP have been treated as one category. Since extraction therapy seems to be the treatment with the highest guarantee for eliminating AP, while epidemiological studies indicate that the healing rate after endodontic treatment is 48-75% (Skudutyte-Rysstad & Eriksen 2006, Frisk *et al.* 2008, Razdan *et al.* 2022), endodontic treatment can be expected to result in a higher frequency of apical periodontitis compared to extraction. This might explain why individuals with low socioeconomic status (measured by education level), who more frequently choose tooth extraction over a conservative approach, may be found to have a lower prevalence of AP (Kirkevang & Wenzel 2003, Frisk & Hakeberg 2006) despite having higher prevalence of caries. Therefore, whether overall apical periodontitis prevalence is associated with low socioeconomic status in individual studies may depend on the prevalence of low socioeconomic status in the study sample. Thus, treating primary and post-treatment AP as separate outcomes may provide more accurate information about the risk indicators for AP.

Paper III

Xerostomia and hyposalivation among a 65-yr-old population living in Oslo, Norway

Saliva collection

Even though the participants were instructed to drool passively into the test cup, the impression was that the majority of the participants spat rather than drooled into the test cup. It may be speculated that drooling felt wrong according to social code, thus was avoided unintentionally by some participants. Nonetheless, the result was that most of the participants spat several times during or at the end for the 5 min saliva-collection period. For those who spat several times, this may have had some degree of stimulating effect on the salivary secretion. While this may have increased the estimated median salivary secretion rate, and even resulted in underestimation of hyposalivation prevalence, the draining method have been shown to produce similar results compared to the spitting method (Navazesh & Christensen 1982).

Although the collection time of 15 min for unstimulated whole saliva is required in connection with the diagnosis of Sjögren's syndrome (Vitali *et al.* 2002), a collection time of 5 min was chosen in the present study. Several comparable epidemiological studies have used the 5 min collection time for measuring both unstimulated- and stimulated whole saliva secretion rate (Närhi *et al.* 1993, Anttila *et al.* 1998, Alaraudanjoki *et al.* 2016). Moreover, a 15 min saliva collection time could not have been performed in the OM65 study due to time constraints, as the study also included several other clinical examinations.

A circadian rhythm for UWS with lower secretion rates early in the morning compared with late in the afternoon has been described (Dawes & Ong 1973). One study has shown that individuals with pathologically low UWS (≤0.1 mL/min) displayed an increase in UWS secretion rate from 7:30 am to 11:30 am, with a significant proportion of the subjects surpassing the limit for hyposalivation at the later measurement time (Flink *et al.* 2005). Therefore, the fact that the saliva collection in the OM65 study was performed between 8:00 am and 3:00 pm may have resulted in an underestimation of the true prevalence of hyposalivation.

Cut-off values for dry mouth

The elected measures and cut-off values for disease definitions may greatly influence the prevalence estimate of a disease and should therefore be well justified. For the present work, the main argument for the choice of cut-off values was that the results should be comparable to other relevant studies.

There is a general agreement in the literature about the cut-off value of ≤ 0.1 mL/min for pathologically low UWS secretion rate (hyposalivation) (Österberg *et al.* 1984, Sreebny & Valdini 1988, Anttila *et al.* 1998, Vitali *et al.* 2002), and some authors have justified this choice by a positive correlation with xerostomia (Österberg *et al.* 1984, Sreebny & Valdini 1988). This argument should, however, be questioned, since the clinical value of finding the salivary secretion rate that best predicts xerostomia is limited, as it is easier to ask the patient about their symptoms than to measure their salivary secretion rate. The salivary secretion rate that is closely associated with the clinical signs of salivary gland hypofunction, such as dental caries, fungal infections, lip dryness etc., is more interesting in the context of the present thesis. This association has been investigated by Navazesh and co-workers, who concluded that the discriminant analysis was most successful in separating groups with and without salivary gland hypofunction complications at values between 0.12 and 0.16 mL/min UWS secretion rates (Navazesh *et al.* 1992). Therefore, the cut-off value for pathologically low UWS in the present thesis may have been too low, and in that case, resulted in underestimation of the hyposalivation prevalence.

In the literature, there is a large variation in cut-off values used for pathologically low stimulated whole saliva (SWS) secretion rate, ranging from ≤0.1 mL/min to 0.8 mL/min with the paraffin wax chewing stimulated method (Österberg *et al.* 1984, Närhi *et al.* 1993, Caplan & Hunt 1996, Anttila *et* *al.* 1998, Kongstad *et al.* 2013, Alaraudanjoki *et al.* 2016, Iwasaki *et al.* 2016). However, xerostomia and the clinical complications of salivary gland hypofunction are more related to the UWS than the SWS secretion rate (Sreebny & Valdini 1988, Navazesh *et al.* 1992).

Discussion and clinical implications of main results

A clear trend towards a higher retention of teeth as we grow older has previously been reported (Skudutyte-Rysstad & Eriksen 2007, Frisk *et al.* 2008, Schmoeckel *et al.* 2021). Results from the present study showed a higher mean number of remaining teeth compared to several other European countries (Carvalho & Schiffner 2019). The social inequalities in health (Syse *et al.* 2022), and the high proportion of individuals with higher education in Norway compared to other European countries (World Economic Forum 2017), may partly explain this difference. In addition, the utilization of dental health services in Norway is high (Grytten *et al.* 2012). However, considering the increased retention of teeth in the elderly, preventive strategies should be emphasised by both the individuals themselves as well as the health authorities.

Approximately one third of the study sample had untreated dentine caries (Paper I). The distribution of caries was skewed; while 5% of the participants had ≥ 4 dentine caries lesions, 82% had no or one dentine caries lesion. However, considering the high prevalence of restored teeth in the present study sample, and that enamel caries- and coronal secondary dentine caries lesions constituted the largest proportion of the total burden of decayed teeth, it will be important to increase the emphasis on caries preventive measures and to ensure maintenance of restored teeth in this birth cohort. Furthermore, dental clinicians should focus on optimizing cleaning accessibility at these sites, such as to detect and improve faulty restoration margins and insufficient proximal contacts causing food impaction.

In the present study, the majority of the participants had at least one root-filled tooth (66%) (Paper II). Almost half of the individuals had at least one tooth with AP, however, the distribution of AP was skewed. Studies have shown that the most decisive risk indicator for AP is an existing root-filled tooth (Kirkevang *et al.* 2004, Meirinhos *et al.* 2020), as supported by the considerable frequency of AP in root-filled teeth in the present study. Therefore, it has been recommended that root-filled teeth should always undergo radiographic examination if the patient is new to the dentist (Kirkevang *et al.* 2004). Currently, there is no digital system for sharing patient records across dental offices. Therefore, to avoid taking unnecessary radiographs, and to enable comparisons between new and old radiographs following this recommendation, it is advisable for patients to see the same dentist, or at least attend the same dental office with a shared patient record. Furthermore, the association found between poor technical quality of the root filling and AP suggests that the performance of endodontic treatment still has great potential for improvement.

Compared to post-treatment AP, primary AP constituted a smaller burden of the overall prevalence of AP, although not negligible (16%) (Paper II). In general, untreated periapical lesions may be attributed to the absence of symptoms, the lack of an adequate endodontic and radiographic evaluation, or an unmet need with respect to treatment of detected periapical lesions (Pak *et al.* 2012). Regular dental check-ups are necessary for the early detection of caries lesions, in order to prevent pulpal involvement. They may also enhance the prognosis of endodontic treatment if periapical lesions are treated as soon as possible, since the prognosis for the successful treatment of periapical lesions is poorer for more serious periapical lesions (Pak *et al.* 2012). However, in the present study, the association between primary AP and an irregular dental attendance pattern was, surprisingly, no longer significant after the adjustment for smoking habits.

The present results showed that the prevalence of dental caries and primary AP in this young-elderly population was, at least partly, determined by the level of education (Paper I and II). In addition, dental caries was more common in individuals that had postponed dental treatment due to limited financial capacity. These findings suggest social inequality in oral health of the studied population. Although the disparities may be explained by differences in oral health behaviour (Schwendicke *et al.* 2015), theories for *why* people with low socioeconomic status display less advantageous health behaviour may be related to more complex material, cultural and psychosocial circumstances (Sisson 2007). One factor may be limited access to dental health services due to the cost of treatment, assuming that regular dental attendance improves oral health. This theory was supported by the present findings, as having at least one caries lesion was associated with irregular dental attendance. Therefore, ensuring access to dental health services for elderly people may be an important priority in the prevention and treatment of caries in this age group. A model for organizing and financing dental health services for elderly people so that they have good and equal access to services has been suggested, recommending a change from a purely market-based organisation of dental health services towards a system for universal health coverage (Grytten & Holst 2013, Winkelmann *et al.* 2023).

In the present study, the prevalence of xerostomia and hyposalivation were low (Paper III). However, dry mouth was more common among those who were affected by diseases or treatment that may directly or indirectly affect the function of salivary glands, e.g. diabetes type II (Chavez *et al.* 2001, Carramolino-Cuellar *et al.* 2018), rheumatic disease (Ohara *et al.* 2016), radiation therapy to the head/neck region (Eisbruch *et al.* 1999), or the use of several medications. Since multipharmacy related to deteriorating general health becomes more prevalent with older age, medication-induced dry mouth is expected to increase in this population with time. Twenty-five percent of the study participants already uses ≥ 4 medications, although the type and duration of use were not assessed in the present study. In a 3-year longitudinal study of independent-living adults who were 50 years and older, the incidence of xerostomia was 19% in the age group 50-64 years (Locker 1995). The risk of xerostomia at follow-up increased with an increasing number of medications used at baseline. Of those taking ≥3 medications, 33.8% became xerostomic during the observation time. In the current study, 38% used ≥3 medications, and 25% used ≥ 4 medications. These figures may indicate that the incidence of xerostomia can be expected to increase as the young-elderly will age. Furthermore, in the present study, having dentine caries was more common in individuals with hyposalivation (Paper I). It is therefore important for clinicians to be aware of the risk indicators, clinical signs, and symptoms of dry mouth, not only in the most senior patients, but also in the young-elderly. Moreover, individuals with dry mouth should pay special attention to caries preventive measures.

Concluding remarks and future perspective

The results presented in this thesis document epidemiological aspects of caries experience, periapical and endodontic status, and salivary status among 65-year-old Oslo-citizens from the year 2019.

The present findings indicated that the majority of 65-year-olds had almost complete dentitions, yet with few sound teeth due to a large amount of dental treatment. Dentine caries was present in approximately one third of the study sample. Furthermore, almost half of the participants had at least one tooth with apical periodontitis, and the majority of these cases were found in root-filled teeth. Hyposalivation and xerostomia were infrequent conditions in this young-elderly group.

The study also showed disparities in the prevalence of oral diseases, and several sociodemographic-, general health-, behavioural- and tooth-specific factors were identified as risk indicators. Moreover, data from the present work will provide a baseline for longitudinal studies in this age group, as these are more powerful in determining causal relationships. In addition, since the distributions of primary apical periodontitis and untreated dentine caries were skewed, exploring the risk indicators for having a larger disease burden may be an interesting subject for further analyses.

Based on this information on the oral health status of urban Norwegian 65-year-olds, and on the fact that this baby boom generation is entering old age, we can expect the demand for dental health services for the elderly to exceed that of previous generations. Hence, to enhance healthy oral ageing, especially for the care-dependent elderly, allocation of public resources will have to correspond with the changes in oral care needs in a society with a changing demography. Furthermore, a reduction in the proportion of the population in the workforce necessitates the development of more effective approaches for prevention of oral diseases.

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Appendices (I-IX)

Appendix I (Invitation letter)

UiO : **Universitetet i Oslo**
Det odontologiske fakultet
Institutt for klinisk odontologi

Invitasjon til deltakelse i OSLOMUNN65-studien

Til ……………………………………………………………………

Du inviteres til å delta i et forskningsprosjekt i regi av Det Odontologiske fakultet (Tannlegehøyskolen) ved Universitetet i Oslo, der formålet er å kartlegge munnhelsen hos dagens 65-åringer i Oslo. Du er tilfeldig valgt ut som deltaker siden du i løpet av 2018/2019 vil fylle 65 år.

TANNHELSESJEKK

Prosjektet innebærer at du vil få en grundig undersøkelse av din orale helse og rådgivning om munn- og tannforhold. Denne vil blant annet omfatte røntgenbilder, spyttprøver, smak-og-luktprøver, men du kan også velge å kun delta i deler av undersøkelsen. Undersøkelsene vil være kostnadsfrie for deltakere.

Undersøkelsene vil bli utført av tannhelsepersonell med betydelig kompetanse på området og du vil få informasjon om eventuelle funn. Hvis vi gjør funn som trenger behandling, vil du få informasjon om dette.

Selv om du har fast tannlege og nettopp har vært til kontroll og føler at du ikke har noen problemer med tennene, håper vi at du ønsker å delta i undersøkelsen.

Undersøkelsen er helt smertefri og vil ta ca. 2 timer.

BIDRA TIL FORSKNING

Ved å delta i denne undersøkelsen bidrar du til å bringe ny og viktig kunnskap om oral helse blant den godt voksne befolkningen i Norge.

BEDRE TANNHELSETJENESTE

Informasjonen fra tannhelseundersøkelsen skal også brukes for å planlegge gode tannhelsetjenester for din generasjon i fremtiden.

FRIVILLIG DELTAKELSE OG MULIGHET FOR Å TREKKE SEG

Det er helt frivillig å delta i prosjektet. All innsamlet data om deg vil bli avidentifisert. Du kan når som helst trekke deg fra prosjektet og kreve å få slettet innsamlede prøver og opplysninger knyttet til deg.

HVOR FOREGÅR UNDERSØKELSEN?

Undersøkelsen foregår på vår klinikk ved Det Odontologiske fakultet (Tannlegehøyskolen), Geitmyrsveien 71, 0455 Oslo.

HVORDAN DELTA?

Du vil i løpet av 14 dager bli kontaktet med forespørsel om du ønsker å delta i prosjektet og eventuelt for å sette opp en timeavtale. Du har også ved den anledning mulighet til å stille spørsmål du måtte ha om prosjektet. For spørsmål kan prosjektleder kontaktes på telefon 22 85 21 42 / 402 16 758.

Du kan reservere deg mot å bli oppringt ved å sende mail (oslomunn65@odont.uio.no), SMS (tlf.nr: 402 16 758) eller ringe (tlf.nr: 402 16 758). Skriv ”Nei hilsen [fullt navn]”. Dine kontaktopplysninger vil da bli slettet fra vårt prosjekt.

Med vennlig hilsen

Lene Hystad Hove	My Tien Diep	Anne Thea Tveit Sødal
Prosjektleder	Stipendiat	Stipendiat

Avdeling for kariologi og gerodontologi
Postadr.: Postboks 1109 Blindern, 0317 Oslo
Besøksadr.: Geitmyrsveien 71, 0455 Oslo
Telefon: 40216758
E-post: oslomunn65@odont.uio.no

Appendix II (Oral Data Collector)

SALIVAPRØVE

USTIMULERT SALIVA 5 minutter	CODS		STIMULERT SALIVA 5 minutter	
Innveiing av kopp		g	Innveiing av kopp	g
Innveiing av kopp m/saliva		g	Innveiing av kopp m/saliva	g
Total mengde <u>ustimulert</u> saliva:	0	g	Innveiing <u>stimulert</u> saliva	0 g
Sekresjonshastighet:	0,00	mL/min	Sekresjonshastighet:	0,00 mL/min
Antall batcher som lagres:				

CODS

1	Positiv test
0	Negativ test

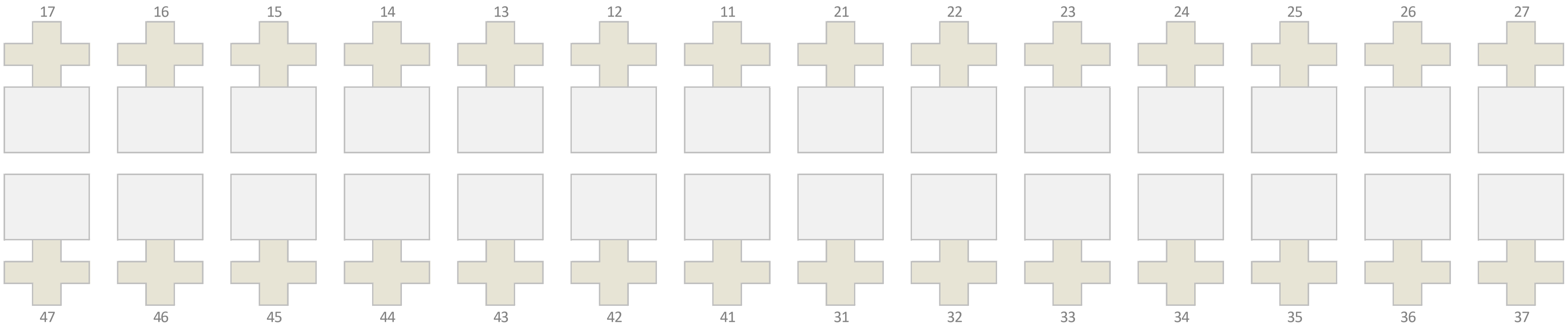
No.	Image	Sign	Interpretation
1		Mirror sticks to buccal mucosa	An additive score of 1 - 3 indicates mild dryness. May not need treatment or management. Sugar-free chewing gum for 15 mins, twice daily and attention to hydration is needed. Many drugs will cause mild dryness. Routine checkup monitoring required.
2		Mirror sticks to tongue	
3		Saliva frothy	
4		No saliva pooling in floor of mouth	An additive score of 4 - 6 indicates moderate dryness. Sugar-free chewing gum or simple sialogogues may be required. Needs to be investigated further if reasons for dryness are not clear. Saliva substitutes and topical fluoride may be helpful. Monitor at regular intervals especially for early decay and symptom change.
5		Tongue shows generalised shortened papillae (mild depapillation)	
6		Altered gingival architecture (ie. smooth)	
7		Glassy appearance of oral mucosa, especially palate	An additive score of 7 - 10 indicates severe dryness. Saliva substitutes and topical fluoride usually needed. Cause of hyposalivation needs to be ascertained and Sjögrens Syndrome excluded. Refer for investigation and diagnosis. Patients then need to be monitored for changing symptoms and signs, with possible further specialist input if worsening.
8		Tongue lobulated / fissured	
9		Cervical caries (more than two teeth)	
10		Debris on palate or sticking to teeth	

* S Osailan et al "Investigating the relationship between hyposalivation and mucosal wetness" (2011) Oral Diseases volume 17, Issue 1, Pages: 109–114

Test	Resultat
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Total score	0

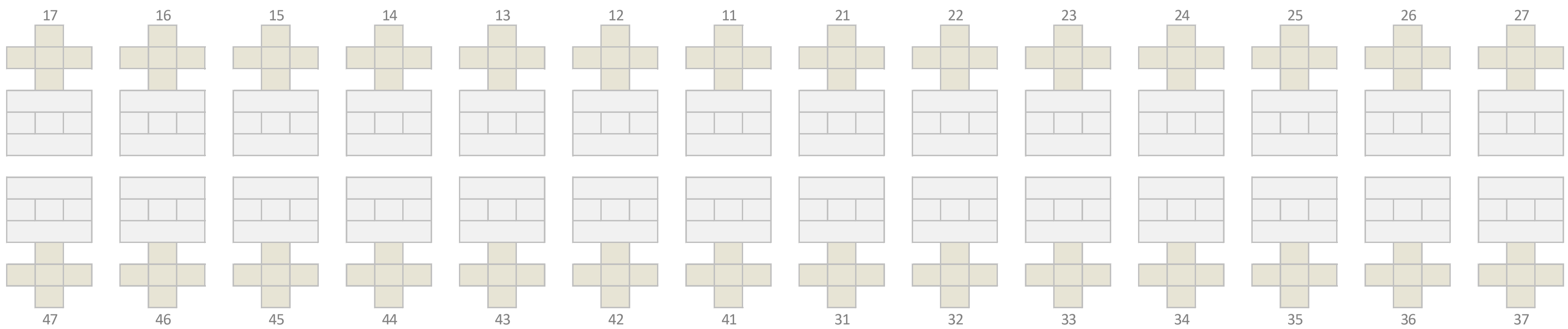
TANNSTATUS

0	Tilstedeværede	5	Broledd
1	Krone	6	Implantat
2	Rotrest	7	Protesetann
3	Bropilar	8	Ikke undersøkt
4	Kuspedekkende fylling	9	Manglende tann



KARIES

0	Intakt flate
1	Karies grad 1
2	Karies grad 2
3	Karies grad 3
4	Karies grad 4
5	Karies grad 5
6	Eksponert rotoverflate, frisk
7	Rotkaries uten kavitet(<0,5 mm substanstap)*
8	Rotkaries med kavitet(>0,5 mm substanstap)**
9	Midlertidig fylling
10	Tannfarget fylling
11	Amalgamfylling
12	Gull
13	Porselen
14	Manglende fylling/ fraktur av tann eller fylling
15	Midlertidig fylling med SK
16	Tannfarget fylling med SK
17	Amalgamfylling med SK
18	Gull med SK
19	Porselen med SK
20	Karies/rotrest
21	Ikke undersøkt
22	Manglende



*Avgrenset, misfarget område på rotoverflaten eller ved emalje-cementgrensen uten kavitet(<0,5 mm substanstap)

**Avgrenset, misfarget område på rotoverflaten eller ved emalje-cementgrensen med kavitet(>0,5 mm substanstap)

ENDO

Status
0 Ikke relevant*
1 Rotfylt
2 Ikke rotfylt (apikal lesjon på OPG)
9 Manglende tann

Periapikal index
0 Ikke relevant*
1 PAI score 1
2 PAI score 2
3 PAI score 3
4 PAI score 4
5 PAI score 5

Lengde fra apex
0 Ikke relevant*
1 <0 mm (surplus)
2 0-1 mm
3 1-2 mm
4 3-5 mm
5 >5 mm

Homogen rotfylling
0 Ikke relevant*
1 Tilfredsstillende rotfylling
2 Ikke tilfredstillende rotfylling

Kvalitet på toppfylling
0 Ikke relevant*
1 Tilfredstillende
2 Ikke tilfredstillende

Stift
0 Ikke relevant*
1 Ja
2 Nei

Approksimal støtte
0 Ikke relevant*
1 Dobbel
2 Enkel
3 Ingen
4 Bakerste tann (enkel)
5 Bakerste tann (ingen)

Antagonist*
0 Ikke relevant*
1 Ja
2 Nei

Kuspedekkende fylling
0 Ikke relevant*
1 Ja
2 Nei

Perkusjonsømhet
0 Ikke relevant
1 Ja
2 Nei

Palpasjonsømhet
0 Ikke relevant
1 Ja
2 Nei

*Relevante tenner: Rotfylte, tenner med synlig periapikal lesjon på OPG

8 Ikke undersøkt
9 Manglende tann

Tooth	Status	PAI	Lesjon (mm)	Lengde fra apex	Homogenitet	Kvalitet på toppfylling	Stift	Approksimal støtte	Antagonist	Kuspedekkende fylling	Palpasjon	Perkusjon
17												
16												
15												
14												
13												
12												
11												
21												
22												
23												
24												
25												
26												
27												
37												
36												
35												
34												
33												
32												
31												
41												
42												
43												
44												
45												
46												
47												

Appendix III (Relevant parts of the questionnaire, in Norwegian)

SPØRRESKJEMA OsloMunn65

Hvordan fylle ut spørreskjemaet?

Utfyllingen av skjemaet skal foretas ved at du setter et kryss i den 'boksen' ☐ som står for det svaret som passer, eller ved å skrive svar på de angitte 'streker' ………………….

Spør hvis noe er uklart.

NOEN GENERELLE SPØRSMÅL

KJØNN

- ☐ Mann
- ☐ Kvinne

FØDELAND:

…………………………………………

HVILKEN UTDANNING HAR DU FULLFØRT? KRYSS AV FOR HØYESTE UTDANNING

- ☐ Grunnskole
- ☐ 1-2 år i videregående skole
- ☐ 3 år i videregående skole
- ☐ Fagbrev eller svennebrev
- ☐ Høyskole/universitet, mindre enn 4 år
- ☐ Høyskole/universitet, 4 år eller mer

HVIS KREFT, HAR DU FÅTT STRÅLEBEHANDLING MOT HODE/HALSREGIONEN?

- ☐ Nei
- ☐ Ja

HAR DU FOR TIDEN NOEN SYKDOMMER?

- ☐ Nei
- ☐ Astma
- ☐ Annen lungesykdom
- ☐ Benskjørhet
- ☐ Blødersykdom
- ☐ Diabetes 1
- ☐ Diabetes 2

- ☐ Epilepsi
- ☐ Hepatitt
- ☐ HIV/AIDS
- ☐ Annen smittsom sykdom (inkl. MRSA)
- ☐ Hjerte/karsykdommer
- ☐ Høyt blodtrykk
- ☐ KOLS
- ☐ Kreft
- ☐ Mage/tarmsykdom
- ☐ Parkinsons
- ☐ Psykiske lidelser
- ☐ Revmatisk sykdom
- ☐ Spiseforstyrrelser
- ☐ Annet, spesifiser:………………………

HVOR MANGE ULIKE MEDISINER BRUKER DU?

………………………..

NOEN SPØRSMÅL OM RØYKING

RØYKER DU DAGLIG ELLER HAR DU NOEN GANG RØKT DAGLIG?

- ☐ Nei, jeg har aldri røkt
- ☐ Jeg har sluttet å røyke
- ☐ Ja, jeg røyke

NOEN SPØRSMÅL OM KOSTHOLD

HVOR OFTE INNTAR DU AV FØLGENDE MAT- OG DRIKKEVARER? (Sett kryss)

	Sjeldent/aldri	**1-2 ganger i måneden**	**1-2 ganger i uka**	**3-4 ganger i uka**	**Hver dag**	**Flere ganger daglig**

Varm drikke med sukker	☐	☐	☐	☐	☐	☐
Sukkerholdig brus, saft, sportsdrikk, næringsdrikk eller juice	☐	☐	☐	☐	☐	☐
Søtsaker som sjokolade, sukkertøy, godteri, is, etc.	☐	☐	☐	☐	☐	☐
Boller, kaker, kjeks	☐	☐	☐	☐	☐	☐
Syltetøy, marmelade, sjokoladepålegg	☐	☐	☐	☐	☐	☐
Yoghurt med sukker	☐	☐	☐	☐	☐	☐

NOEN SPØRSMÅL OM DITT RENHOLD AV TENNENE

HVOR OFTE PUSSER DU VANLIGVIS TENNENE?

- ☐ Pusser ikke tennene i det hele tatt
- ☐ Ikke hver dag
- ☐ En gang per dag
- ☐ Mer enn en gang pr dag

NOEN SPØRSMÅL OM TANNLEGEBESØK

HVOR OFTE PLEIER DU Å GÅ TIL TANNLEGEN/TANNPLEIER?

- ☐ Regelmessige undersøkelser (ikke sjeldnere enn annethvert år)
- ☐ Sporadiske undersøkelser
- ☐ Bare akutt (ved smerter eller andre plager)
- ☐ Aldri

HAR DU NOEN GANG OPPLEVD AT TANNBEHANDLINGEN HAR VÆRT PÅVIRKET ELLER MÅTTE UTSETTES PGA. PRISEN?

- ☐ Ja
- ☐ Nei

NOEN SPØRSMÅL OM MUNNTØRRHET

Hvor ofte er du plaget av munntørrhet?

- ☐ Aldri
- ☐ Av og til
- ☐ Ofte
- ☐ Alltid

HVOR OFTE OPPLEVER DU FØLGENDE SCENARIER? Kryss av på hver linje

	Aldri	**Av og til**	**Ofte**
Jeg føler meg tørr i munnen når jeg spiser et måltid	☐	☐	☐
Jeg føler meg i tørr i munnen	☐	☐	☐
Jeg har problemer med å spise tørr mat	☐	☐	☐

Jeg har problemer med å svelge enkelte typer mat	☐	☐	☐
Leppene mine føles tørre	☐	☐	☐

Appendix IV (Overview of questionnaire items in English)

Overview of the self-reported sociodemographic-, general health-, behavioural, as well as self-perceived oral dryness parameters used in the three papers.

Self-reported parameters	**Analysis categories and response alternatives**
Gender	Male Female
Education level	Basic Elementary and/or middle school High school, 1-2 years High school, 3 years Certificate of apprenticeship Higher College/University, < 4 years College/University, ≥ 4 years
Country of birth *(Free text question)*	Western Nordic countries Western Europe North America Australia Non-western Rest of the world
Dental treatment affected by or postponed due to financial reasons	Yes No
Number of medications	< 4 ≥ 4
Radiotherapy to the head/neck region	Yes

	No
Diabetes type II	Yes No
Rheumatic disease	Yes No
Smoking	Never Former Current
Dental visiting pattern	Regular Regular check-ups (not less than every second year) Irregular Occasionally Only emergency visits Never
Toothbrushing frequency	Less than twice daily Never Not every day Once a day Twice daily or more More than once a day
Sugar intake frequency; Intake of sugary drinks (hot drinks, soda, sports drink, juice) or sugary foods (chocolate, candy, ice cream, cakes, cookies, jam, marmalade, chocolate spread, yoghurt)	Twice a week or less Seldom or never 1-2 times a month 1-2 times a week More than twice a week 3-4 times a week

	Daily Several times daily
Xerostomia; Frequency of self-perceived oral dryness (Thomson *et al.* 1999)	Non-xerostomic Never Occasionally Xerostomic Frequently Always
Xerostomia; SXI-D (Thomson *et al.* 2011) 1) Mouth feels dry when eating a meal 2) Mouth feels dry 3) Difficulty in eating dry foods 4) Difficulties swallowing certain foods 5) Lips feel dry	Score 0 – Never Score 1 – Occasionally Score 2 – Frequently Score 3 – Always Sum score 0-15

Appendix V (Diagnostic criteria for coronal primary caries lesions)

Occlusal caries	
Grade 1	Caries characterized by white or brown discolouring without substance loss. No radiographic findings
Grade 2	Little substance loss with break in the enamel surface or discolouring fissure with grey/opaque adjacent enamel and/or caries restricted to enamel in the X-ray
Grade 3	Moderate substance loss and/or caries in the external 1/3 of the dentin radiographically
Grade 4	Considerable substance loss and/or caries in the middle 1/3 of the dentin radiographically
Grade 5	Great substance loss and/or caries in the internal 1/3 of the dentin radiographically
Buccal and lingual surfaces (smooth surfaces)	
Grade 1	Caries characterized by white or brown discolouring without substance loss. Dull surface can be seen after drying
Grade 2	Little substance loss with break in the enamel surface
Grade 3	Moderate substance loss with exposure of dentin (can be explored with probe)
Grade 4	Considerable substance loss in enamel with moderate cavity formation in dentin
Grade 5	Great substance loss with considerable cavity formation/softened dentin
Approximal surfaces (radiographic diagnosis)	
Grade 1	Lesion in the external (initial) half of enamel
Grade 2	Lesion in the external half of enamel (up to enamel-dentin junction)
Grade 3	Lesion in the external 1/3 of dentin (up to 1/3 of dentin thickness)
Grade 4	Lesion in the middle 1/3 of dentin (up to 2/3 of the dentin thickness)
Grade 5	Lesion in the internal 1/3 of dentin

Table reproduced from Amarante et al. 1998.

Appendix VI (The Challacombe Scale of Clinical Oral Dryness)

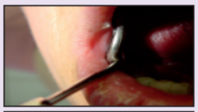
The Challacombe Scale

of Clinical Oral Dryness

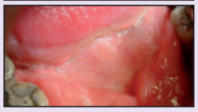
KING'S College LONDON

The Challacombe Scale was developed from research conducted at King's College London Dental Institute under the supervision of Professor Stephen Challacombe*. The purpose of this scale is to be able to visually identify and quantify whether your patient has xerostomia (dry mouth) and if so, how it changes over time and the most appropriate therapy options. This scale is applicable whatever your profession.

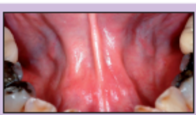
The Challacombe Scale works as an additive score of 1 to 10 : 1 being the least and 10 being the most severe. Each feature scores 1 and symptoms will not necessarily progress in the order shown, but summated scores indicate likely patient needs. Score changes over time can be used to monitor symptom progression or regression.

1  Mirror sticks to buccal mucosa

2  Mirror sticks to tongue

3  Saliva frothy

An additive score of 1 - 3 indicates mild dryness. May not need treatment or management. Sugar-free chewing gum for 15 mins, twice daily and attention to hydration is needed. Many drugs will cause mild dryness. Routine checkup monitoring required.

4  No saliva pooling in floor of mouth

5  Tongue shows generalised shortened papillae (mild depapillation)

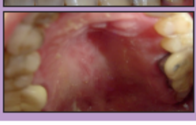
6  Altered gingival architecture (ie. smooth)

An additive score of 4 - 6 indicates moderate dryness. Sugar-free chewing gum or simple sialogogues may be required. Needs to be investigated further if reasons for dryness are not clear. Saliva substitutes and topical fluoride may be helpful. Monitor at regular intervals especially for early decay and symptom change.

7  Glassy appearance of oral mucosa, especially palate

8  Tongue lobulated / fissured

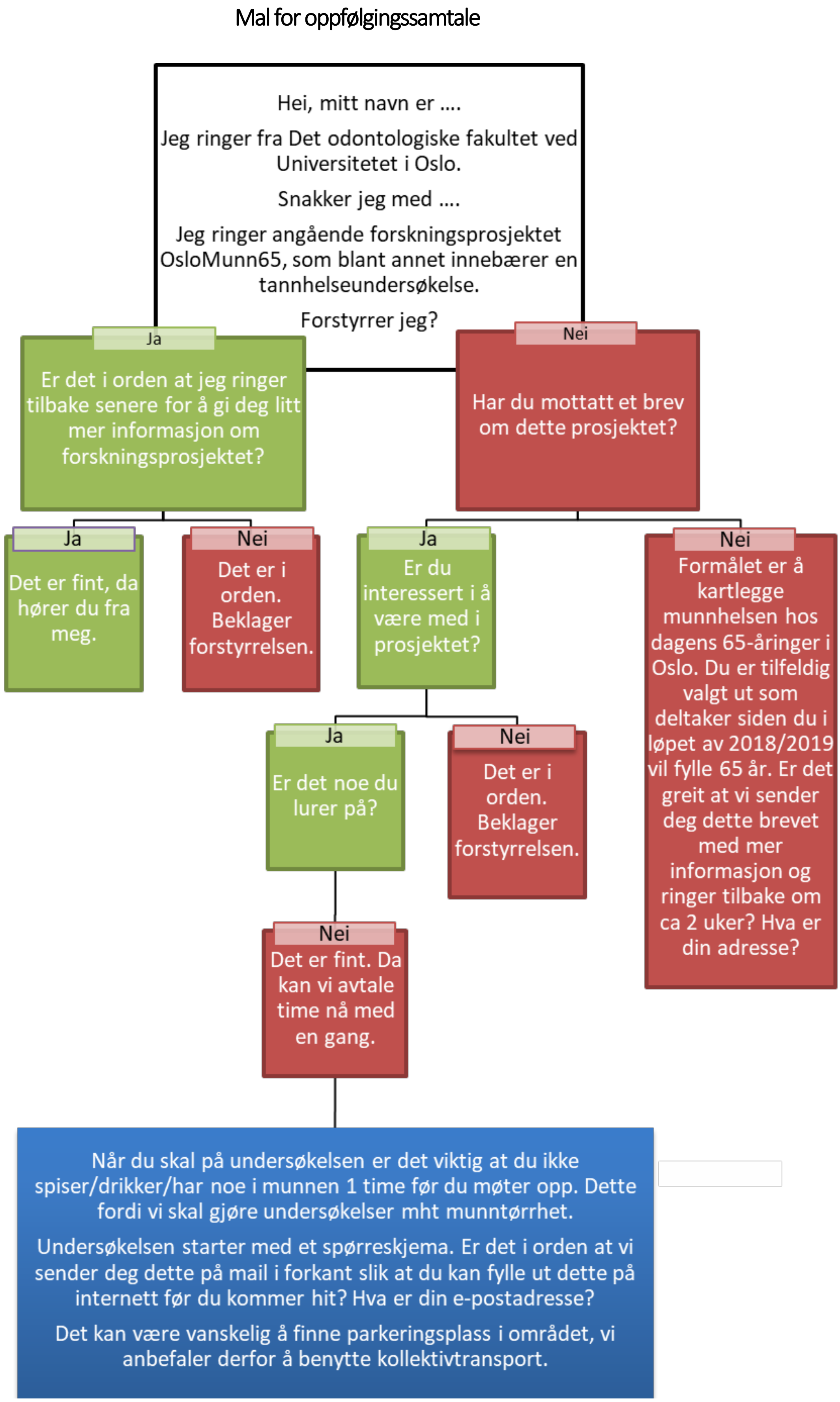
9  Cervical caries (more than two teeth)

10  Debris on palate or sticking to teeth

An additive score of 7 - 10 indicates severe dryness. Saliva substitutes and topical fluoride usually needed. Cause of hyposalivation needs to be ascertained and Sjögrens Syndrome excluded. Refer for investigation and diagnosis. Patients then need to be monitored for changing symptoms and signs, with possible further specialist input if worsening.

* S Osailan et al "Investigating the relationship between hyposalivation and mucosal wetness" (2011) Oral Diseases volume 17, Issue 1, Pages: 109–114

Appendix VII (Flowchart for recruitment phone call)



Appendix VIII (Consent form)

UiO : Institutt for klinisk odontologi
Det odontologiske fakultet

FORESPØRSEL OM DELTAKELSE I FORSKNINGSPROSJEKTET

ORAL HELSE HOS 65-ÅRINGER I OSLO

Dette er et spørsmål til deg om å delta i et forskningsprosjekt der formålet er å kartlegge den orale helsen hos dagens 65-åringer i Oslo. Du er tilfeldig valgt ut som deltaker siden du i løpet av 2018/2019 vil fylle 65 år. Prosjektet går ut fra det Odontologiske fakultet ved Universitetet i Oslo som også er ansvarlig for gjennomføringen av undersøkelsen.

HVA INNEBÆRER PROSJEKTET?

Prosjektet innebærer at du vil få en grundig undersøkelse av din orale helse. I tillegg til undersøkelser som man vanligvis får utført ved konsultasjon hos tannlege som klinisk og røntgenologisk undersøkelse av tenner samt spyttprøver, vil vi utføre en mer grundig undersøkelse av andre tannhelseparametre. Det bli tatt smak- og luktprøver, undersøkelse av bittforhold og munntørrhet. I tillegg, vil du bli bedt om å fylle ut et enkelt spørreskjema. Undersøkelsen er helt smertefri og vil bli utført av tannleger og ved Odontologiske fakultet.

Denne undersøkelsen vil ta ca. 2 timer.

Hvis relevant, vil du bli forespurt om å delta i et subprosjekt, hvor du vil bli mer inngående undersøkt enten for munntørrhet, kjeveleddsproblematikk og/eller tannkjøttsykdom.

MULIGE FORDELER OG ULEMPER

Undersøkelsen innebærer gratis rådgivning om munn- og tannforhold. Undersøkelsene vil bli utført av tannhelsepersonell med betydelig kompetanse på området og du vil få informasjon om eventuelle funn. Hvis vi gjør funn som trenger behandling, vil du få informasjon om dette. Dette er en noe mer grundig tannlegekonsultasjon enn det du er vant til, men det vil ikke være noen risiko, bivirkninger eller ubehag forbundet med undersøkelsen. Ved å delta i denne undersøkelsen bidrar du til å bringe ny og viktig kunnskap om oral helse blant den godt voksne befolkningen i Norge. Denne informasjonen er viktig for å planlegge gode tannhelsetjenester for den aldrende befolkningen.

FRIVILLIG DELTAKELSE OG MULIGHET FOR Å TREKKE SITT SAMTYKKE

Det er frivillig å delta i prosjektet. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke. Dersom du trekker deg fra prosjektet, kan du kreve å få slettet innsamlede prøver og opplysninger, med mindre opplysningene allerede er inngått i analyser eller brukt i vitenskapelige publikasjoner. Dersom du senere ønsker å trekke deg eller har spørsmål til prosjektet, kan du kontakte prosjektleder Lene Hystad Hove, telefonnummer 22852142 eller via e-postadresse lenehh@odont.uio.no

HVA SKJER MED INFORMASJONEN OM DEG?

Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Du har rett til innsyn i hvilke opplysninger som er registrert om deg og rett til å få korrigert eventuelle feil i de opplysningene som er registrert.

Personopplysninger og røntgenbilder vil registreres i Det Odontologiske fakultets lukkede journalsystem (Salud), og sikres på samme måte som andre pasientrelaterte data ved Det Odontologiske fakultet. Alle andre innsamlede data (spørreskjema, tannhelsedata, spyttprøveresultater) vil lagres i Tjenester for sensitive data (TSD) ved UiO.

Alle forskningsdata vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kodenøkkel knytter deg til dine opplysninger gjennom hospitalnummer, som vil bli vil bli lagret i TSD.

Prosjektleder har ansvar for den daglige driften av forskningsprosjektet og at opplysninger om deg blir behandlet på en sikker måte. Informasjon om deg vil bli anonymisert eller slettet senest fem år etter prosjektslutt.

HVA SKJER MED PRØVER SOM BLIR TATT AV DEG?

Spyttprøvene som tas skal oppbevares i en forskningsbiobank. Disse blir lagret i biobank 2010/1292, lokalisert på Det Odontologiske fakultet. Prosjektleder er Lene Hystad Hove og er ansvarshavende for biobanken.

Spyttprøvene i biobanken vil bli analysert for viskositet (smørende effekt) og proteinanalyser.

Biobanken opphører etter prosjektslutt og prøvene vil bli destruert.

FORSIKRING

Under undersøkelsen vil du være dekket av pasientskadeloven.

OPPFØLGINGSPROSJEKT

Det er planlagt en oppfølgingsundersøkelse om 5-10 år hvor du vil bli kontaktet for ny deltagelse. Det er selvfølgelig helt frivillig å være med på denne oppfølgingsstudien.

GODKJENNING

Prosjektet er godkjent av Regional komité for medisinsk og helsefaglig forskningsetikk (REK). Saksnummer hos REK: 2018/1383.

Etter ny personopplysningslov har behandlingsansvarlig Institutt for klinisk odontologi (IKO) ved Det odontologiske fakultetet og prosjektleder Lene Hystad Hove et selvstendig ansvar for å sikre at behandlingen av dine opplysninger har et lovlig grunnlag. Dette prosjektet har rettslig grunnlag i Dette prosjektet har rettslig grunnlag i EUs personvernforordning kapittel IV, artikkel 25-26 og 28-30.

KONTAKTOPPLYSNINGER

Dersom du har spørsmål til prosjektet kan du ta kontakt med prosjektleder Lene Hystad Hove, telefonnummer 22852142 eller via e-postadresse lenehh@odont.uio.no.

Du kan ta kontakt med institusjonens personvernombud dersom du har spørsmål om behandlingen av dine personopplysninger i prosjektet. (Maren Magnus Voll, e-post: personvernombud@uio.no)

SAMTYKKE TIL DELTAKELSE I PROSJEKTET

JEG ER VILLIG TIL Å DELTA I PROSJEKTET ☐

JEG ER VILLIG TIL Å BLI KONTAKTET FOR OPPFØLGINGSUNDERSØKELSE ☐

JEG SAMTYKKER TIL AT KLINISKE OG RADIOLOGISKE BILDER, FRA UNDERSØKELSEN OG EVENTUELLE TILLEGGSUNDERSØKELSER, KAN BRUKES TIL PRESENTASJON AV PROSJEKTET OG I UNDERVISNINGSØYEMED ☐

Sted og dato — Deltakers signatur

Deltakers navn med trykte bokstaver

Jeg bekrefter å ha gitt informasjon om prosjektet.

Sted og dato — Signatur

Rolle i prosjektet

Appendix IX (Feedback forms)

Universitetet i Oslo
Det odontologiske fakultet

1

Deltaker ønsker ikke tilbakemelding ☐

Deltaker ønsker tilbakemelding ☐

Dato:

Navnelapp

Tilbakemelding

For deltaker i OsloMunn65

Tusen takk for at du deltok i OsloMunn65! Vi anbefaler at du kontakter din faste tannklinikk på grunn av følgende:

Karies (hull i tennene) ☐

Aktuelle tenner:

Periodontitt (betennelse i tannkjøtt og støttevev) ☐

Røntgenfunn ☐ **Bilder utleveres til pasient** ☐

Kommentar:

Tannlegen/tannpleieren din får i utgangspunktet ikke tilsendt resultatene dine. Ta derfor med dette brevet hvis du oppsøker tannlege/tannpleier på grunn av vår anbefaling. Vi utelukker ikke at din faste tannlege allerede har registrert funnene og følger det opp ved rutinemessige undesøkelser.

Ved spørsmål, ta kontakt med vår klinikk eller prosjektleder Lene Hystad Hove på telefonnummer: 228 52 142.

Postadresse: Postboks 1109, Blindern, 0317 Oslo
E-post: l.h.hove@odont.uio.no
www.uio.no

2

Skjema for radiologiske undersøkelser i OsloMunn65

Navnelapp

Fylles ut av tannlege ved avd. for kjeve- og ansiktsradiologi

Tenner med mistanke om apikal periodontitt:

Evt. kommentar:

CBCT undersøkelse utført: Ja ☐ Nei ☐

Postadresse: Postboks 1109, Blindern, 0317 Oslo
E-post: l.h.hove@odont.uio.no
www.uio.no

Papers I-III

I

II

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https://doi.org/10.1186/s12903-022-02406-9

BMC Oral Health

RESEARCH

Open Access

Periapical and endodontic status among 65-year-old Oslo-citizens

My Tien Diep[1*], Lene Hystad Hove[1], Dag Ørstavik[2], Rasa Skudutyte-Rysstad[1], Anne Thea Tveit Sødal[1] and Pia Titterud Sunde[2]

Abstract

Aim: This cross-sectional study aimed to investigate the prevalence of apical periodontitis (AP) and root-filled teeth in a 65-year-old population in Oslo, Norway, and to investigate associations of pathosis and endodontic treatment with selected individual risk indicators and technical quality of root fillings.

Material and methods: A random sample of 450 65-year-olds in Oslo answered a questionnaire and underwent a clinical and radiological examination (52% men and 48% women). Periapical radiographs were taken of all root-filled teeth and of teeth with apical radiolucency, and periapical status was evaluated using the Periapical Index. Apex-to-filling distance and homogeneity were assessed for all root fillings. Analyses on individual level and tooth level were performed. The outcome variables were 'non-root-filled tooth with AP' ('untreated AP'), 'root-filled tooth', and 'root-filled tooth with AP'. The explanatory variables were gender, education, dental attendance pattern, smoking, remaining teeth (n), tooth group, and root filling quality. Chi-square test and logistic regression analyses were used to assess the associations between outcome variables and explanatory variables. The level of significance was set to $p < 0.05$.

Results: The mean number of remaining teeth was 26 (SD: 4). AP was present in 45% of the individuals. Sixteen percent of the individuals had untreated AP and 38% had at least one root-filled tooth with AP. Sixty-six percent of the individuals had one or more root-filled teeth. Untreated AP was significantly associated with a decreasing number of remaining teeth and smoking. All the outcome variables were significantly more prevalent in molars compared with premolars and anterior teeth. Thirty-five percent of the root-filled teeth had AP, and AP was more prevalent in teeth with too short apex-to-filling distance (53%) or unsatisfactory homogeneity (46%).

Conclusions: The remaining number of teeth was high, and AP and root-filled teeth were prevalent in the present young-elderly population. A notable amount of untreated AP was observed, especially in smokers. The findings in the present study indicate a substantial need for dental care associated with endodontic conditions in the future elderly.

Keywords: Aged, Epidemiology, Apical periodontitis, Endodontics

Introduction

Periapical and endodontic conditions influence tooth survival [1]. From a public health perspective, it is therefore important to map these conditions in the young-elderly in order to plan for future dental health needs and services in an aging population. The beginning of old age is often defined as 65 years of age, although there is no general agreement [2, 3].

Apical periodontitis (AP) is inflammation and destruction of periapical tissues caused by endodontic infection [4, 5]. The infection is treated by root canal disinfection and subsequent root-filling, endodontic microsurgery or tooth extraction [6]. Researchers have pointed out that

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in the elderly, endodontic treatment may become more difficult to perform due to potentially previous treatment traumas and age changes to the pulp [7]. The fact that aging is correlated with reduced general health can also impose challenges for endodontic treatment, as elderly, fragile patients may find prolonged dental visits exhausting.

During the last two decades, several studies on the prevalence of AP and root-filled teeth have been performed [8–22], but few have studied random samples recruited from the general population [9, 11, 14, 18, 19, 22], and even fewer have focused on the young-elderly. A recent meta-analysis showed that the frequency of AP was higher in individuals recruited from dental care services and hospitals than from the general population [23]. Moreover, several studies on random samples from the general population [24–28] were carried out more than 20 years ago, which may limit their representativeness of the present young-elderly population.

Results from a systematic review [29] found a higher prevalence of AP and endodontically treated teeth among subjects older than 50 years. Previous studies investigating the relationship between periapical pathosis and socioeconomic and behavioural variables found that AP was statistically associated with smoking status [30], level of education [31] and regularity of dental attendance [30, 31]. In addition, the association between the number of remaining teeth and AP has previously both been confirmed [30] and disconfirmed [32]. However, these studies did not differentiate between AP in endodontically treated and untreated teeth, which may not be associated with the same determinants, as demonstrated in the longitudinal study by Kirkevang & co-workers [1]. For instance, tooth-specific factors, such as poor technical quality of the root filling, are strong risk indicators for AP in root-filled teeth [17, 21, 33].

The aims of this study were therefore to investigate the prevalence of AP and root-filled teeth among 65-year-olds in Oslo, Norway, and to investigate associations of pathosis and endodontic treatment with selected individual risk indicators and technical quality of root fillings.

Material and methods

Study design and setting

The present cross-sectional study was part of a larger study investigating oral health in 65-year-olds in Oslo, Norway (the OM65 study). As previously described [34], the participants were examined by two dentists (MTD and ATTS) at the Research Clinic, Institute of Clinical Dentistry, University of Oslo, between February and December 2019. The study protocol was approved by the Norwegian Regional Committee for Research Ethics (REK 2018/1383) and the study was performed in compliance with the tenets of the Declaration of Helsinki. All participants signed a written informed consent form. The present paper was written using the 'strengthening the reporting of observational studies in epidemiology' (STROBE) guidelines.

Participants

The study population was 65-year-old (born in 1954) residents of Oslo, Norway. Accounting for the possibility of a longitudinal follow-up study after 5 years, the calculated sample size was 450 participants. Eligible individuals were randomly selected from the National Population Register, which is administered by the Norwegian Tax Administration authorities, and invitation letters were sent to 1230 individuals. Within 2 weeks, the individuals were called and asked if they were interested in participating in the study.

Questionnaire

A self-administered questionnaire was sent to the participants via an electronic link to an online questionnaire program (Nettskjema, University of Oslo). Participants answered the questionnaire prior to attending the clinical examination. The participants were asked about smoking status (never, former or current), highest level of completed education, and dental attendance pattern. The participants' level of education was dichotomised into 'higher education' (university/college) and 'basic education' (high school, elementary school, or lower). Dental attendance pattern was dichotomised into 'regular' and 'irregular' (occasionally, only emergency visits, or never).

Radiographic examination

Panoramic radiographs (orthopantomogram, OPG) were taken of all participants (ProMax X-ray Dimax 3 and Planmeca ProOne, Planmeca Oy, Helsinki). Dentists, working at the Department of Maxillofacial Radiology at the Faculty of Dentistry, University of Oslo, screened the OPGs, and ordered additional periapical radiographs of all the root-filled teeth and of the teeth with apical radiolucency. These radiographs were taken with an intraoral imaging unit (Focus, KAVO, Instrumentarium Dental, PaloDEx Group Oy, Tuusula, Finland) with a rectangular collimator (length 30.5 cm, radiation area 35 × 45 mm), exposure 70 kV, 7 mA, 0.10–0.16 s, using the paralleling technique and intraoral phosphor plates (DIGORA Accessory intraoral imaging plates, Soredex Tuusula, Finland).

Radiographic registration methods

Table 1 describes the parameters assessed from the periapical radiographs. Periapical status was evaluated for root-filled teeth and teeth with AP using the

Table 1 Radiographic parameters for periapical status and root-filling quality

Parameters	Registration category	Analysis category
Periapical index (PAI)[a]	1 = Normal periapical structures 2 = Small changes in bone structure 3 = Changes in bone structure with some mineral loss 4 = Periodontitis with well-defined radiolucent area 5 = Severe periodontitis with exacerbating features	Not pathological = 1 + 2 Pathological = 3 + 4 + 5
Apex-to-filling distance[b]	1 = Root filling ending ≤ 3 mm from radiographic apex 2 = Root filling ending > 3 mm from radiographic apex 3 = Pulpotomy, material seen only in the pulp chamber 4 = Flush, root filling ending at the radiographic apex 5 = Over-filling, root filling material seen in the periapical area	Satisfactory = 1 + 4 Short = 2 + 3 Long = 5
Homogeneity of root filling[c]	1 = Homogeneous root filling 2 = Minor irregularities in the root filling 3 = Voids in the root filling 4 = Larger voids in the root filling	Satisfactory = 1 Unsatisfactory = 2 + 3 + 4

[a] Ørstavik et al. 1996

[b] Kirkevang et al. 2000

[c] The description of the registration categories is based on the visual scale for evaluation of root filling quality published by Jordal et al. 2014

periapical index (PAI) [35]. In cases of multi-rooted teeth, the score of the root with the highest PAI score was used. AP was defined as PAI score > 2. The distance from the radiographic apex to the root filling was also measured. For multi-rooted teeth, the largest apex-to-filling distance among the roots (over- and under-filling treated equally) was used, independently of the PAI score and homogeneity. The registration categories were as defined by Kirkevang and co-workers [7]. Homogeneity of the root filling was evaluated using the visual scoring system developed by Jordal and co-workers [36]. For multi-rooted teeth, the highest homogeneity score among the roots was used, independently of the PAI score and apex-to-filling distance. Table 1 also describes the categorisations used for statistical analyses. The radiographs were assessed using the ImageJ software [37].

Observer

One observer evaluated all periapical radiographs (MTD). The observer was prepared for using the PAI system by calibration against a reference set of 100 radiographic images of teeth. The weighted kappa value was 0.73 (95% CI 0.71–0.77) for reproducibility compared to the reference set and 0.72 (95% CI 0.69–0.75) for intra-observer reproducibility. The same calibration procedure has been described in more detail by Kirkevang and co-workers [38]. In cases of doubt, the radiographs were discussed with an endodontist (PTS), in order to achieve a consensus.

Statistical analyses

Registrations were entered in the Oral Data Collector (ODC) sheet specifically designed for data entry in this study, developed in Microsoft Excel 2016 (Microsoft Corporation, Redmond, Washington, USA), processed using openpyxl 3.0.4 and pandas 1.1.0 in Python 3.8 (Python Software Foundation, https://www.python.org/) and imported into STATA (Stata version 16.1; College Station, TX, USA) for statistical analyses. Descriptive statistical analyses were performed and the results are presented in the form of numbers (n) with percentages (%) and mean with standard deviation (SD). The outcome variables were 'untreated AP' (non-root-filled teeth with AP), 'root-filled', and 'root-filled with AP' on both individual level and tooth level, and the prevalence on individual level was defined as having at least one tooth with the respective condition. The chi-square test was used to determine significant differences in the prevalence of periapical and endodontic conditions related to gender, education level, dental attendance pattern, and smoking status (categorical variables). For continuous explanatory variables (number of remaining teeth), univariate logistic regression was used to assess the associations with the outcome variables. Since untreated AP showed a significant association with the highest number of socio-economic and behavioural variables, this relationship was further explored using univariate and multivariate logistic regression. In all cases of multivariate logistic regression, the analyses were only adjusted for the variables shown in the respective table. For the analyses on tooth level, generalised estimating equation for logistic regression was used, accounting for possible correlations between the teeth belonging to the same individual (dependence within clusters). The results from the regression analyses are presented as unadjusted and adjusted odds ratios with a 95% confidence interval. The level of significance was set to $p < 0.05$. The data were securely stored and the analyses were performed in Service for Sensitive Data (TSD), Centre for Information Technology Services, University of Oslo.

Results

Of the 797 eligible participants who were reached by telephone after having received the invitation letter, 460 attended the clinical and radiographic examination (response rate of 58%). Ten individuals were excluded from the analyses due to missing periapical radiographs or low quality of the radiographs. Thus, the final sample comprised 450 individuals. However, three individuals did not answer the questionnaire, resulting in self-reported data from 447 individuals. The sample population was characterised by an almost even gender distribution (52% men, 48% women), and a predominance of those with higher education (66%), regular dental attenders (89%), and non-smokers (89%) (Table 2). The mean number of teeth per individual was 26 (SD: 4, range: 0–28) and 94% of the individuals had more than 20 remaining teeth. Two individuals were edentulous.

Individual level

AP was present in 45% of the individuals. Sixteen percent of the individuals had at least one tooth with untreated AP and 38% had at least one root-filled tooth with AP. Sixty-six percent of the individuals had one or more root-filled teeth. Ten percent of the individuals had three or more teeth with AP, and 25% of the individuals had three or more root-filled teeth. The distribution of individuals according to the total number of teeth with AP, untreated AP, root-filled teeth, and root-filled teeth with AP may be seen in Additional file 1: Table S1.

Number of remaining teeth

Table 3 shows the distribution of untreated AP, root-filled teeth, and root-filled teeth with AP by number of remaining teeth. Untreated AP was significantly associated with decreasing number of remaining teeth (logistic regression: $p < 0.05$) [Additional file 1: Table S2].

Socioeconomic and behavioural variables: bivariate analyses

Table 2 sums up the results from the bivariate analyses on the prevalence of untreated AP, root-filled teeth, and root-filled teeth with AP on individual level according to gender, level of education, smoking status, and dental attendance pattern. Untreated AP was significantly associated with the level of education, dental attendance pattern, and smoking status; it was more prevalent in those with basic education compared to those with higher education (22 vs. 13%), in irregular dental attenders

Table 2 Untreated AP, root-filled teeth and root-filled teeth with AP according to gender, level of education, smoking and dental visiting habits

		No. of individuals (%)	At least one tooth with untreated AP n (%)	At least one root-filled tooth n (%)	At least one root-filled tooth with AP n (%)
All*		447 (100)	72 (16)	296 (66)	170 (38)
Gender					
	Male	232 (52)	44 (19)	162 (70)	96 (41)
	Female	215 (48)	28 (13)	134 (62)	74 (34)
Education					
	Higher education	297 (66)	39 (13)[a]	198 (67)	113 (38)
	Basic education	150 (34)	33 (22)[a]	98 (65)	57 (38)
Dental attendance					
	Regular	398 (89)	59 (15)[a]	272 (68)[a]	149 (37)
	Irregular	49 (11)	13 (27)[a]	24 (49)[a]	21 (43)
Smoking					
	Never	193 (43)	25 (13)[a]	113 (59)[a]	65 (34)
	Former	205 (46)	30 (15)[b]	151 (74)[a]	82 (40)
	Current	49 (11)	17 (35)[ab]	32 (65)	23 (47)

AP Apical periodontitis

*Missing data because three individuals did not answer the questionnaire

Letters indicate a statistically significant difference between groups of the same letter within the same variable ($p < 0.05$: Chi-square)

Table 3 Untreated AP, root-filled teeth and root-filled teeth with AP according to number of remaining teeth

	No. of individuals (%)	At least one tooth with untreated AP n (%)	At least one root-filled tooth n (%)	At least one root-filled tooth with AP n (%)
All No. of remaining teeth	450 (100)	72 (16)	296 (66)	169 (38)
0	2 (0.4)	–	–	–
1–5	4 (0.9)	2 (50)	1 (25)	1 (25)
6–10	0 (0)	–	–	–
11–15	7 (2)	1 (14)	6 (86)	4 (57)
16–20	14 (3)	5 (36)	8 (57)	5 (36)
21–25	126 (28)	25 (20)	87 (69)	53 (42)
26–28	297 (66)	39 (13)	195 (66)	107 (36)

AP Apical periodontitis

compared to regular dental attenders (27 vs. 15%), and in current smokers (35%) compared to former smokers (15%) and never-smokers (13%). Furthermore, root-filled teeth were significantly more prevalent in former smokers compared to never-smokers (74 vs. 59%) and in regular dental attenders compared to irregular dental attenders (68 vs. 49%). No statistically significant associations were found between the socioeconomic and behavioural variables and the prevalence of root-filled teeth with AP.

Socioeconomic and behavioural variables: logistic regression

Basic educational level, irregular dental attendance, and current smoking were significantly associated with the presence of at least one tooth with untreated AP in the unadjusted analyses (Table 4). However, current smoking was the only significant risk indicator in the adjusted analyses and was associated with a threefold increase in odds ratio of having untreated AP.

Table 4 Exploratory logistic regression model: untreated AP and socioeconomic and behavioural factors

N = 447 Explanatory variables	Unadjusted odds ratio (95% CI)	Adjusted odds ratio (95% CI)
Gender		
Female	1	1
Male	1.6 (0.9–2.6)	1.4 (0.8–2.5)
Education level		
Higher education	1	1
Basic education	**1.7 (1.1–3.1)**	1.6 (0.9–2.7)
Dental visits		
Regular	1	1
Irregular	**2.1 (1.0–4.1)**	1.5 (0.7–3.2)
Smoking		
Never	1	1
Former	1.2 (0.7–2.0)	1.1 (0.6–2.0)
Current	**3.6 (1.7–7.4)**	**3.0 (1.4–6.4)**

CI Confidence interval

Outcome variable: at least one tooth with untreated AP

Values shown in bold text differ significantly ($p < 0.05$: Logistic regression) from the reference category

Tooth level

Figure 1 shows the distribution of the total number of teeth examined (N = 11,484) according to periapical and endodontic status. In total, 368 teeth (3%) had AP, and 28% of these were not root-filled. The total number of root-filled teeth was 756 (7%), of which 35% had AP.

Tooth group and jaw

The distribution of untreated AP, root-filled teeth, and root-filled teeth with AP in tooth groups divided by jaw is shown in Table 5. The outcome variables were more strongly associated with molars compared with premolars and anterior teeth (logistic regression: $p < 0.05$). Maxillary premolars and molars had higher odds of having untreated AP compared to the same tooth groups in the mandible (logistic regression: $p < 0.05$). This difference was not found for anterior teeth. Maxillary anterior teeth and premolars had higher odds of being root-filled or having AP related to a root filling compared to the same tooth groups in the mandible (logistic regression: $p < 0.05$). This difference was not found for molars.

Quality of root filling

In total, 76% of the root fillings were satisfactory in the apex-to-filling distance, 57% were satisfactory in homogeneity and 48% were satisfactory in both apex-to-filling distance and homogeneity (Table 6). AP was significantly associated with teeth with too short root fillings or unsatisfactory homogeneity (logistic regression: $p < 0.05$) [Additional file 1: Table S3].

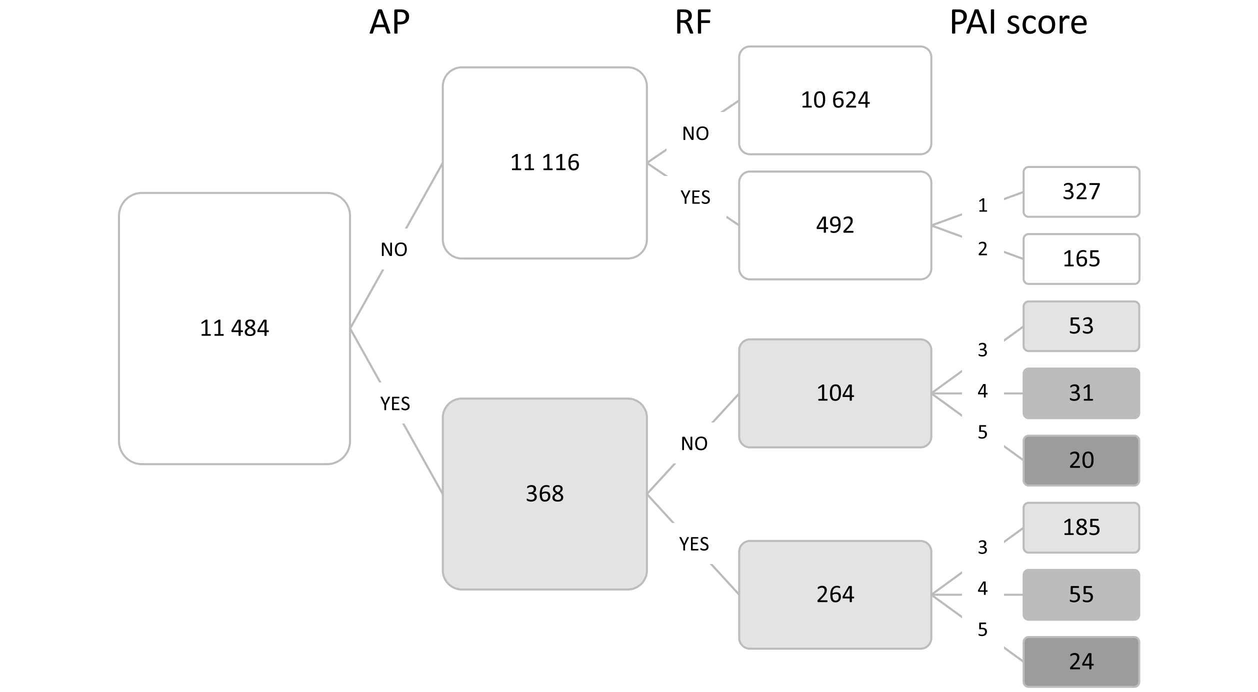

Fig. 1 Distribution of number of teeth (N = 11 484) according to AP, RF and PAI. AP = apical periodontitis; RF = root filled; PAI = Periapical Index

Table 5 Distribution of untreated AP, root-filled teeth and root-filled teeth with AP in tooth groups stratified by jaw

	No. of teeth (%)	Untreated AP n (%)	RF n (%)	RF with AP n (%)
Total	11,484 (100)	104 (0.9)	756 (7)	263 (2)
Maxillary				
Anterior teeth	2601 (23)	10 (0.4)	110 (4)	33 (1)
Premolars	1542 (13)	21 (1.4)	154 (10)	49 (3)
Molars	1549 (13)	33 (2.1)	176 (11)	85 (5)
Mandibular				
Anterior teeth	2623 (23)	12 (0.5)	30 (1)	7 (< 1)
Premolars	1608 (14)	9 (0.6)	101 (6)	18 (1)
Molars	1561 (14)	19 (1.2)	185 (12)	72 (5)

AP Apical periodontitis, *RF* root-filled

Discussion

This paper describes the prevalence of apical pathology and root-filled teeth in a random sample of 65-year-old Oslo-citizens, and explores the associations of pathosis and treatment with selected individual risk indicators and the technical quality of endodontic treatment. To our knowledge, the present study is one of few studies that focus on these conditions in a young-elderly population.

The results demonstrate that AP and root-filled teeth were prevalent in the present sample population. This and the fact that the present young-elderly population has retained most of their own teeth indicates that many of these individuals may be at risk of dental problems when facing old age.

In Norway, dental services are divided into a public and private sector [39, 40]. Dental treatment provided by the public dental service is free for patients 0–18 years of age, mentally handicapped adults and elderly living in an institution or receiving home nursing care. The majority of adults receive dental care from private general dental practitioners, mainly financed by patient charges. Thus, the dental treatment experience of 65-year-olds in Norway will mainly be based on self-financed treatments in the private sector. Certified endodontists also mainly

Table 6 Periapical status according to root filling quality

N = 756	No. of root filled teeth (%)	No AP n (%)	AP n (%)
Apex-to-filling distance (ATF)			
Satisfactory	575 (76)	401 (70)	174 (30)
Short	142 (19)	67 (47)	75 (53)
Long	39 (5)	24 (62)	15 (38)
Homogeneity			
Satisfactory	434 (57)	319 (74)	115 (27)
Unsatisfactory	322 (43)	173 (54)	149 (46)
ATF & homogeneity			
Satisfactory	361 (48)	269 (75)	92 (25)
Unsatisfactory*	395 (52)	223 (56)	172 (44)

AP Apical periodontitis

*Unsatisfactory apex-to-filling distance, homogeneity or both

work in the private sector, but the proportion of patients or teeth receiving specialist treatment is unknown.

Comparison of prevalence estimates

AP and root-filled teeth are more prevalent in older compared to younger age groups [38]. This is confirmed by comparing the findings from the present study with previous findings in 35-year-old Oslo-citizens [9]. Therefore, the present study sought to compare the present prevalence estimates with findings in similar age groups if such data were available. Table 7 lists a selection of studies on periapical and endodontic conditions, which are considered comparable to the present study due to similar recruitment procedures and the fact that they were performed during the last two decades. All the listed studies evaluated the periapical status on periapical radiographs and defined AP as a PAI score > 2, except for one study [19], which registered AP in panoramic radiographs and defined AP as the periodontal ligament being two times the normal width.

The prevalence of AP in the present population sample (45%) was somewhat higher compared to findings in a similar age group in Finland (34%) [19] and Sweden (41%) [18], but lower compared to results from Denmark (69%) [22]. Unlike the present study, separate prevalence estimates for untreated AP and root-filled teeth with AP on individual level were not reported in any of the papers listed in Table 7. However, on tooth level, Razdan and coworkers found a 2,sixfold higher prevalence of untreated AP compared to the present study [22]. Furthermore, the prevalence of AP in root-filled teeth in the present study (35%) was within the range of the results from the comparable studies (15–57%) [9, 11, 14, 19, 22].

Sixty-six percent of the individuals in the present study had one or more root-filled teeth, which is in line with previous reports (61–68%) [18, 19, 22].

The variation among the populations examined, for example in age distribution and socioeconomic status, can probably explain some of the discrepancies between the different prevalence estimates. In addition, differences in study designs regarding inclusion criteria, types of radiographs, and definition of AP may have influenced the results, as well as possibly different treatment routines between the countries. In the present study, the intention of not excluding edentulous individuals was that the prevalence estimates were meant to represent the whole target population, not only the dentate population. However, it did not notably affect the results, since only 0.4% of the present sample were edentulous.

Number of remaining teeth

The presence of untreated AP was associated with a decreasing number of remaining teeth. This may indicate that the missing teeth were mainly lost or extracted for other reasons than AP, such as periodontitis or dental trauma. It can also be speculated that the incidence of caries and subsequent AP is higher in individuals with fewer remaining teeth, without a matching treatment rate, and therefore the undergone extractions have not resulted in a lower prevalence of AP compared to individuals with more remaining teeth. However, longitudinal studies are needed to provide further insight related to this hypothesis. Nevertheless, it is important to underline that, in the present study, only 11 individuals had 1–15 teeth, hence the results should be interpreted with caution.

Gender

In accordance with previous studies [38, 41], there was not a significant difference in the presence of AP between the genders. Other studies have reported both that the presence of AP was more prevalent in men [11, 19], and in women [18]. In addition, the present study did not find a significant gender difference in the prevalence of root-filled teeth, unlike other studies that found that it was more prevalent in women [42].

Dental attendance pattern

In the present study, having at least one root-filled tooth was more frequent among regular dental attenders compared with irregular dental attenders. This indicates that regular dental attenders are more subjected to conservative treatment (e.g. endodontic treatment) compared with irregular dental attenders who may be more subjected to emergency treatment (e.g. tooth extractions) or no treatment.

Table 7 Previous studies on periapical and endodontic conditions in the general population conducted after year 2000

Country	Author	Exam year	No. of individuals	No. of teeth	Age range	Comparable age group (n)	Individual level		Tooth level			
							AP/total (%)	RF/total (%)	AP/total (%)	Untreated AP/total (%)	RF/total (%)	RF with AP/RF (%)
Norway	Diep et al. (present study)	2019	450	11 484	65	–	45	66	3,2	0,9	6,6	35
Denmark	Razdan et al. (2022)	2009	398	10 668	20–64	60–64 (109)	68,8*	67,9*	5,5*	2,4*	5,6*	57,0*
Denmark	Kirkevang et al. (2012)	2008	360	9 350	30–72	–	53	59	4,2	–	5,8	42,9
Sweden	Virtanen et al. (2017)	2003	120	–	49–58	49–58	40,8*	60,8	–	–	–	–
Sweden	Frisk et al. (2008)	2003	491	12 433	20–70	–	–	–	–	–	–	24,8
Norway	Skudutyte et al. (2006)	2003	146	3 971	35	–	16	23	1,1	0,4	1,5	43
Finland	Huumonen et al. (2017)**	2001	5335	120 635	30–95	55–64 (929)	34*	67*	–	–	6,6	15,3

AP apical periodontitis, *RF* root-filled

*Results in comparable age group

**Registered AP in panoramic radiographs and defined AP as the periodontal ligament being two times the normal width

Smoking

The presence of untreated AP was associated with basic educational level, irregular dental attendance, and current smoking in the bivariate analyses. However, only current smoking was significant in the multivariate regression analysis. This indicates that among individuals with the same smoking status, education and dental attendance pattern did not significantly affect the outcome. Smoking may increase the risk of developing caries [43], followed by a possible increased risk of AP and endodontic treatment. In the present study, the presence of root-filled teeth was more frequent in former smokers than never-smokers.

Previous reports have shown an association between AP and smoking [18, 30]. The authors explained this observation with potentially delayed bone healing in smokers compared to non-smokers. However, since untreated AP cannot be in a healing process, this can only be a reasonable explanation for AP related to root-filled teeth. Nonetheless, in accordance with previous findings [32], no significant association was found between root-filled teeth with AP and smoking status in the present study. This indicates that although delayed bone healing may be present in smokers, once the AP has been treated, other determinants, such as the treatment quality, may be more relevant. A previous study showed that after accounting for the quality of root filling, smoking was no longer associated with AP [44].

Tooth group and jaw

Overall, in the present study, the prevalence of endodontically treated and untreated AP was higher in molars compared with the other tooth groups. Achieving satisfactory root filling quality in molars compared to premolars and anterior teeth can be more challenging due to multiple roots and more complicated root canal anatomy, especially in maxillary first molars. Huumonen and coworkers found that only 26% of root fillings in maxillary molars and 34% of root fillings in mandibular molars had satisfactory apex-to-filling distance [42].

In the present study, mandibular molars were the tooth group most frequently root-filled (12%), in line with a study from Finland (12%) [42]. However, in the same study, twice as many maxillary anterior teeth were root-filled compared to the present study (8% vs. 4%).

Maxillary anterior teeth and premolars had a higher risk of being root-filled and having a root filling with AP compared with mandibular anterior teeth and premolars. This pattern may be due to more dental caries and trauma in the maxillary compared to the mandibular anterior teeth. Moreover, it has been shown in children 5–16 years old that maxillary premolars are more susceptible to caries than mandibular premolars, which may also apply for adults [45].

Quality of root fillings

Previous studies have found that the periapical outcome is strongly influenced by the quality of the endodontic treatment [11, 19]. In the present study, both too short apex-to-filling distance and voids in the root filling were associated with the presence of AP. These findings confirm previous reports, in which some have only looked at the apex-to-filling distance [19, 42], whereas others have reported both apex-to-filling distance and homogeneity separately [7, 11] or combined [24, 31, 46]. In the present study, 76% of the root fillings had satisfactory apex-to-filling distance, compared to 47% in a Finish study [42]. Despite this, the occurrence of AP in root-filled teeth in the present study was higher than in the Finish study (35% vs. 15%). The fact that there was a higher root-filled molars/root-filled anterior teeth ratio in the Finish study (33%/32%) compared to the present study (48%/19%) may partly explain this paradoxical observation, given that endodontic treatment has a better success rate in anterior teeth compared to molars, as previously discussed. In the present study, having root-filled teeth with AP was not associated with any of the socioeconomic or behavioural variables.

Study limitations

The present study has potential limitations. The attendance rate in this study was 58%, which is comparable to previous studies with similar recruitment procedures (51–64%) [9, 38]. Due to restrictions from the Ethics Committee, we were not permitted to ask non-attenders why they declined to participate. Therefore, in order to explore potential selection bias, the gender distribution and education level of the sample population were compared with the corresponding proportions of the study population (based on register data on 65-year-olds living in Oslo, from Statistics Norway). The gender distribution was similar, but the proportion with higher education in the current sample population was higher than the average in the study population. This may have affected the prevalence estimates; untreated AP was more prevalent in those with only basic education, which means that the prevalence of untreated AP in the present study may have been underestimated.

A self-administered questionnaire was used to assess smoking status and dental attendance patterns. Therefore, these data are dependent on the responder's interpretation of the questions and their ability to recall or identify the requested information, potentially resulting in recall bias.

Cross-sectional studies cannot distinguish between healing and progressing cases of AP in root-filled teeth. Some studies have demonstrated that elapsed time plays an important role in the healing of AP [14], while other results suggest that this is not a major issue in large epidemiological studies, since the proportion of developing lesions (not detectable in radiographs) and healing lesions are similar [26].

The success rate of endodontic treatment is influenced by the periapical status at the start of treatment; root-filling of a non-infected tooth (vital pulp extirpation) has a better prognosis than root-filling of an infected tooth (treatment of AP) [47]. Another potential distorting factor may therefore be the missing information about the pre-treatment diagnosis, e.g. optimal apex-to-filling distance of the root filling is probably less determining in teeth without preoperative AP [48].

Periapical radiographs are more sensitive to the detection of periapical lesions than panoramic radiographs [49]. In the present study, only non-root-filled teeth suspected of having AP in panoramic radiographs were selected for further evaluation using periapical radiography. This may have led to an underestimation of untreated AP. Furthermore, 3D radiographic examinations, such as cone beam computed tomography (CBCT), may be more sensitive in detecting periapical pathology compared to 2D radiographic examinations. However, the latter retains an effective validity [50, 51], inflicts less radiation to the study participants and are less time consuming, all beneficial factors in larger observational studies.

Conclusions

The remaining number of teeth was high, and AP and root-filled teeth were prevalent among 65-year-olds in Oslo. A notable amount of untreated AP was observed, especially in current smokers. Approximately one-third of the root-filled teeth had AP; this was significantly more common if the apex-to-filling distance was too short or if the root filling was not homogeneous. The findings in this young-elderly population indicate a substantial need for dental care associated with endodontic conditions in the future elderly.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-022-02406-9.

Additional file 1: Supplementary Table 1: Distribution of individuals (N = 450) by frequency of AP, untreated AP, RF teeth and RF teeth with AP. **Supplementary Table 2:** Associations of untreated AP, root-filled teeth and root-filled teeth with AP with number of remaining teeth (n). **Supplementary Table 3:** The association between apical periodontitis and quality of root filling.

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Author contributions

Study concept and design: MTD, LHH, DØ, ATTS, RSR, PTS. Subject recruitment: MTD, LHH, ATTS. Clinical data collection: MTD, LHH, ATTS. Analysis and interpretation of data: MTD, LHH, DØ, ATTS, RSR, PTS. Writing the manuscript: MTD, LHH, DØ, ATTS, RSR, PTS. Critically evaluating the manuscript: MTD, LHH, DØ, ATTS, RSR, PTS. Project leader: LHH. All authors read and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Norwegian Regional Committee for Research Ethics (REK 2018/1383) and the study was performed in compliance with the tenets of the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Patient consent statement

All participants signed a written informed consent form.

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Publisher's Note

Supplementary Table 1. Distribution of individuals (N = 450) by frequency of AP, untreated AP, RF teeth and RF teeth with AP

Frequency	AP n (%)	Untreated AP n (%)	RF n (%)	RF with AP n (%)
0	249 (55)	378 (84)	153 (34)	280 (62)
1	115 (26)	52 (12)	101 (22)	109 (24)
2	42 (9)	11 (2)	82 (18)	42 (9)
3	23 (5)	8 (2)	47 (10)	12 (3)
4	14 (3)	0 (0)	26 (6)	4 (<1)
5	4 (1)	0 (0)	14 (3)	2 (<1)
6	1 (<1)	1 (<1)	18 (4)	0 (0)
7	0 (0)	0 (0)	5 (<1)	0 (0)
8	1 (<1)	0 (0)	3 (<1)	0 (0)
9	1 (<1)	0 (0)	1 (<1)	1 (<1)

AP = apical periodontitis; RF = root-filled

Supplementary Table 2. Associations of untreated AP, root-filled teeth and root-filled teeth with AP with number of remaining teeth (n)

N = 11 484	Untreated AP Odds ratio (95% CI)	RF Odds ratio (95% CI)	RF with AP Odds ratio (95% CI)
Number of remaining teeth	**0.93 (0.88-0.98)**	1.02 (0.98-1.07)	0.98 (0.94-1.03)

AP = apical periodontitis; RF = root-filled; CI = confidence interval

Values shown in bold text are statistically significant ($p < 0.05$: Logistic regression)

Supplementary Table 3. The association between apical periodontitis and quality of root filling

N = 756	Odds ratio (95% CI)
Length of root filling	
Satisfactory	1
Short	**2.0 (1.4-2.8)**
Long	1.2 (0.6-2.5)
Homogeneity of root filling	
Satisfactory	1
Unsatisfactory	**2.1 (1.5-2.9)**

CI = confidence interval
Values shown in bold text differ significantly from the reference category ($p < 0.05$: Logistic regression)
Only adjusted (not crude) odds ratios are shown.

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ORIGINAL ARTICLE

Xerostomia and hyposalivation among a 65-yr-old population living in Oslo, Norway

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Abstract

This study aimed to describe the prevalence and associated factors for xerostomia and hyposalivation in a young-elderly population. A random sample of 460 65-yr-old people living in Oslo, Norway, answered a questionnaire and underwent a clinical examination (237 men and 223 women; response rate 58%). Ten percent of respondents reported xerostomia. The median Summated Xerostomia Index was 6 (interquartile range [IQR]: 5–7) and the median Clinical Oral Dryness Score was 2 (IQR: 1–3). The median unstimulated whole saliva (UWS) secretion rate was 0.34 (IQR: 0.20–0.53) mL min^{-1} and the median stimulated whole saliva (SWS) secretion rate was 1.74 (IQR: 1.24–2.38) mL min^{-1}. In 8% of the study participants the UWS secretion rate was $\leq$0.1 mL min^{-1} and in 4% the SWS secretion rate was $\leq$0.7 mL min^{-1}. Three percent of the study participants had both xerostomia and hyposalivation with respect to UWS. Xerostomia was significantly associated with medication use, having rheumatic disease, and having received radiation therapy to the head/neck region. Hyposalivation with respect to UWS and SWS was significantly associated with medication use and type II diabetes. Even though xerostomia and hyposalivation were not prevalent conditions in this population, clinicians should be especially aware of the salivary conditions in patients taking four or more medications, patients diagnosed with type II diabetes, and those who have undergone radiation therapy to the head/neck region.

KEYWORDS

epidemiology, mouth dryness, saliva

INTRODUCTION

In many societies, the proportion of elderly people is gradually increasing (1). Many elderly people have declining general and oral health, and an increasing proportion of older people with general and oral health challenges may lead to higher individual and societal costs (2). It is therefore important to map the oral health status of the 'young elderly' in order to plan for future dental health needs and services as they age.

Saliva is important in maintaining a healthy oral cavity because it lubricates the oral surfaces, rinses the mouth, and neutralizes acids, and thus protects against caries and erosive wear, as well as mucosal infections. Reduced salivary secretion can cause problems with eating, speaking, and wearing dental prostheses (3–5). Having an adequate volume of saliva is therefore crucial for good oral health-related quality of life.

Salivary secretion rate is commonly determined by collecting unstimulated and/or stimulated whole saliva using a standardized protocol. If the secretion rates measured are below designated thresholds, the patient is diagnosed with 'hyposalivation' (6). Epidemiological studies show a varying prevalence of hyposalivation among the elderly, potentially because of different definitions and measurement methods (6,7). In addition, social demographics and medical background characteristics may influence salivary conditions. Furthermore, it has been reported that women, in general, have lower salivary secretion rates than men (8), and hyposalivation is associated with female gender (9–11), use of xerogenic medications (9,12), increasing age (13), and chronic diseases, such as diabetes and Sjögren's syndrome (14).

Hyposalivation may lead to xerostomia, the sensation of dry mouth. However, hyposalivation and xerostomia are not necessarily correlated (15). Information on xerostomia is obtained by interviews or questionnaires. A variety of questions with predetermined response alternatives have been used for this purpose: some only determine the presence of dry mouth ('Does your mouth feel dry?') (9), whereas others explore the extent of dry mouth ('How often does your mouth feel dry?') (10), as well as investigate the problems related to dry mouth ('Do you have difficulty with swallowing?') (5). A comprehensive approach is to use the Xerostomia Inventory, a multi-item questionnaire developed to measure the severity of chronic xerostomia (16). The original questionnaire was shortened to the Summated Xerostomia Inventory-Dutch Version (17).

Previous studies have shown that the prevalence of xerostomia increases with age (12,13,18,19). Xerostomia is reported more commonly in women (10,18–20), smokers (12,20), and individuals with symptoms of depression (9,20). Xerostomia is also associated with impaired general health (12,21) and use of medication (12) – in particular, a high number of medications (19) or xerogenic medications (20). Individuals with xerostomia also tend to report reduced oral health-related quality of life (21–23).

In most developed countries, 65 yr of age is the accepted beginning of old age, although there is no general agreement (24). Accordingly, 65 yr of age can be considered as the threshold age for the group 'young elderly'.

Even though saliva is important for maintaining good oral health, few studies focus on both subjective and objective salivary conditions among the young-elderly population. The aims of this study were therefore to determine the prevalence of xerostomia and hyposalivation among 65-yr-old people living in Oslo, Norway, to explore the correlation between the two conditions, and to investigate their association with gender, smoking, education, medical conditions, and medication use in this population.

MATERIAL AND METHODS

Study design and setting

The data presented in this cross-sectional study were part of a larger study investigating oral health in 65-yr-old people in Oslo, Norway (the OM65-study). The participants were examined at the Research Clinic of the Institute of Clinical Dentistry, University of Oslo, between 26 February 2019 and 13 December 2019. The study protocol was approved by the Norwegian Regional Committee for Research Ethics (REK 2018/1383) and was performed in compliance with the tenets of the Declaration of Helsinki. Prior to study inclusion, all participants signed a written informed consent form, including a plain language statement.

Participants

The target population was 65-yr-old (born in 1954) residents of Oslo, Norway. Eligible individuals were randomly selected from the Norwegian tax registry, and invitation letters were sent to 1230 individuals. No later than 2 wk after sending the invitation letters, the individuals were contacted by telephone and asked if they were interested in participating in the study.

Questionnaire

The self-administered questionnaire was sent to the participants via an electronic link to an online questionnaire program (Nettskjema; University of Oslo). Participants answered the questionnaire prior to attending the clinical examination. Xerostomia was assessed using the standardized question 'How often does your mouth feel dry?', with response categories 'Never', 'Occasionally', 'Frequently', and 'Always' (10,25). Those who reported dry mouth 'Frequently' or 'Always' were grouped as 'xerostomic'.

Symptoms of dry mouth were assessed further using the Summated Xerostomia Inventory-Dutch Version (SXI-D), which contains five questions related to dry mouth. The SXI-D sum score ranges between 5 and 15, with a higher score representing an increased number of symptoms and/or an increased frequency of symptoms related to dry mouth (17).

The participants were also asked about smoking habits, their highest level of completed education, whether they have previously received radiation therapy in the head/neck region, how many medications they use regularly, and whether they have type II diabetes or rheumatic disease (subgroups not specified). Use of medications was categorized into 'no medications', '1–3 medications', and '≥4 medications'. The participants' level of education was dichotomized into 'higher education' (university/college education) and 'basic education' (high school, elementary school, or lower).

Clinical examinations

Participants were instructed to refrain from eating, drinking, and smoking for at least 1 h before the clinical examination. Standardized sialometry was performed on all participants between 8 AM and 3 PM. For collection of unstimulated whole saliva (UWS), participants were instructed to sit relaxed and swallow any saliva in their mouth. During the 5 min saliva-collection period, the participants were asked to avoid swallowing saliva by spitting regularly into a test cup. After 5 min, each participant was asked to spit any remaining saliva into the test cup. For collection of stimulated whole saliva (SWS), the participants were first instructed to chew on a paraffin wax tablet (Ivoclar Vivadent) for 30 s, and then to swallow the saliva that was produced. Participants were then instructed to continue to chew on the wax tablet for a further period of 5 min and to spit out all saliva, produced regularly, into a fresh test cup. The test cups were preweighed and chilled on ice, and saliva samples were weighed after sample collection. The assumed density of saliva was 1 g mL^{-1}. In this study, hyposalivation was defined as a salivary secretion rate of ≤0.1 mL min^{-1} for UWS (20,26) and of ≤0.7 mL/min^{-1} for SWS (20).

Objective oral dryness was also assessed clinically using the Clinical Oral Dryness Score (CODS) (27,28). In this scoring system, 10 signs of oral dryness are evaluated (score range 0–10; higher scores represent more severe dryness), including mirror tests and visual signs of mucosal wetness, presence and frothiness of saliva, and presence of cervical caries and debris. This examination was performed after UWS sampling and before SWS sampling.

Statistical analyses

Data were collected in the Oral Data Collector sheet specifically designed for data entry in this study, developed in Microsoft Excel 2016 (Microsoft) and imported into STATA (Stata version 16.1; StataCorp) for statistical analyses. Descriptive statistical analyses were performed and the results are presented in the form of number (*n*) with percentage or median with interquartile range (IQR). All data were stored, and analyses performed, in the TSD (Service for Sensitive Data, Centre for Information Technology Services, University of Oslo).

Chi-square and Fisher's exact tests were used to determine any differences in the distribution of categorical variables. As the continuous variables did not follow a normal distribution, Kruskal–Wallis ANOVA and the Mann–Whitney *U*-test were used to detect differences in median values of continuous, numerical variables between two or three groups. Spearman rank correlation analysis was used to measure the strength and direction of the linear relationships between the parameters used to determine dry mouth.

As the number of medications taken showed a significant association with both xerostomia and hyposalivation, this variable was chosen as the main factor for further investigation using regression analysis. Gender, education level, smoking habits, presence of type II diabetes or rheumatic disease, and experience with radiation therapy to the head/neck were all explored as confounding factors. However, only factors that were significantly associated with the outcome variable in the multivariate analysis were included in the final model. To study the relationship between xerostomia and the number of medications taken, univariate and multivariate logistic regression were used, and data are presented in the form of unadjusted and adjusted ORs with their 95% CI. To study the relationship between UWS and SWS secretion rates and the number of medications taken, univariate and multivariate linear regression were used. As a result of the high number of unusual and influential data (outliers), failure of the data to follow a normal distribution, and heteroscedasticity of the residuals, square root transformation was applied, and linear regression with robust function was used. The data are presented in the form of crude and adjusted β-coefficients, with their 95% CI. The level of significance was set to $P < 0.05$.

RESULTS

Of the 797 eligible participants who both received a letter and were contacted by telephone, 460 attended the examination (response rate 58%). Three of the attendees did not answer the questionnaire and were therefore excluded from the analyses. The sociodemographic and medical background characteristics of the study population ($n = 457$) are presented in Table 1.

Subjective dry mouth parameters

Data on the prevalence of subjective dry mouth and related factors are presented in Table 2. Ninety percent of the participants reported having dry mouth 'never' or 'occasionally'. The presence of symptoms of dry mouth according to the standard xerostomia question was significantly associated with the number of medications taken, rheumatic disease, and radiation therapy to the head/neck region. A feeling of dry mouth 'frequently' or 'always' was significantly more

TABLE 1 Sociodemographic and medical background characteristics of the study population.

Characteristic	*n* (%)
All	457 (100)
Gender	
Male	236 (52)
Female	221 (48)
Education level	
Higher education	305 (67)
Basic education	152 (33)
Smoking	
Current	50 (11)
Former	210 (46)
Never	197 (43)
Medications (no.)	
≥4	117 (26)
1–3	216 (47)
0	124 (27)
Type II diabetes	
Yes	31 (7)
No	426 (93)
Rheumatic disease	
Yes	56 (12)
No	401 (88)
Radiation head/neck[a]	
Yes	7 (2)
No	450 (98)

[a]Experience with radiation therapy to the head and neck area.

TABLE 2 Subjective dry mouth parameters according to gender, education level, smoking, and general health factors.

Characteristic	Xerostomia (frequently/ always)	SXI-D score
All	45 (10)	6 (5–7)
Gender		
Male	21 (9)	**6 (5–7)**
Female	24 (11)	7 (6–8)
Education level		
Higher education	25 (8)	**6 (5–7)**
Basic education	20 (13)	7 (6–8)
Smoking		
Current	4 (8)	7 (6–8)
Former	23 (11)	6 (5–8)
Never	18 (9)	6 (5–7)
Medications (no.)		
≥4	**20 (17)**	**7 (6–8)**
1–3	20 (9)	6 (5–7)
0	5 (4)	6 (5–7)
Type II diabetes		
Yes	3 (10)	7 (5–8)
No	42 (10)	6 (5–7)
Rheumatic disease		
Yes	**10 (18)**	**7 (6–8)**
No	35 (9)	6 (5–7)
Radiation head/neck		
Yes	**4 (57)**	**11 (7–15)**
No	41 (9)	6 (5–7)

Values are given as *n* (%) or median (interquartile range). Total number of study participants = 457.

Values shown in bold text are statistically significant ($P < 0.05$: chi-square/ Fisher's exact, Kruskal–Wallis, or Mann–Whitney *U* test, as appropriate).

Abbreviations: SXI-D, Summated Xerostomia Inventory-Dutch Version.

common among those who used ≥4 medications (17%), than those who used no or 1–3 medications (4% and 9%, respectively).

The median SXI-D score was 6, and 95% of the participants had a score of less than 11. Although there were significant differences in many of the comparisons in relation to the median SXI-D score, the most pronounced difference was between individuals who had undergone radiation therapy to the head/neck region and those who had not (median SXI-D score: 11 vs. 6).

Objective dry mouth parameters

The overall median UWS secretion rate was 0.34 (0.20–0.53) mL min^{-1}. It was significantly higher in male participants (0.40 mL min^{-1}) than in female participants (0.28 mL min^{-1}) and significantly lower in individuals who had undergone radiation therapy to the head/neck region (0.18 mL min^{-1}) than in those who had not (0.34 mL min^{-1}) (Figure 1). Overall, 8% of the participants had hyposalivation with respect to UWS (≤0.1 mL min^{-1}), and the condition was significantly associated with the number of medications used and type II diabetes (Table 3). Hyposalivation with respect to UWS was significantly more common among those who took ≥4 medications (13%) than in those who took no medications (5%).

The overall median SWS secretion rate was 1.74 (1.24–2.38) mL min^{-1} and 4% of all participants had hyposalivation with respect to SWS (≤0.7 mL min^{-1}). Women, those who took ≥4 medications, those with type II diabetes, and those who had undergone radiation therapy to the head/neck region had a significantly lower median SWS secretion rate than their counterparts (Figure 2A–E). Current smokers had a significantly lower median SWS secretion rate than former smokers but not when compared with never smokers (Figure 2B). Hyposalivation with respect to SWS showed significant

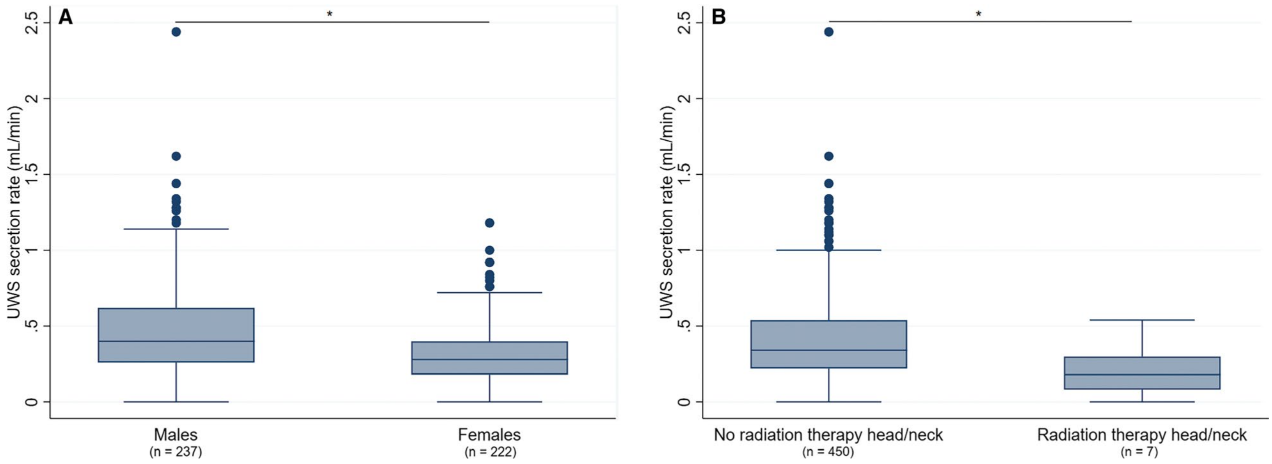

FIGURE 1 Unstimulated whole saliva (UWS) secretion rate according to gender (A) and radiation therapy to the head/neck area (B). Boxplots illustrate the distribution of UWS secretion rate, with each box showing median, interquartile range, and upper and lower quartiles. Dots in the figure represent outliers. *$P < 0.05$, Mann–Whitney *U*-test. [Colour figure can be viewed at wileyonlinelibrary.com]

association with gender, smoking status, number of medications taken, and type II diabetes (Table 3). A significantly greater proportion of current smokers (10%) than of former smokers (2%) had hyposalivation with respect to SWS, but the difference was not statistically significant compared with never smokers (5%). Furthermore, a significantly greater proportion of those who took ≥4 medications (8%) than of those who took 1–3 medications (2%) had hyposalivation with respect to SWS, but the difference was not statistically significant compared with those who took no medications (3%).

The overall median CODS was 2 (Table 3). Current smokers and those who had received radiation therapy to the head/neck region had a significantly higher median CODS than their counterparts.

Relationship between xerostomia and hyposalivation

We found a positive, strong, and significant correlation between the responses to the standard xerostomia question (never/occasionally/frequently/always) and the SXI-D score ($r_s = 0.73$). Both the standard xerostomia question and the SXI-D score were significantly correlated with UWS and SWS secretion rates, but the correlation was strongest for UWS. The correlation between the standard xerostomia question and UWS secretion rate was negative and weak, but statistically significant ($r_s = -0.20$). The same was shown for the correlation between UWS secretion rate and the SXI-D score ($r_s = -0.23$). Three percent of participants had both often/always dry mouth and hyposalivation with respect to UWS, while 85% of the participants had neither condition.

There was a positive, moderate, and significant correlation between UWS and SWS secretion rates ($r_s = 0.48$). Two percent of the participants had hyposalivation with respect to both UWS and SWS and 90% had neither condition.

The CODS showed a positive, weak, but significant, correlation with the standard xerostomia question ($r_s = 0.22$) and the SXI-D score ($r_s = 0.22$). Furthermore, the CODS showed a negative, weak, but significant, correlation with the UWS secretion rate ($r_s = -0.30$) and the SWS secretion rate ($r_s = -0.17$).

Regression models

The number of medications taken was significantly associated with xerostomia in both the crude and adjusted analyses, while the presence of rheumatic disease and experience with radiation therapy to the head/neck were found to be confounding factors (Table 4). Medication intake (≥4 medications) was associated with a 4.4-fold increased risk of xerostomia compared with those of the reference categories, after adjusting for rheumatic disease and radiation therapy.

Tables 5 and 6 present the linear regression model for UWS and SWS secretion rates. The number of medications taken showed no association with UWS secretion rate in either the unadjusted or the adjusted model, while medication intake (≥4 medications) was associated with a decreased SWS section rate.

DISCUSSION

This paper describes the occurrence of dry mouth and factors associated with this condition in a sample of 65-yr-old people living in Oslo. To our knowledge, the present study is one of only a few studies that focus on both subjective and objective

TABLE 3 Objective dry mouth parameters according to gender, education level, smoking, and general health factors.

Characteristic	Hyposalivation UWS	Hyposalivation SWS[a]	CODS
All	36 (8)	18 (4)	2 (1–3)
Gender			
Male	17 (7)	**15 (6)**	2 (1–3)
Female	19 (9)	3 (1)	2 (1–3)
Education			
Higher education	24 (8)	13 (4)	2 (1–3)
Basic education	12 (8)	5 (3)	2 (1–3)
Smoking			
Current	6 (12)	**5 (10)**	**2 (2–3)**
Former	14 (7)	4 (2)	2 (1–3)
Never	16 (8)	9 (5)	2 (1–3)
Medications (no.)			
≥4	**15 (13)**	**9 (8)**	2 (1–3)
1–3	15 (7)	5 (2)	2 (1–3)
0	6 (5)	4 (3)	2 (1–3)
Type II diabetes			
Yes	**6 (19)**	**5 (16)**	2 (1–4)
No	30 (7)	13 (3)	2 (1–3)
Rheumatic disease			
Yes	6 (11)	1 (2)	2 (1–3)
No	30 (7)	17 (4)	2 (1–3)
Radiation head/neck			
Yes	2 (29)	1 (14)	**3 (2–6)**
No	34 (8)	17 (4)	2 (1–3)

Values are given as *n* (%) or median (interquartile range). Total number of study participants = 457.

Values shown in bold text are statistically significant ($P < 0.05$: chi-square/Fisher's exact, Kruskal–Wallis, or Mann–Whitney *U* test, as appropriate.

Abbreviations: CODS, Clinical Oral Dryness Score; SWS, stimulated whole saliva secretion rate ≤0.7 mL min^{-1}; UWS, unstimulated whole saliva secretion rate ≤0.1 mL min^{-1}.

[a]Date were missing for eight study participants.

dry mouth findings based on a comprehensive selection of measurements in a general population of young-elderly people.

The overall prevalence of xerostomia in the present study was 10%, which is lower than found in previous studies in the same age group. JOHANSEN and coworkers performed a study on 65-yr-old Swedish people and found a prevalence of 15% for xerostomia (29). A study from Australia, using the same question for xerostomia as in the current study, showed that 20% of the participants within the age group 65–69 yr had ‘frequently’ or ‘always’ dry mouth (10). Furthermore, in 2009, EKBACK and coworkers reported the prevalence of xerostomia to be 30% in 65-yr-old Norwegians from the western part of Norway (30). However, as the definition of xerostomia used in the Norwegian study was slightly different from that used in the present study, the prevalence of xerostomia between studies is not directly comparable. Studies in younger age groups have shown a prevalence of xerostomia similar to that reported in the present study for 65-yr-old people; a study from Finland showed a prevalence of xerostomia of 11% among a group of 55-yr-old adults (20), and a study from New Zealand showed a prevalence of xerostomia of 10% among a group of 32-yr-old adults (25). These findings may suggest that age alone does not have a strong, direct effect on xerostomia. In addition, the use of different questionnaires to map xerostomia can also influence the results and makes it more challenging to compare the findings from different studies.

Previous studies have used several different definitions for hyposalivation (10,18,20,31). In the present study, we chose the definition according to the 2002 classification criteria for Sjögren's syndrome (UWS secretion rate of ≤0.1 mL min^{-1}) (26). The prevalence of hyposalivation with respect to UWS was 8% in our study. This is lower than reported in previous studies carried out on the young-elderly/elderly age groups. ANTTILA and coworkers used the same definition for hyposalivation as in the current study and reported a prevalence of hyposalivation of 16% among 55-yr-old Finns (20). Studies using a slightly lower threshold for hyposalivation (<0.1 mL/min^{-1}) showed a prevalence of hyposalivation of 12%–47% in different age groups ranging from 65–86 yr (9,10,31). In this context, if a threshold of hyposalivation of <0.1 mL/min^{-1} had been used in the current study, the prevalence of hyposalivation would have been reduced to 5%.

The prevalence of hyposalivation with respect to SWS was 4% in the present study. KONGSTAD and coworkers found a prevalence of hyposalivation among Danes, 65–74 yr of age, of 4% in men and 5% in women, which was similar to that reported in the present study (18). However, as in the study by KONGSTAD *et al.*, the threshold for hyposalivation (SWS ≤0.5 mL min^{-1}) was lower than that used in the present study, it can be speculated that the prevalence of hyposalivation would have been higher if they had used the same threshold as that in the present study. Many studies on older age groups have shown a higher prevalence of SWS (11%–31%) than reported in the present study (5,8,11,31).

Medication use and general health of study participants are factors that can be causally related to dry mouth (8,20,21), and will vary between study populations. This, in addition to different definitions of xerostomia and hyposalivation, may partly explain the different prevalence estimates of these two conditions reported in the studies discussed above. Furthermore, the fact that new and improved drugs have fewer side effects may also contribute to the differences in the prevalence of dry mouth observed between studies from different periods in time.

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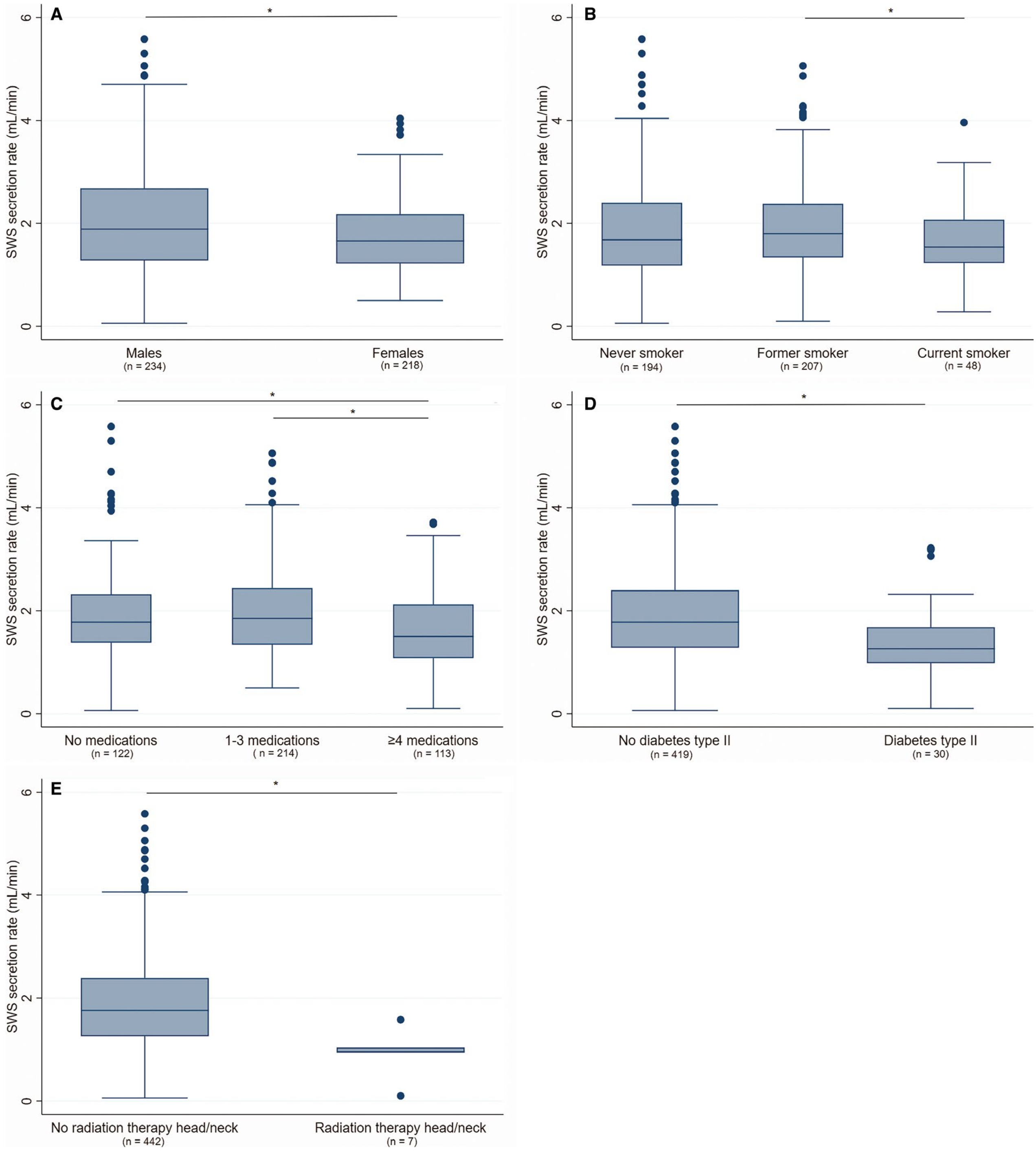

FIGURE 2 Stimulated whole saliva (SWS) secretion rate according to gender (A), smoking habits (B), medications (C), diabetes (D), and radiation therapy to the head/neck area (E). Boxplots illustrate the distribution of SWS secretion rate, with each box showing median, interquartile range, and upper and lower quartiles. Dots in the figure represent outliers. *$P < 0.05$, Mann–Whitney *U*-test. [Colour figure can be viewed at wileyonlinelibrary.com]

Previous literature has highlighted the need for an increased focus on the relationship between xerostomia and hyposalivation (6). In the present study, only 3% of the participants had both 'hyposalivation with respect to UWS' and 'xerostomia', which is equivalent to one in five of those who had either condition. This proportion was somewhat larger than in the study by THOMSON and coworkers (10), in which one in six participants were reported to have both conditions. The combination of 'hyposalivation with respect to SWS' and 'xerostomia' occurred in only 0.7% of the current study population and the two conditions were not significantly associated, the latter being in accordance

TABLE 4 Logistic regression model for xerostomia with number of medications as the main exposure variable.

Independent variables	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Medications (no.)		
0[a]	1	1
1–3	2.4 (0.9–6.6)	2.0 (0.7–5.5)
≥4	**4.9 (1.8–13.6)**	**4.4 (1.6–12.6)**
Rheumatic disease		
No[a]	1	1
Yes	**2.3 (1.1–4.9)**	**2.3 (1.0–5.0)**
Radiation head/neck		
No[a]	1	1
Yes	**13.3 (2.9–61.5)**	**12.5 (2.6–60.6)**

[a]Reference category; values with $P < 0.05$ are shown in bold text.

TABLE 5 Linear regression model for unstimulated whole saliva (UWS) secretion rate with number of medications as the main exposure variable.

Independent variables	Unadjusted β-coefficient (95% CI)	Adjusted β-coefficient (95% CI)
Medications (no.)		
0[a]	0	0
1–3	−0.02 (−0.07 to 0.02)	−0.01 (−0.06 to 0.04)
≥4	−0.05 (−0.10 to 0.01)	−0.05 (−0.10 to 0.01)
Gender		
Male[a]	0	0
Female	**−0.10 (−0.13 to −0.06)**	**−0.10 (−0.14 to −0.06)**
Radiation head/neck		
No[a]	0	0
Yes	**−0.20 (−0.36 to −0.04)**	**−0.20 (−0.38 to −0.02)**

Note: Constant = 0.66.

As a result of the high number of unusual and influential data (outliers), failure of the data to follow a normal distribution, and heteroscedasticity of the residuals, the data were square root transformed.

[a]Reference category; values with $P < 0.05$ are shown in bold text.

TABLE 6 Linear regression model for stimulated whole saliva (SWS) secretion rate with number of medications as the main exposure variable.

Independent variables	Unadjusted β-coefficient (95% CI)	Adjusted β-coefficient (95% CI)
Medications (no.)		
0[a]	0	0
1–3	−0.01 (−0.08 to 0.06)	0.02 (−0.05 to 0.09)
≥4	**−0.13 (−0.22 to −0.05)**	**−0.09 (−0.18 to −0.01)**
Gender		
Male[a]	0	0
Female	**−0.08 (−0.14 to −0.02)**	**−0.10 (−0.15 to −0.04)**
Type II diabetes		
No[a]	0	0
Yes	**−0.22 (−0.35 to −0.08)**	**−0.17 (−0.30 to −0.05)**
Radiation head/neck		
No[a]	0	0
Yes	**−0.42 (−0.62 to −0.22)**	**−0.41 (−0.58 to −0.24)**

Note: Constant = 1.42.

As a result of the high number of unusual and influential data (outliers), failure of the data to follow a normal distribution, and heteroscedasticity of the residuals, the data were square root transformed.

[a]Reference category; values with $P < 0.05$ are shown in bold text.

with the report by SREEBNY & VALDINI (32). The low correlation reported between xerostomia and hyposalivation suggests that the aetiology of xerostomia is complex, and that certain qualities of saliva, such as viscosity and the ability to lubricate mucosal surfaces, may play important roles. Limitations of the present study in this respect were that the composition and viscosity of saliva were not investigated.

Xerostomia and hyposalivation are common manifestations of some rheumatic diseases that affect the salivary glands, such as Sjögren's syndrome (33). In the current study, the presence of rheumatic disease was significantly associated with xerostomia but not with hyposalivation (UWS and SWS). In these subjects, both the rheumatic disease and the medical treatment may have affected the composition, but not the secretion rate of saliva, inducing xerostomia as a result of changes in the quality of the saliva (34). However, information on the type of rheumatic disease was not collected in the present study, thus limiting analysis of the relationship between rheumatic diseases and dry mouth.

Radiation therapy to the head/neck region is associated with a high risk of damage to the salivary glands (35). In the current study, individuals who had undergone radiation therapy had significantly lower median UWS and SWS secretion rates than those who had not had any radiation therapy. Both xerostomia and hyposalivation were more prevalent among those who had undergone radiation therapy to the head/neck region, although this relationship was not significant for hyposalivation. This could partly be a result of the low number of subjects included in this study.

The effect of medications on dry mouth is a complex phenomenon. Certain medications have dry mouth as a direct side effect, but interactions and additive effects may occur when using combinations of several different medications. Furthermore, it can be challenging to distinguish between side effects of medications on dry mouth and those of the underlying medical conditions (6). Twenty-five percent of the participants took four or more medications, and this was significantly associated with having both xerostomia and hyposalivation. The logistic regression analysis confirmed that taking four or more medications compared with taking no medications was significantly associated with xerostomia. In addition, the linear regression analysis showed that those taking four or more medications had a lower SWS secretion rate than those who took no medications. These findings support the fact that taking four or more medications can have a direct, negative effect on xerostomia and stimulated saliva secretion rate. The prevalence of dry mouth in this study was quite low considering that 26% of the study participants took four or more medications. However, the type of medication and duration of use were not assessed in the present study.

Compared with the other participants, a greater proportion of those with type II diabetes had hyposalivation with respect to UWS and SWS. In accordance with the study by CHAVEZ and coworkers, they had a significantly lower median stimulated salivary secretion rate, but this association was not found for unstimulated saliva (36). As discussed by CHAVEZ and coworkers, these findings can be explained by the fact that diabetes can lead to autonomic neuropathies and microvascular changes that reduce the ability to respond to a salivary stimulus; therefore, the stimulated, but not the unstimulated, salivary secretion rate is affected. Furthermore, a previous study showed that individuals with type II diabetes more commonly experience xerostomia than their counterparts (37). However, in the present study and in the study by CHAVEZ *et al*., xerostomia was not prevalent in individuals with type II diabetes. More detailed data on the duration of type II diabetes and the level of blood glucose control were not collected in the present study. Such data may have provided a basis for more specific analyses of the effect of type II diabetes on salivary conditions.

The female participants in the present study had lower median UWS and SWS secretion rates than the male participants. This may be explained by the fact that women, in general, have smaller saliva glands than men (38), in addition to postmenopausal hormonal changes that can affect the glands (39). However, hyposalivation (SWS) was significantly more common among men than women in the present study, which is in contrast to previous findings (8,11,18). This may be related to the fact that 71% of those with type II diabetes in our study population were men. Taking four or more medications and having undergone radiation therapy to the head/neck were also more common among the male participants. In the present study, xerostomia was not associated with gender, although many studies have found that xerostomia is more common in women (8,10,18–21).

The present study has some potential limitations. First, the response rate was 58%, meaning that there was a sizable proportion of non-responders. As a result of restrictions from the Ethics Committee, we were not permitted to ask potential study participants why they declined to participate. A second potential limitation was selection bias. Therefore, to explore potential selection bias, the gender distribution and education level of the study population were compared with the corresponding proportions of the target population (based on register data from Statistics Norway). The gender distribution was similar, but the proportion with higher education in the current study population was higher than the average in the target population. This may have affected the prevalence estimates; however, the level of education did not show a significant association with either subjective or objective measures of dry mouth in this study.

Third, a self-administered questionnaire was used to assess smoking habits, presence of diseases, use of medications, and symptoms of dry mouth. Therefore, these data are dependent on the responder's interpretation of the questions and their ability to recall or identify the requested information, potentially resulting in recall bias.

Finally, some factors may have affected the saliva samples. All participants were asked if they had fasted for the hour before the appointment, and 4% replied that they had not. This could have influenced the measured salivary secretion rates. Despite this, saliva was collected from all participants and it was found that the median and IQR values for the UWS secretion rate among those who did not fast (0.39 [0.16–0.48] mL min^{-1}) were only slightly different from those who did fast (0.34 [0.20–0.54] mL min^{-1}). However, some of the UWS secretion values among those who had not fasted were only slightly above 0.1 mL min^{-1}, and these study participants may have been classified incorrectly as not having hyposalivation. Furthermore, considering the fact that the measurements were performed between 8 AM and 3 PM, diurnal variations in salivary secretion rate may also have affected the results. Regarding salivary collection time, GILL and coworkers found no significant differences in salivary secretion rates between collection times (40). However, their study was performed in a younger study population (mean age ± SD: 24 ± 4 yr), and they tested only the unstimulated salivary secretion rate over a time period of 1–6 min, during which saliva was collected.

In conclusion, hyposalivation and xerostomia were infrequent among the 65-yr-old study population from Oslo, Norway. However, clinicians should be especially aware of the saliva status in patients taking four or more medications, those with type II diabetes, and those who have undergone radiation therapy to the head/neck region. Considering the low correlation between xerostomia and hyposalivation, not only the quantity of saliva, but also its quality, should be investigated in future studies examining xerostomia and hyposalivation.

CONFLICT OF INTEREST

There are no conflicts of interest.

AUTHOR CONTRIBUTION

Conception and design: My Tien Diep, Janicke Liaaen Jensen, Rasa Skudutyte-Rysstad, Alix Young, Anne Thea

Tveit Sødal, Lene Hystad Hove; Data collection: My Tien Diep, Rasa Skudutyte-Rysstad, Anne Thea Tveit Sødal, Lene Hystad Hove; Analysis and interpretation of data: My Tien Diep, Janicke Liaaen Jensen, Rasa Skudutyte-Rysstad, Alix Young, Anne Thea Tveit Sødal, Beáta Éva Petrovski, Lene Hystad Hove; Drafting and revising of the manuscript: My Tien Diep, Janicke Liaaen Jensen, Rasa Skudutyte-Rysstad, Alix Young, Anne Thea Tveit Sødal, Beáta Éva Petrovski, Lene Hystad Hove.

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