Aus dem

Institut für Gesundheitswissenschaften

Abteilung Population-Based Medicine

Oral health-related quality of life and depressive symptoms in older adults

Inaugural-Dissertation
zur Erlangung des Doktorgrades
der Zahnheilkunde

der Medizinischen Fakultät
der Eberhard Karls Universität
zu Tübingen

vorgelegt von

Zwick, Luisa Natalie

2024

Dekan:	Professor Dr. B. Pichler
1. Berichterstatter:	Professor Dr. N. Schmitz
2. Berichterstatter:	Professor Dr. F. Hüttig
Tag der Disputation:	29.04.2024

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List of abbreviations

ADL	Activities of Daily Living
BMS	Burning mouth syndrome
BoP	Bleeding on probing
CAL	Clinical attachment loss
CES-D	Center for Epidemiologic Studies Depression Scale
CI	Confidence interval
CRP	C reactive protein
CVD	Cardiovascular diseases
DM	Diabetes mellitus
DMFT	Decayed-missing-filled-teeth index
DSM-5	The Diagnostic and Statistical Manual of Mental Disorders fifth edition
ELSA	English Longitudinal Study of Ageing
EQ-5D	Euro Quality of Life 5 Dimensions
GDS	Geriatric Depression Scale
GOHAI	General or Geriatric Oral Health Assessment Index
HRQoL	Health-Related Quality of Life
HSE	Health Survey for England
HSI	Health Status Index
IBM	International Business Machines Corporation
ICD-11	International Classification of Diseases 11th revision
IL-6	Interleukin 6
MDD	Major Depressive Disorder
NCD	Noncommunicable disease
OHIP	Oral Health Impacts Profile
OHRQoL	Oral Health-Related Quality of Life
OIDP	Oral Impacts on Daily Performances
OR	Odds ratio
PA	Physical activity
PD	Pocket depth

PHQ-9	Patient Health Questionnaire 9 Items
QoL	Quality of Life
SCID	Structured Clinical Interview for DSM disorders
SDS	Self-rating Depression Scale
SES	Socioeconomic status
SF-36	Short Form 36
SPSS	Statistical Package for the Social Sciences
SSS	Secondary Sjögren’s syndrome
SWB	Subjective Well-Being
TMD	Temporomandibular disorders
TNF-α	Tumor necrosis factor
WHO	World Health Organization

1 Introduction

1.1 Oral health

Oral health is an increasingly important component of overall health, particularly in the elderly population. However, people of all ages suffer from a variety of oral health problems, including tooth loss, dental caries, periodontal diseases, and temporomandibular disorders (TMD) (Zwick et al., 2023). Poor oral health can also manifest as oral cancer, oral infections, oro-dental trauma (Petersen et al., 2020), mucosal lesions such as noma and congenital malformation such as cleft palate (WHO, 2022).

Oral diseases share common risk factors with some noncommunicable diseases, including cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes, such as a poor, sugary diet and tobacco and alcohol use (Petersen et al., 2020).
Dental caries is the most prevalent oral disease, affecting 44 % of the world's population. According to the 2017 Global Disease Burden Study, oral diseases affected 3.5 billion people worldwide in 2016 (Zwick et al., 2023).

General health is defined by the World Health Organization (WHO) as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 2021). One of the main issues with this definition is the integration of social aspects, which may not be obvious at the first glance (Karimi & Brazier, 2016). All of these issues have a similar impact on oral health (Wong et al., 2019)

While objective oral health can be measured by clinical symptoms, such as the number of missing and decayed teeth, subjective oral health refers to an individual's self-perceived oral status. Self-perceived oral health can be assessed using questionnaires about satisfaction with oral function in everyday life. The burden of oral disease can vary between individuals with similar objective oral health outcomes. A subjective assessment of oral health was considered

appropriate for this study, due to the focus on oral health-related quality of life and the subjective nature of quality of life.

Poor oral health is more common in the elderly, as evidenced by the increased prevalence of root caries, periodontitis, and tooth loss in older adults (Coll et al., 2020). In addition, many older adults suffer from chronic diseases and take various medications, which can lead to hyposalivation and an elevated risk of dental caries (Wong et al., 2019). However, the self-perceived oral health of older adults may differ from the clinical situation (Koistinen et al., 2020).

1.2 Quality of life

1.2.1 Definition

Quality of life (QoL) is a frequently used but not always clearly defined term. It refers to wide domains including medicine, economics, political science, and sociology (Owolabi, 2008). Nevertheless, there is agreement on some important aspects, such as the consistency of QoL with both objective and subjective elements (Vanleerberghe et al., 2017).

The WHO defines QoL as “the proper and correct perception that a person has of itself in the cultural context and values on which it is embedded, in relation to its objectives, standards, hopes and concerns” (Lindmark et al., 2021).

1.2.1.1 Health-related quality of life

Health is one of the determinants of QoL. Health-related quality of life (HRQoL) focuses on social, physical, and psychological functioning such as activities of daily living (ADL) including personal hygiene and self-feeding among other things and subjective well-being (SWB). Biological variables (e.g. blood test results) and clinical symptoms (e.g. clinical attachment loss (CAL)) are less important for this type of record (Karimi & Brazier, 2016).

1.2.1.2 Oral health-related quality of life

Oral health problems are not always isolated from the rest of the body. On the contrary, they can have a direct impact on quality of life. Oral health-related quality of life (OHRQoL) is a multidimensional construct that can include both professional measurement and subjective assessment of an individual's oral health (Zwick et al., 2023).

1.2.2 Historical background

In the 1960s the concept of Quality of Life was first mentioned in medical literature (Karimi & Brazier, 2016). The term gained importance in health care as medical treatment was able to increase life expectancy. It was no longer sufficient to measure simple mortality rates (Karimi & Brazier, 2016). In the 1970s, quality of life was measured to assess the performance of a health care system. The Health Status Index (HSI), a general measure of health, was one of the first methods to assess health without focusing on the economic benefits. The conditions ranged from "well-being" to "disabled" to "death" (Karimi & Brazier, 2016).

The term OHRQoL did not emerge until the early 1980s. Before then, dental care was only of clinical importance and not related to general health. As the WHO's definition of health included also social and mental dimensions, clinical indicators were no longer adequate to assess them. Therefore, researchers developed standardized questionnaires to combine oral health and QoL (Bennadi & Reddy, 2013). In 1976, Cohen and Jago first described that dental indicators, including dental caries, periodontal disease, and other oral conditions, were associated with chronic disease and personal lifestyle in the United States. (Cohen & Jago, 1976). Between 1980 and 2000, several methods of measuring oral health outcomes were developed (Allen, 2003). During the last two decades, OHRQoL has become increasingly important, and more and more studies have been conducted on it (Lindmark et al., 2021; Sischo & Broder, 2011; Skoskiewicz-Malinowska et al., 2016).

1.2.3 Assessment of quality of life

The Short Form 36 (SF-36) is a very common method of measuring HRQoL, which consists of 36 questions divided into eight domains: physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH). Each domain has a score ranging from 0 to 100, with higher scores indicating better health (Abbasi-Ghahramanloo et al., 2020). These domains refer to the different dimensions of HRQoL, which are devided into mental, physical, social, and medical domains (Krawczyk-Suszek & Kleinrok, 2022). Emotional role and physical role refer to regular daily activities that are limited due to emotional/physical health problems, such as accomplishing less work than one would like. Physical functioning includes lifting or carrying groceries and vigorous activities such as running, for example. Vitality refers to feelings such as happiness and having lots of energy.

Another assessment of health status is the Euro Quality of Life 5 Dimensions (EQ-5D) from the EuroQoL Group, which consists of five questions on mobility, self-care, usual activities, pain/discomfort and depression/anxiety (Rabin & de Charro, 2001). It was initially divided into three levels (no problems/some or moderate problems/extreme problems) and has recently been expanded to a five-category questionnaire (no problems, slight problems, moderate problems, severe problems, and unable to/extreme problems) (van Hout et al., 2012).

There are several ways to collect OHRQoL, such as the Oral Health Impacts Profile (OHIP) and the General or Geriatric Oral Health Assessment Index (GOHAI) (Wong et al., 2019). Another way to estimate OHRQoL is through a questionnaire, such as the Oral Impacts on Daily Performances (OIDP). This is a method that asks about the self-perceived impact of oral health conditions on daily activities (Gülcan et al., 2014). An example of such a question is given below.

During the past 6 months, how often did you have problems with your mouth and teeth that caused you any difficulty with:

1) eating and enjoying food
2) speaking and pronouncing clearly
3) cleaning teeth
4) sleeping and relaxing
5) smiling and showing teeth without embarrassment
6) maintaining usual emotional state
7) enjoying contact with people
8) carrying out major work

On a 5-point scale the elements above can be rated as 1: never affected, 2: less than once a month, 3: once or twice a month, 4: once or twice a week, 5: every/ nearly every day (Gülcan et al., 2014).

1.2.4 Association between oral health and quality of life

The term “oral health” is often used in isolation from the rest of the body, referring only to clinical symptoms in the oral cavity. In contrast, “quality of life” encompasses several aspects of general living conditions. Finally, OHRQoL describes the self-perceived impact of oral health status on an individual’s quality of life. It is therefore a holistic view of oral health in relation to the QoL.

Dental caries as the most prevalent disease of the oral cavity, and periodontitis (global prevalence of severe periodontitis: approximately 11 % (Kwon et al., 2021)) can lead to tooth loss (Lindmark et al., 2021). The number of remaining natural teeth has been found to be associated with oral health-related quality of life, as abilities such as chewing, speaking, and smiling are reduced in edentulous patients and those with a smaller number of existing teeth. In particular, institutionalized older adults who require assistance with their oral hygiene often suffer from poor oral health associated with caries and periodontal disease. Lack of time and limited staff knowledge about the importance of oral cleanliness, as well as patients’ self-determination and resistance to care, can impede proper oral hygiene (Saarela et al., 2022). However, the elderly living in institutions

should be included in separate studies in order to being able to provide appropriate oral health support.

Other oral conditions, such as TMD, can also affect quality of life. When TMD becomes severe including joint cracking, pain, and reduced joint flexibility, it can affect quality of life. Although they are most common in adults aged 20-40 years, the prevalence is very high at 7-30 %, and older adults can also be affected. The etiology of TMD is multifactorial and includes trauma, stress, parafunctional habits, hereditary defects, occlusal and psychological factors. Parafunctional habits, such as bruxism may have the greatest impact on TMD. Bruxism in turn, is often a consequence of psychological stress which is also associated with sleep disturbance. In addition, TMD patients are more likely to suffer from anxiety, stress, somatic awareness dysfunction, and as well depression (Wu et al., 2021).

Another important determinant of oral health is the access to the health care system. Untreated dental diseases may be the result of limited access to dental care. The frequency of dental visits depends on several variables, including health insurance, age, and ethnicity. The uninsured, older adults and ethnic minorities have higher rates of untreated dental disease (Griffin et al., 2012). Socio-economic characteristics such as low income and low educational level can lead to unattended dental appointments and thus to poorer oral health (Stepović et al., 2020).

1.3 Depression

1.3.1 Definition of depression

Major depressive disorder (MDD) or depression is characterized by an increased feeling of sadness and low energy lasting for at least two weeks. The illness impairs daily functioning and is expressed by a loss of interest in activities which were delightful before (Skoskiewicz-Malinowska et al., 2018).
Currently, depression is most commonly diagnosed using two different instruments based on the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) and the International Classification of Diseases, 11th

Revision (ICD-11). According to the DSM-5 five or more of the following symptoms must exist during a two-week period to be diagnosed of depression. In addition, either 1) or 2) must be included (Lam et al., 2016).

DSM-5 criteria:

1) Depressed mood
2) Anhedonia (loss of interest or pleasure most of the day)
3) Significant weight loss or gain
4) Insomnia or hypersomnia
5) Psychomotor restlessness or retardation
6) Fatigue or loss of energy
7) Feelings of guilt or worthlessness
8) Difficulties in concentrating or making decisions
9) Thoughts of death or suicide

The DSM is a categorization composed by the American Psychiatric Association, which is used only for mental disorders (APA, 2022). In contrast, the ICD, developed by WHO is an international classification tool for medical diagnoses which can be used for every type of disease (ICD, 2022).

Several risk factors for depression have been identified, but the exact mechanisms vary among individuals (Li et al., 2021). A depressive person does not always suffer from the same symptoms, that is why the disease is very intricate (Aldosari et al., 2020).
While the most common type of depression is unipolar depression, other forms including dysthymia, seasonal affective disorders, postnatal depression, and bipolar disorder exist.
Dysthymia can be understood as an attenuated but chronic form of unipolar depression. Different from classic depression, affected patients are not that impaired in their everyday life by symptoms such as melancholy and restlessness

as depressive people. Anyway, when suffering at least two years from the mentioned symptoms the condition is called chronic depressive disorder or dysthymia.

Bipolar disorder is characterized by alternating phases of typical depressive symptoms and extreme mood changes to euphoria. These euphoric or “manic” episodes can include delusional ideas and concerned people often do not sleep much.

Seasonal affective disorders are of temporary character; due to the lack of light in winter people can develop depressive symptoms which disappear in the spring.

Symptomatology of postnatal depression is equal to unipolar depression and can occur in mothers after giving birth to a child. Causes for postpartum depression have still not been investigated sufficiently, thus affected women experience lack of understanding from those around them (IQWiG, 2020).

Due to the complex character of depressive disorders, there are different methods for diagnosing the condition. Moreover, especially in the older population overlapping symptoms with other diseases make it difficult to clearly identify MDD. For instance, medication induced xerostomia can lead to loss of appetite, as can depression. Or, sleep disorders and fatigue can also result from heart or pulmonary diseases (Friedlander et al., 2003).

1.3.2 Measurement of depression

Given that there are no standardized questions in the DSM criteria, diagnoses depend on the interviewer’s experience and are not always reliable. Therefore, the Structured Clinical Interview for DSM disorders (SCID) was developed. It helps mental health professionals to assess the patient’s symptoms in a specific and extensive way. As the interviewer needs to evaluate the responses, experiences in psychopathology and DSM assessment are of crucial importance. While the diagnosis for depressive disorders is based on a detailed interview, depressive symptoms can be determined by short questionnaires. That is why depressive symptoms can also be diagnosed as false positive.

The Center for Epidemiologic Studies Depression Scale (CES-D) is a device which grasps the frequency of depressive symptoms over the past week. It consists of 20 items ranging from 0 (rarely or none of the time) to 3 (most or all of the time) (Zhang et al., 2015).
Another instrument assessing the existence and severity of depressive symptoms is the 9-item Patient Health Questionnaire (PHQ-9) which is based on the DSM criteria. The frequency of the items scored from 0 (not at all) to 3 (nearly every day) are detected concerning the former 14 days (Sun et al., 2020).

The CES-D and PHQ-9 are important tools used in many studies because they are adequate rating scales to assess present depressive symptoms. They do not involve a specific quantity of current symptoms. Thus, they can be used to detect depressive symptoms in general. The current study relates to prevalent depressive symptoms rather than depression. In addition, ELSA is based on an abbreviated version of the CES-D adapted for older adults, which consists of only 8 items and has a binary response category.

1.3.3 Epidemiology of depression

Depression is one of the leading causes of disability (James et al., 2018) and the most common mental disorder, affecting approximately 300 million people worldwide (Nobis et al., 2020). One reason for the increased incidence of depression may be the aging population. It is expected that by 2030, one in six people will be 60 years of age or older (Zwick et al., 2023). Physiological changes including pregnancy, childbearing, and menopause cause stress in adult women and lead to depressive symptoms (Koo & Kim, 2021). As a result, women are twice as likely as men to develop a depressive disorder (Sekiguchi et al., 2020). In addition, in Germany, the prevalence of depressive disorders in 2019 was approximately 4 % in individuals younger than 40 years and approximately 5 % in adults ≥ 40 years. In the United Kingdom, the prevalence of depressive disorders was approximately 5 % in individuals younger than 35 years and older than 65 years and approximately 6 % in adults aged 35 to 65 years (Institute for Health Metrics and Evaluation, 2019).

1.4 Correlation between health-related quality of life and depression

1.4.1 Factors associated with health-related quality of life

Several diseases, including obesity and type 2 diabetes mellitus, can affect HRQoL (Kolotkin & Andersen, 2017). Patients with obesity or diabetes suffer from lower self-esteem and uncertainty about their future (Chew et al., 2015). These conditions lead to poorer physical and mental components of HRQoL.
Furthermore, physical activity (PA) can improve a person's HRQoL (Koo & Kim, 2021). Another important determinant of HRQoL is social support, which can reduce stress and thus improve QoL (Garey et al., 2019). Other parameters such as educational level, marital status, income, smoking status, and alcohol consumption may also impair QoL (Kim et al., 2015).

1.4.2 Risk factors of depression

Cognitive and functional impairments, medical disorders, low levels of education, and social withdrawal are considered as risk factors for depressive disorders (Aldosari et al., 2020; Kim et al., 2013). Older adults living and/or eating alone are more likely to develop depressive symptoms, due to the loss of opportunities to communicate with others and reduced social contact (Kuroda et al., 2015). Dental caries, obesity, and tobacco use are associated with increased inflammation and risk of depression (Nobis et al., 2020). Unhealthy lifestyles including alcohol consumption and physical inactivity, increase the risk of depressive symptoms (Aldosari et al., 2020; Geidl et al., 2020). People with chronic conditions such as diabetes and cardiovascular disease are at higher risk for depression (Aldosari et al., 2020; Pan et al., 2012).

1.5 Associations between oral health-related quality of life and depression

Previous studies have found an association between OHRQoL and depression (Yamamoto et al., 2017; Zhang et al., 2019). Zhang et al. examined the cross-sectional association between OHRQoL and depression in a sample of 3,461 Chinese college students using the OHIP and a Self-rating Depression Scale (SDS), which is similar to the CES-D. The study concluded that students with lower OHRQoL were more likely to have depressive symptoms.
Psychological reasons for poor oral health include a lack of self-interest and self-care, which are often seen in people with depressive symptoms. This leads to neglect of dental hygiene, such as poor toothbrushing technique. Careless brushing can lead to gum recession and exposed cervicals, which in turn can lead to root caries (AlQranei et al., 2021).

On the other hand, an increased number of lost and decayed teeth leads to problems with daily activities such as speaking and chewing. These limitations may lead to lower self-esteem, resulting in social distancing and poorer mental health (Zwick et al., 2023).

Poor oral health is also associated with poor nutrition (Tynan et al., 2018). Lost and decayed teeth can limit food choices and reduce enjoyment of food (Griffin et al., 2012). Chewing ability is poorer without full dentures, thus food high in vitamin C and fiber are often substituted with unhealthy products (Griffin et al., 2012). Vitamin and mineral deficiencies are associated with other conditions including depressive symptoms (Garcia-Montero et al., 2022).

1.5.1 Risk factors of poor oral health

Acquired risk factors for dental caries and periodontal diseases may include undiagnosed or suboptimally controlled diabetes, rheumatoid arthritis, and obesity (Lindmark et al., 2021). In addition, medications such as antidepressants as well as others taken for comorbid cardiovascular and metabolic diseases, can

induce xerostomia. Reduced salivary flow leads to a decreased buffering capacity of organic acids, resulting in oral diseases such as caries (Stepović et al., 2020). Furthermore, dental anxiety is more prevalent in individuals with depressive symptoms (Talo Yildirim et al., 2017) or high psychological distress (Sekiguchi et al., 2020), which may lead to avoidance of dentists and progression of oral diseases.

Loss of energy and motivation due to depression can lead to cariogenic diet characterized by high sugar intake and neglect of oral hygiene procedures (Skoskiewicz-Malinowska et al., 2018). Smoking and consumption of sweets as common habits of people with depression reduce salivary flow and oral pH, thus increasing the risk of oral diseases (Stepović et al., 2020).

On the other hand, depression causes immune dysregulation, and thus oral diseases may be easier to implement (Hybels et al., 2016). In addition, antidepressants cause not only hyposalivation, but also higher levels of oral lactobacilli and therefore dental caries (Hybels et al., 2016). The risk of oral disease has been shown to be reduced by higher levels of physical activity (Sanchez et al., 2020). Loneliness and being male were associated with a lower likelihood of visiting a dentist and therefore an increased risk of oral disease (Lipsky et al., 2021; Rouxel et al., 2017).

In conclusion, poor oral health and depression have several risk factors in common, which have been selected as covariates in the analysis.

1.6 Previous outcomes of cross-sectional and longitudinal studies

Several studies have found out that oral health is strongly related to general health and well-being and has a significant impact on the development of depressive symptoms (Badewy et al., 2021; Skoskiewicz-Malinowska et al., 2018).

In a cross-sectional study conducted in Poland in 2015/2016, the relationship between oral health and depression was investigated by recruiting 500 participants aged ≥ 65 years. Socioeconomic characteristics such as age,

gender, marital status, educational level, monthly income, and current/past medical conditions were measured. In addition, clinical dental examinations including decayed-missing-filled teeth index (DMFT), bleeding on probing (BoP), pocket depth (PD), CAL, tooth mobility and oral dryness were conducted. On the other hand, psychometric analysis was performed to determine depression using PHQ-9.

Each participant of the study was affected by dental caries and depression was detected at mild (22.2 %), moderate (6.0 %), and moderate severe (2.6 %) levels. No depression or minimum depression was reported in 69.2 % of the participants. The results showed a positive correlation between the severity of depression and the number of decayed and missing teeth as well as oral dryness (Skoskiewicz-Malinowska et al., 2018).

The National Health and Nutrition Examination Survey (NHANES) was another cross-sectional study conducted in the United States between 2009 and 2014. A total of 9,799 individuals aged ≥ 30 years completed a periodontal and depression screening using the PHQ-9. Mild depressive symptoms were found in 21.6 % of the respondents. Female gender, co-existing diabetes, lower income, and education level, smoking and alcohol consumption were associated with a higher prevalence of depressive symptoms. More than 50 % of the adults with moderate depressive symptoms had periodontal disease, and more than 33 % had teeth with untreated dental caries. In general, depressive symptoms were associated with mild periodontitis and a higher number of missing teeth. In contrast, untreated dental caries was related to sociodemographic factors such as age, education, and income (Aldosari et al., 2020). Although the association between mental and oral health could be established, the significance for the HRQoL of the participants was not part of the study.

These cross-sectional studies lack the temporal relationship between oral health and depression.

A longitudinal study was conducted in Japan in various communities between 2010 and 2013. A total of 14,279 subjects aged ≥ 65 years participated in an

online survey. The study aimed to determine the association between oral health problems and subsequent depressive disorders. Depression was measured using the Geriatric Depression Scale (GDS), and oral health variables were assessed by counting the number of teeth and using a modified version of the Oral Impacts on Daily Performances.

The results of the study showed that participants with fewer teeth and oral health problems were more likely to suffer from depression.

A limitation of the study was that oral health was measured solely by self-report and no clinical examinations were included (Yamamoto et al., 2017). However, this type of recording is widely used in epidemiological surveys and has been shown to be valid.

1.7 Research gaps and aim of the study

Most examinations on the relationship between depression and oral health have been cross-sectional in design (AlJameel et al., 2015), and some have been in younger and middle-aged adults (Oancea et al., 2020), (Zhang et al., 2019). Further research is needed on this topic in older adults, as oral health conditions in the elderly population are significantly more complex than in younger adults (Oancea et al., 2020). In addition, the etiology of depression also varies with increasing age (Hutka et al., 2021; Irwin et al., 2022; Srivastava et al., 2021). Furthermore, few studies have investigated the longitudinal relationship between oral health and depressive symptoms (Kunrath and Silva, 2021; Ohi et al., 2022; Yamamoto et al., 2017). The existing longitudinal studies had a short time frame with only one follow-up, and the results may not be generalizable to Europe due to differences in culture and health care systems. In addition, the samples studied differed in age. The deficiency of longitudinal studies should be addressed to understand the direction of causality (Kragt et al., 2016). Existing cross-sectional studies can identify general correlations, but longitudinal research is important to identify possible mechanisms. As oral health and depressive symptoms are not consistent variables and may change over the years, it is crucial to monitor their evolution. Although there are several studies on HRQoL and depression (Koo &

Kim, 2021; Sivertsen et al., 2015), knowledge on the correlation of oral health with QoL and depressive symptoms is still scarce (Ortiz-Barrios et al., 2019). Previous studies have mainly induced objective records such as tooth decay and CAL, but these findings do not sufficiently reflect the subjective perception of the patient's oral health status. Therefore, a combination of biological, psychological and social factors is needed (Oancea et al., 2020).
Most of the existing studies on HRQoL have been conducted with diseased participants (Krawczyk-Suszek & Kleinrok, 2022). However, it is also important to examine the healthy population to avoid possible confounding by comorbidities.

The English Longitudinal Study of Ageing (ELSA), from which the data in this study were drawn, was developed in order to provide longitudinal data for investigations of aging and related changes (Steptoe et al., 2013).

The aim of the current study is to assess the longitudinal relationship between OHRQoL and depressive symptoms in older adults living in England. More specifically, the aim is to assess the impact of oral health decline on the risk of developing depression. Conversely, current depressive symptoms and their effect on changes in oral health will be elucidated. Research in this area is important for the aging society in terms of prevention of oral diseases and/or depressive symptoms. It is important for medical practitioners to be aware of the various correlations and influencing factors in order to provide appropriate treatment. Oral health and quality of life should be mutually reinforcing.

2 Materials and Methods

2.1 Study design

The current study used a combined methodological approach that included both cross-sectional and longitudinal designs. The data used in this study are from ELSA, a continuous cohort study of adults living in private households in England and born before March 1, 1952. A total of 6,790 adults with a mean age (± SD) of 64 ± 9.5 years were recruited. ELSA collects data from the same respondents every two years, known as “waves”. The first wave took place in 2002 and the original sample was drawn from participants in the Health Survey for England (HSE) in 1998, 1999 and 2001. In Wave 3 (2006/2007), the sample was updated to retain the 50-53 age group. Wave 3 data were used as the baseline in this study, while Wave 5 (2010/2011) and Wave 7 (2014/2015) were used as the follow-up. Changes in both oral health parameters and depressive symptoms were compared across waves (Zwick et al., 2023).

2.1.1 Inclusion and exclusion criteria

Of the 9,771 participants in ELSA Wave 3, a total of 9,343 were aged ≥ 50 years old. For this study, 133 individuals were excluded because they had Alzheimer’s disease or dementia. Due to lack of transparency, they were not considered comparable to other respondents and were therefore excluded from the analysis. Those who reported having a proxy interview and those with missing information in this regard were also excluded from the analysis resulting in a further 396 participants. After creating a longitudinal dataset, that included only participants who provided self-rated oral health responses at each of Waves 3, 5, and 7, the results of 6,790 participants were finally used for statistical analysis. This step was necessary to be able to evaluate the study’s participants data for longitudinal analyses.

2.2 Measurements

2.2.1 Assessment of depressive symptoms

Depressive symptoms during the past week were measured with the 8-item CES-D. These included two aspects of depression: depressed mood with five items (felt depressed, was happy, felt lonely, enjoyed life, and felt sad) and somatic complaints with three items (everything was an effort, restless sleep, and could not get going). Scores were categorized as no/low depressive symptoms (CES-D < 4) and elevated depressive symptoms (CES-D ≥ 4) according to previously published ELSA studies (Zwick et al., 2023). While the original CES-D scale consists of 20 items, the 8-item CES-D is the most widely used version. Its reliability and validity are comparable to the 20-item CES-D, and its reduction to the most relevant questions makes it particularly appropriate for older adults (Karim et al., 2014). Many studies have used the CES-D to assess depressive symptoms (AlJameel et al., 2015; Hybels et al., 2016).

2.2.2 Assessment of oral health

Self-rated oral health information was collected by asking participants about their oral health status in the past year. Possible answers included “excellent”, “very good”, “good”, “fair”, and “poor”. These were categorized as “good oral health” (excellent, very good, good) and “poor oral health” (fair and poor).

Oral health outcomes were assessed using the OIDP questionnaire. The OIDP is a self-administered instrument that measures the impact of oral conditions on an individual's ability to perform eight daily activities: eating and enjoying food, speaking and pronouncing clearly, cleaning teeth, sleeping and relaxing, smiling/laughing/showing teeth without embarrassment, maintaining usual emotional state without being irritable, performing important work or social roles, and enjoying contact with people during the past six months (Gülcan et al., 2014). Possible responses were categorized as "at least one oral effect" and "no oral effects" (Zwick et al., 2023). This categorization was based on previous studies (Gülcan et al., 2014; Rouxel et al., 2017).

A public-use file from the UK Data Archive was used for the present analysis (project number 172488, PI Prof. Dr. Norbert Schmitz). All participants in the ELSA cohort gave full written informed consent to participate in the study, and ethical approval was granted by the London Multi-center Research Ethics Committee.

2.2.3 Covariates

Based on previous studies (Skoskiewicz-Malinowska et al., 2018; Venturelli et al., 2021), several demographic, lifestyle, and clinical variables were included in the analysis of baseline characteristics. These variables may confound the association between oral health-related quality of life and depressive symptoms and are therefore important to consider.

Sociodemographic variables included age, sex, and marital status (married/partner/single/divorced/widowed/separated) dichotomized as married/with a partner or single/without a partner. Marital status was included because of the established association between loneliness and a lower likelihood of visiting a dentist (Rouxel et al., 2017). Ethnic groups are not presented, because the majority (99 %) of the ELSA sample is Caucasian (Au et al., 2014).

Socioeconomic status (SES) was estimated from the highest level of education (university degree or equivalent, less than a university degree, or no education). Previous studies have claimed equal effects of income and education level on self-rated oral health (Farmer et al., 2017). Thus, reporting of educational attainment was considered representative of income and wealth.

Lifestyle variables such as smoking status (current smoker or non-smoker) and physical activity level (sedentary/low, moderate, or high) were collected. Frequency of alcohol consumption (a few times a year or never, once or twice a month, once or twice a week, three to four times a week, five to seven times a week), which was recoded into fewer categories (never/rarely, occasional, 1-4 times/week, or ≥ 5 times/week), was also included in the analysis (Zwick et al., 2023).

Cigarette smoking is associated with a higher risk of many oral conditions, so smoking status was included in the analysis. Associations have been made

between gingival and periodontal disease, dental caries, and oral pain with tobacco use (Chaffee et al., 2021), which supported our decision to include smoking status.

Increased physical activity may reduce inflammatory markers, including tumor necrosis factor (TNF-α), interleukin-6 (IL-6), and C-reactive protein (CRP), and therefore protect against an increased risk of oral disease (Sanchez et al., 2020). Because people who drink a lot of alcohol are more likely to develop dental caries and loose teeth, alcohol consumption was considered necessary to add to the statistical analyses (Priyanka et al., 2017).

In addition, existing comorbidities such as cardiovascular disease (arrhythmia, myocardial infarction, congestive heart failure, angina, heart murmur, and stroke) and diabetes were recorded (Zwick et al., 2023).

They were included equal to other studies due to their confirmed association with oral health conditions (Sekiguchi et al., 2020; Skoskiewicz-Malinowska et al., 2018).

2.3 Statistical analysis

First, baseline characteristics and longitudinal associations between oral health and elevated depressive symptoms were calculated using descriptive statistics. Results were then tested for significance using the chi-square test.

Second, logistic regression analyses were conducted to assess the association between oral health at Wave 3 and the development of elevated depressive symptoms at Waves 5 and 7. Individuals with elevated depressive symptoms at Wave 3 were excluded from these analyses. Several models with different adjustments were considered: Model 1 assessed the strength of the association between oral health and depressive symptoms without adjustment. Model 2 was adjusted for sex and age; model 3 included additional sociodemographic variables (education level and marital status); model 4 was additionally adjusted for alcohol consumption and PA levels; model 5 extended model 4 by including smoking status; and model 6 was additionally adjusted for cardiovascular disease and diabetes.

Third, logistic regression analyses were performed to assess the association between depressive symptoms at Wave 3 and the development of poor oral health at Waves 5 and 7. Individuals with poor oral health at Wave 3 were excluded and the same adjustment strategy as described above was applied (Zwick et al., 2023).

Results are presented as odds ratios (OR), confidence intervals (CI), and Nagelkerke R-squared. Statistical analyses of the data were performed using IBM SPSS Statistics 28.0. Results with a p-value of ≤ 0.05 were defined as statistically significant. An OR < 1 indicates a lower likelihood of having poor self-rated oral health, having ≥ 1 oral impairments, or having elevated depressive symptoms. In contrast, an OR > 1 indicates higher odds of poor oral health and elevated depressive symptoms.

A test for multicollinearity was performed as part of the logistic regression. The highest variance inflation factor was 1.37, so all variables were considered independent contributors (Zwick et al., 2023).

3 Results

3.1 Demographic information

In the total sample, the mean age (± SD) was 64 ± 9.5 years, ranging from 50 to 91 years. Age was categorized into three groups (50-64, 65-74, and ≥ 75 years). More than half of the participants (57.1 %) were between 50 and 64 years of age. The majority of participants (56.2 %) were female, and 56.5 % were married or living together. In addition, 17.6 % of participants reported poor oral health and 7.6 % reported one or more oral conditions. Overall, 12.9 % of participants reported elevated depressive symptoms (Zwick et al., 2023). For more information on baseline characteristics, see Tables 1 and 2.

Table 1. Baseline characteristics of the study sample regarding depressive symptoms; ELSA Wave 3 (2006-2007) N = 6,790

Variables	Total N (%)	No depressive symptoms (CES-D < 4) N (%)	Depressive symptoms (CES-D ≥ 4) N (%)	P values
Age				
50-64	3,876 (57.1)	2,455 (88.4)	322 (11.6)	**< 0.001**
65-74	1,821 (26.8)	1,501 (87.6)	213 (12.4)	
≥ 75	1,093 (16.1)	861 (82.8)	179 (17.2)	
Sex				
Male	2,977 (43.8)	2,134 (90.8)	217 (9.2)	**< 0.001**
Female	3,813 (56.2)	2,683 (84.4)	497 (15.6)	
Current marital status				
Married/Partner	3,833 (56.5)	2,851 (91.1)	277 (8.9)	**< 0.001**
Single/Divorced/Widowed	2,957 (43.5)	1,966 (81.8)	437 (18.2)	
Education				
University degree or equivalent	1,287 (19.0)	917 (94.1)	57 (5.9)	**< 0.001**
Less than university	2,462 (36.4)	1,808 (89.2)	220 (10.8)	
No professional qualification	3,023 (44.6)	2,092 (82.7)	437 (17.3)	
Smoking status				
Current smoker	976 (15.4)	554 (78.2)	154 (21.8)	**< 0.001**
Not current smoker	5,362 (84.6)	4,261 (88.4)	560 (11.6)	
Frequency of alcohol consumption				
Never/rarely	1,455 (24.9)	1,000 (81.0)	234 (19.0)	**< 0.001**
Occasional	726 (12.4)	556 (88.4)	73 (11.6)	
1-4 times/week	2,282 (39.0)	1,699 (91.0)	169 (9.0)	
≥ 5 times/week	1,385 (23.7)	1,046 (91.0)	104 (9.0)	
Physical activity				
Sedentary/low	1,740 (25.7)	1,118 (76.8)	337 (23.2)	**< 0.001**
Moderate	3,574 (52.7)	2,654 (89.7)	304 (10.3)	
High	1,469 (21.7)	1,040 (93.4)	73 (6.6)	
CVD				
Yes	1,880 (27.7)	1,363 (82.6)	287 (17.4)	**< 0.001**
No	4,910 (72.3)	3,454 (89.0)	427 (11.0)	
Diabetes				
Yes	583 (8.6)	412 (82.7)	86 (17.3)	**0.002**
No	6,207 (91.4)	4,405 (87.5)	628 (12.5)	
Self-rated oral health				
Good oral health	5,596 (82.4)	4,115 (89.2)	496 (10.8)	**< 0.001**
Poor oral health	1,194 (17.6)	702 (76.3)	218 (23.7)	

ELSA: English Longitudinal Study of Ageing, CES-D: Center for Epidemiologic Studies Depression Scale, CVD: Cardiovascular diseases including abnormal heart rhythm, myocardial infarction, congestive heart failure, angina, heart murmur, and stroke, Bold p values: $p < 0.05$

3.2 Descriptive statistics

Those who reported poor self-rated oral health at baseline had more depressive symptoms at baseline (23.7 %) than those who reported good oral health (10.8 %). Individuals with elevated depressive symptoms were more likely to be older, female, less educated, a smoker, and less physically active than those without elevated depressive symptoms (Zwick et al., 2023). In addition, the presence of chronic diseases such as cardiovascular disease (CVD) and diabetes was associated with a higher incidence of elevated depressive symptoms. Among participants with CVD, 17.4 % had depressive symptoms, while only 11.0 % of those without CVD had elevated depressive symptoms. The percentage of diabetics with depressive symptoms was 4.8 % higher than that of non-diabetics. Furthermore, people living alone were twice as likely to experience depressive symptoms as those living with a partner. Interestingly, elevated depressive symptoms were less common in individuals with increased alcohol consumption. Detailed information can be found in Table 1.

No significant differences were found between age groups or sex regarding self-rated oral health and OIDP. However, 27.3 % of the current smokers had poor self-rated oral health compared with 16.0 % of non-smokers. Similarly, cigarette smokers were almost twice as likely to report oral impairment. Participants with poor self-rated oral health or ≥ 1 oral impacts were less likely to be married and physically active, had a lower educational level, and were more likely to be smokers than those with good self-rated oral health/no oral impacts (Zwick et al., 2023). In addition, subjects with cardiovascular disease or diabetes had a higher percentage of poor oral health than those without these conditions. Higher alcohol consumption was associated with lower rates of poor oral health.
Interestingly, only 25.2 % of participants with poor oral health also had ≥ 1 oral impairment. Table 2 and 3 show explicit results for oral health parameters.

Table 2. Baseline characteristics of the study sample regarding self-rated oral health; ELSA Wave 3 (2006-2007) N = 6,790

Variables	Total N (%)	Good self-rated oral health N (%)	Poor self-rated oral health N (%)	P values
Age				
50-64	3,876 (57.1)	3,138 (81.0)	738 (19.0)	**0.001**
65-74	1,821 (26.8)	1,530 (84.0)	291 (16.0)	
≥ 75	1,093 (16.1)	928 (84.9)	165 (15.1)	
Sex				
Male	2,977 (43.8)	2,424 (81.4)	553 (18.6)	0.058
Female	3,813 (56.2)	3,172 (83.2)	641 (16.8)	
Current marital status				
Married/Partner	3,833 (56.5)	3,243 (84.6)	590 (15.4)	**< 0.001**
Single/Divorced/Married	2,957 (43.5)	2,353 (79.6)	604 (20.4)	
Education				
University degree or equivalent	1,287 (19.0)	1,102 (85.6)	185 (14.4)	**< 0.001**
Less than university	2,462 (36.4)	2,055 (83.5)	407 (16.5)	
No professional qualification	3,023 (44.6)	2,423 (80.2)	600 (19.8)	
Smoking status				
Current smoker	976 (15.4)	710 (72.7)	266 (27.3)	**< 0.001**
Not current smoker	5,362 (84.6)	4,504 (84.0)	858 (16.0)	
Frequency of alcohol consumption				
Never/rarely	1,455 (24.9)	1,143 (78.6)	312 (21.4)	**< 0.001**
Occasional	726 (12.4)	594 (81.8)	132 (18.2)	
1-4 times/week	2,282 (39.0)	1,929 (84.5)	353 (15.5)	
≥ 5 times/week	1,385 (23.7)	1,202 (86.8)	183 (13.2)	
Physical activity				
Sedentary/low	1,740 (25.7)	1,344 (77.2)	396 (22.8)	**< 0.001**
Moderate	3,574 (52.7)	2,960 (82.8)	614 (17.2)	
High	1,469 (21.7)	1,287 (87.6)	182 (12.4)	
CVD				
Yes	1,880 (27.7)	1,483 (78.9)	397 (21.1)	**< 0.001**
No	4,910 (72.3)	4,113 (83.8)	797 (16.2)	
Diabetes				
Yes	583 (8.6)	446 (76.5)	137 (23.5)	**< 0.001**
No	6,207 (91.4)	5,150 (83.0)	1,057 (17.0)	
Depressive symptoms				
CES-D < 4	4,817 (87.1)	4,115 (85.4)	702 (14.6)	**< 0.001**
CES-D ≥ 4	714 (12.9)	496 (59.5)	218 (30.5)	

ELSA: English Longitudinal Study of Ageing, CES-D: Center for Epidemiologic Studies Depression Scale, CVD: Cardiovascular diseases including abnormal heart rhythm, myocardial infarction, congestive heart failure, angina, heart murmur, and stroke
Bold p values: $p < 0.05$

Table 3. Baseline characteristics of the study sample regarding OIDP; ELSA Wave 3 (2006-2007) N = 6,790

Variables	Total N (%)	No oral impacts	≥ 1 oral impact	P values
Age				
50-64	3,876 (57.1)	3,563 (92.4)	291 (7.6)	0.157
65-74	1,821 (26.8)	1,649 (91.2)	159 (8.8)	
≥ 75	1,093 (16.1)	991 (91.1)	97 (8.9)	
Sex				
Male	2,977 (43.8)	2,722 (92.1)	233 (7.9)	0.561
Female	3,813 (56.2)	3,481 (91.7)	314 (8.3)	
Current marital status				
Married/Partner	3,833 (56.5)	3,530 (92.7)	276 (7.3)	**0.004**
Single/Divorced/Widowed	2,957 (43.5)	2,673 (90.8)	271 (9.2)	
Education				
University degree or equivalent	1,287 (19.0)	1,203 (93.7)	81 (6.3)	**0.017**
Less than university	2,462 (36.4)	2,253 (92.0)	196 (8.0)	
No professional qualification	3,023 (44.6)	2,733 (91.1)	267 (8.9)	
Smoking status				
Current smoker	976 (15.4)	839 (86.2)	134 (13.8)	**< 0.001**
Not current smoker	5,362 (84.6)	4,944 (92.6)	393 (7.4)	
Frequency of alcohol consumption				
Never/rarely	1,455 (24.9)	1,303 (89.6)	152 (10.4)	**< 0.001**
Occasional	726 (12.4)	665 (91.6)	61 (8.4)	
1-4 times/week	2,282 (39.0)	2,143 (93.9)	139 (6.1)	
≥ 5 times/week	1,385 (23.7)	1,289 (93.1)	96 (6.9)	
Physical activity				
Sedentary/low	1,740 (25.7)	1,511 (87.7)	211 (12.3)	**< 0.001**
Moderate	3,574 (52.7)	3,294 (92.6)	262 (7.4)	
High	1,469 (21.7)	1,392 (95.0)	74 (5.0)	
CVD				
Yes	1,880 (27.7)	1,667 (89.3)	200 (10.7)	**< 0.001**
No	4,910 (72.3)	4,536 (92.9)	347 (7.1)	
Diabetes				
Yes	583 (8.6)	519 (90.3)	56 (9.7)	0.133
No	6,207 (91.4)	5,684 (92.0)	491 (8.0)	
Depressive symptoms				
CES-D < 4	4,817 (87.1)	4,514 (93.7)	303 (6.3)	**< 0.001**
CES-D ≥ 4	714 (12.9)	580 (81.2)	134 (18.8)	
Self-rated oral health				
Good oral health	5,596 (82.4)	5,314 (95.5)	248 (4.5)	**< 0.001**
Poor oral health	1,194 (17.6)	889 (74.8)	299 (25.2)	

OIDP: Oral Impacts on Daily Performances, ELSA: English Longitudinal Study of Ageing, CES-D: Center for Epidemiologic Studies Depression Scale, CVD: Cardiovascular diseases including abnormal heart rhythm, myocardial infarction, congestive heart failure, angina, heart murmur, and stroke, Bold p values: $p < 0.05$

3.3 Development of key variables

The presence of depressive symptoms varied between Waves 3, 5, and 7. While 90.7 % of those with no or low depressive symptoms in Wave 3 retained this status in Wave 5 (94.6 % in Wave 7), more than half of those with elevated depressive symptoms in Wave 3 recovered and reported no or low depressive symptoms in Wave 5. Of the latter, 76.9 % remained with no/low depressive symptoms at Wave 7.

These observations show that depressive episodes are temporary in nature but become less frequent during follow-up. Detailed results are shown in Figure 1.

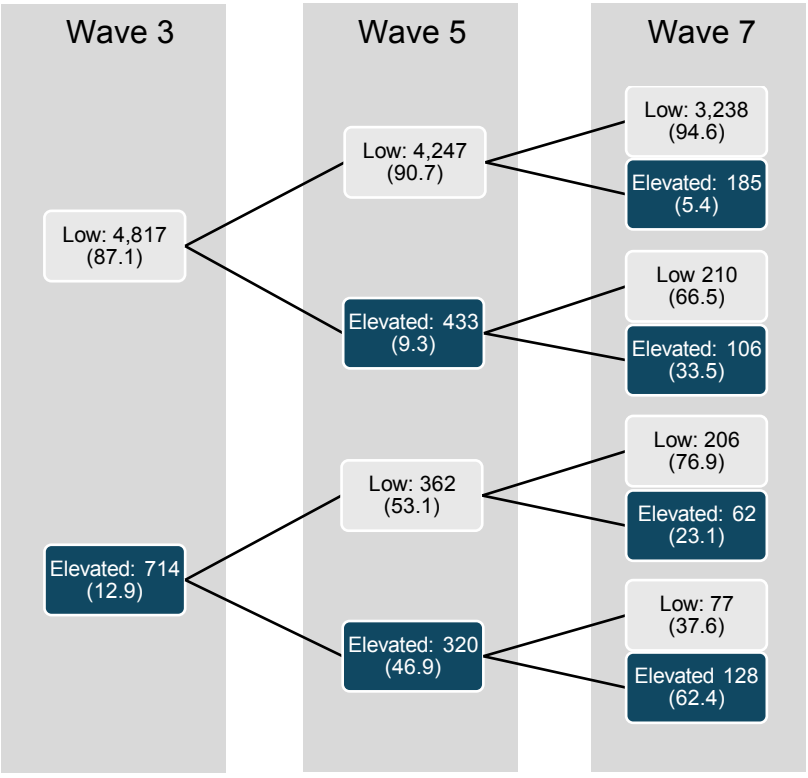

Figure 1. Development of depression: low and elevated depressive symptoms: N (%)
Low: CES-D < 4, Elevated: CES-D ≥ 4, Wave 3: 2006/07; Wave 5: 2010/11; Wave 7: 2014/15

The development of self-rated oral health during Waves 3, 5, and 7 was examined and showed that 82.4 % of the participants rated their oral health status as “good”

in Wave 3 (2006/07). In addition, most of them (88.1 %) reported good oral health status at Wave 5 and Wave 7. However, 10.4 % of Wave 5 participants who reported good oral health in Wave 3 showed a deterioration in dental conditions, indicating poor oral health in that year.

Of the 17.6 % of participants who reported poor oral health in Wave 3, 50.0 % updated their oral health status to “good” in Wave 5 (2010/11), and the other half (50.0 %) remained in poor oral health. In Wave 7 (2014/15), 70.9 % still reported poor oral health, although 29.1 % reported good oral health in that year. For more information see Figure 2.

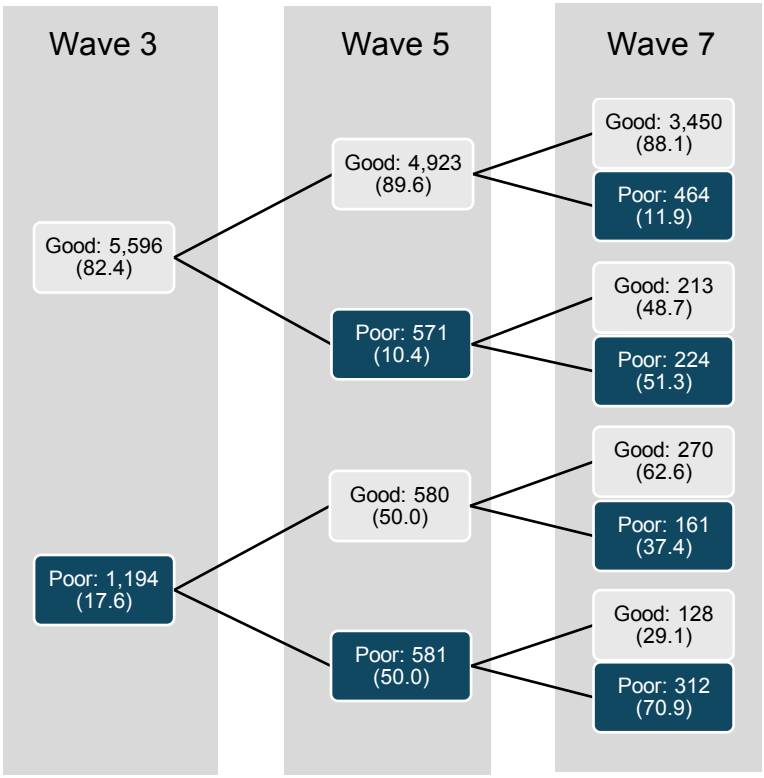

Figure 2. Development of self-rated oral health: N (%)
Wave 3: 2006/07; Wave 5: 2010/11; Wave 7: 2014/15

The majority of older adults with no Oral Impacts on Daily Performances (91.9 %) in Wave 3 (2006/07), remained free of oral impact in subsequent years (92.3 %

in Wave 5 and 93.0 % in Wave 7, respectively). Suffering from oral impairment in Wave 3 (8.1 %) was improved in Wave 5 (63.0 % with no more oral impairment) and Wave 7 (77.5 % with no more oral impairment).

As Figure 1 shows, the majority of participants with low depressive symptoms at Wave 3 reported no change at Waves 5 and 7. Neither self-rated oral health nor OIDP is a consistent variable, but the majority of participants with good oral health and no oral impairments maintained this condition throughout follow-up (Figures 2 and 3) (Zwick et al., 2023).

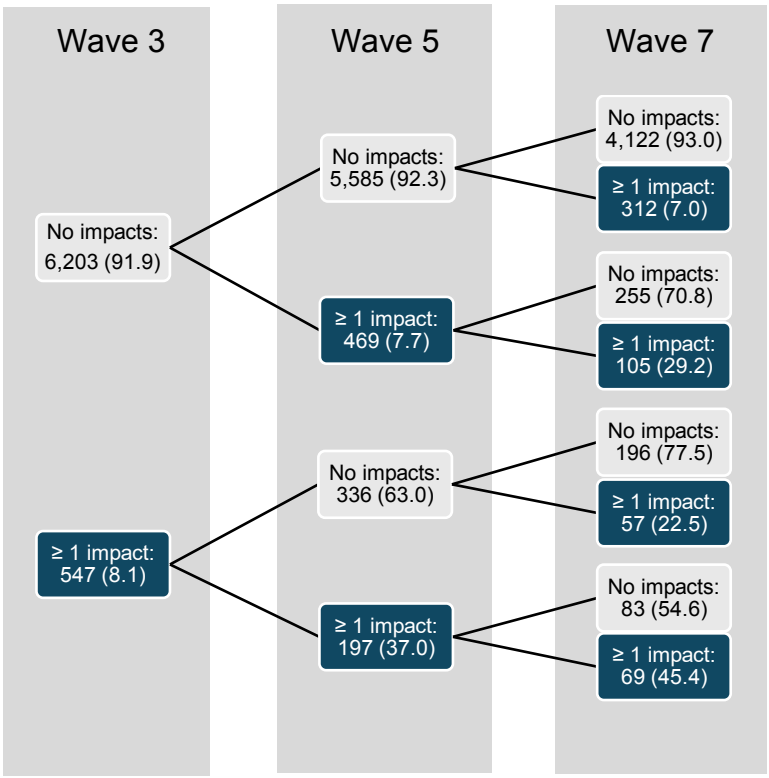

Figure 3. Development of Oral Impacts on Daily Performances: N (%)
No impacts: no oral impacts on daily performances, ≥ 1 impact: at least one oral impact on daily performances, Wave 3: 2006/07; Wave 5: 2010/11; Wave 7: 2014/15

3.4 Longitudinal associations between depressive symptoms and oral health

The following tables present results from ELSA Wave 3 and Wave 5, the same calculation was performed for associations between Wave 3 and Wave 7, and

between Wave 5 and Wave 7. For the sake of clarity and due to similar results, longitudinal associations including Wave 7 are not presented in this paper.

The influence of depression on oral health was analyzed by calculating the longitudinal association between CES-D at Wave 3 and self-rated oral health outcomes at Wave 5 (Table 4). Participants with elevated depressive symptoms who had good self-rated oral health at Wave 3 had worse self-rated oral health at Wave 5 (19.6 %) than subjects with no or low depressive symptoms at Wave 3 (9.1 %) (Zwick et al., 2023).

Table 4. Longitudinal relation between Wave 3 depression and Wave 5 self-rated oral health

W3 Good self-rated oral health	W5 Good self-rated oral health N (%)	W5 Poor self-rated oral health N (%)	P value
W3 No depressive symptoms	3,685 (90.9)	370 (9.1)	< 0.001
W3 Depressive symptoms	390 (80.4)	95 (19.6)	

W 3: Wave 3; W 5: Wave 5

Similarly, individuals with elevated depressive symptoms and no oral impairment at Wave 3 reported more oral impairment at Wave 5 (14.1 %) compared with participants with no or low depressive symptoms at Wave 3 (7.0 %) (Zwick et al., 2023). The results are shown in Table 5.

Table 5. Longitudinal relation between Wave 3 depression and Wave 5 OIDP

W3 No oral impacts	W5 No oral impacts N (%)	W5 ≥ 1 oral impact N (%)	P value
W3 No depressive symptoms	4,129 (93.0)	309 (7.0)	< 0.001
W3 Depressive symptoms	486 (85.9)	80 (14.1)	

W 3: Wave 3; W 5: Wave 5; OIDP: Oral Impacts on Daily Performances

Similarly, an association was found between poor oral health and the development of depressive symptoms (Tables 6 and 7). Specifically, the percentage of participants with poor self-rated oral health but no/low depressive

symptoms at Wave 3 who developed elevated depressive symptoms at Wave 5 (15.6 %) was higher than that of participants with good self-rated oral health at Wave 3 (8.2 %). Oral conditions also appeared to be associated with the development of depressive symptoms: 18.6 % of participants with at least one oral condition but no depressive symptoms at Wave 3 reported depressive symptoms at Wave 5, whereas the percentage of depressed patients at Wave 5 who had no oral conditions at Wave 3 was 8.6 % (Zwick et al., 2023).

Table 6. Longitudinal relation between Wave 3 self-rated oral health and Wave 5 depressive symptoms

W3 No depressive symptoms	W5 No depressive symptoms N (%)	W5 Depressive symptoms N (%)	P value
W3 Good self-rated oral health	3,680 (91.8)	328 (8.2)	< 0.001
W3 Poor self-rated oral health	567 (84.4)	105 (15.6)	

W 3: Wave 3; W 5: Wave 5

Table 7. Association between Wave 3 OIDP and Wave 5 depressive symptoms

W3 No depressive symptoms	W5 No depressive symptoms N (%)	W5 Depressive symptoms N (%)	P value
W3 No oral impacts	4,007 (91.4)	378 (8.6)	< 0.001
W3 ≥ 1 oral impact	240 (81.4)	55 (18.6)	

W 3: Wave 3; W 5: Wave 5; OIDP: Oral Impacts on Daily Performances

3.5 Binary logistic regression

To better understand the longitudinal relationship between depressive symptoms and self-rated oral health, while controlling for potential confounders, we applied six logistic regression models (Zwick et al., 2023). Logistic regression analysis confirmed that both self-rated oral health and OIDP were associated with depressive symptoms. Concerning self-rated oral health, participants with elevated depressive symptoms at Wave 3 were 2.58 (95 % CI: 2.15-3.08) times more likely to rate their oral health as poor in contrast to those with no or low

depressive symptoms. This correlation remained significant after adjustment for all covariates (OR: 2.05, 95 % CI: 1.66-2.53).

With regard to OIDP, those who reported elevated depressive symptoms were 3.44 (95 % CI: 2.76-4.29) times more likely to report poor oral health. After adjustment for covariates, this relationship also remained significant (OR: 2.56, 95 % CI: 1.96-3.33). The results are presented in Table 8.

Table 8. Logistic regression analysis for the association of depressive symptoms at Wave 3 with oral health at Wave 3

	Model 1 OR (95 % CI) R^2	Model 2 OR (95 % CI) R^2	Model 3 OR (95 % CI) R^2	Model 4 OR (95 % CI) R^2	Model 5 OR (95 % CI) R^2	Model 6 OR (95 % CI) R^2
Wave 3 self-rated oral health						
W3 No depressive symptoms	1	1	1	1	1	1
W3 Depressive symptoms	2.58 (2.15-3.08) 0.03	2.68 (2.24-3.21) 0.03	2.48 (2.07-2.98) 0.04	2.11 (1.71-2.60) 0.05	2.07 (1.68-2.56) 0.06	2.05 (1.66-2.53) 0.06
Wave 3 OIDP						
W3 No depressive symptoms	1	1	1	1	1	1
W3 Depressive symptoms	3.44 (2.76-4.29) 0.04	3.41 (2.73-4.26) 0.05	3.37 (2.68-4.23) 0.05	2.63 (2.02-3.41) 0.05	2.56 (1.97-3.34) 0.06	2.56 (1.96-3.33) 0.06

Model 1: unadjusted model
Model 2: Model 1 + age + sex
Model 3: Model 2 + sociodemographic variables (education level & marital status)
Model 4: Model 3 + alcohol consumption + physical activity
Model 5: Model 4 + smoking status
Model 6: Model 5 + diseases (CVD + diabetes)
OR: odds ratio; CI: confidence interval; R^2: Nagelkerke R-squared; W3: Wave 3; OIDP: Oral Impacts on Daily Performances

Poor self-rated oral health at Wave 5 was 2.43 (95 % CI: 1.89-3.11) times more frequently among participants who reported increased depressive symptoms at Wave 3 compared to participants without depressive symptoms. The odds ratio decreased only slightly in fully adjusted models (OR: 2.33, 95 % CI: 1.76-3.09). Similarly, oral impairment was more common in this group at Wave 5 (OR: 2.20, 95 % CI: 1.69-2.86). After adjustment for potential confounders, these results

remained significant (OR: 1.99, 95 % CI: 1.46-2.70). The results are presented in Table 9.

Table 9. Logistic regression analysis for the association of depressive symptoms at Wave 3 with oral health at Wave 5

	Model 1 OR (95 % CI) R^2	Model 2 OR (95 % CI) R^2	Model 3 OR (95 % CI) R^2	Model 4 OR (95 % CI) R^2	Model 5 OR (95 % CI) R^2	Model 6 OR (95 % CI) R^2
Wave 5 self-rated oral health						
W3 No depressive symptoms	1	1	1	1	1	1
W3 Depressive symptoms	2.43 (1.89-3.11) 0.02	2.55 (1.98-3.28) 0.02	2.47 (1.91-3.19) 0.02	2.39 (1.80-3.16) 0.03	2.35 (1.77-3.12) 0.04	2.33 (1.76-3.09) 0.04
Wave 5 OIDP						
W3 No depressive symptoms	1	1	1	1	1	1
W3 Depressive symptoms	2.20 (1.69-2.86) 0.01	2.23 (1.71-2.91) 0.02	2.10 (1.61-2.76) 0.02	2.03 (1.50-2.76) 0.02	2.00 (1.47-2.72) 0.03	1.99 (1.46-2.70) 0.03

Model 1: unadjusted model
Model 2: Model 1 + age + sex
Model 3: Model 2 + sociodemographic variables (marital status + education level)
Model 4: Model 3 + alcohol consumption + physical activity
Model 5: Model 4 + smoking status
Model 6: Model 5 + CVD + diabetes
OR: odds ratio; CI: confidence interval; R^2: Nagelkerke R-squared; W3: Wave 3; OIDP: Oral Impacts on Daily Performances
Participants with poor oral health in Wave 3 were excluded.

The impact of oral health on depressive symptoms was examined by analyzing data on self-rated oral health and OIDP at Wave 3 such as depressive symptoms at Wave 5 (Table 10). The analyses showed that those who had poor self-rated oral health at Wave 3 were 2.08 (95 % CI: 1.64-2.63) times more likely to have depressive symptoms at Wave 5. The odds ratio decreased only slightly in fully adjusted models (OR: 1.98, 95 % CI: 1.52-2.58).

In addition, participants with an oral impairment in Wave 3 were also more likely to develop depressive symptoms (OR: 2.43, 95 % CI: 1.78-3.32), even after adjustment for sociodemographic, behavioral, and clinical risk factors (OR: 1.46, 95 % CI: 1.15-1.86).

Table 10. Logistic regression analysis for the association of oral health at Wave 3 with depressive symptoms at Wave 5

	Model 1 OR (95 % CI) R^2	Model 2 OR (95 % CI) R^2	Model 3 OR (95 % CI) R^2	Model 4 OR (95 % CI) R^2	Model 5 OR (95 % CI) R^2	Model 6 OR (95 % CI) R^2
Wave 5 depressive symptoms						
W3 good self-rated oral health	1	1	1	1	1	1
W3 poor self-rated oral health	2.08 (1.64-2.63) 0.02	2.15 (1.69-2.73) 0.03	2.08 (1.64-2.64) 0.04	2.01 (1.55-2.62) 0.06	1.99 (1.53-2.59) 0.07	1.98 (1.52-2.58) 0.07
Wave 5 depressive symptoms						
W3 no oral impacts	1	1	1	1	1	1
W3 ≥ 1 oral impacts	2.43 (1.78-3.32) 0.01	1.49 (1.22-1.84) 0.03	1.36 (1.10-1.68) 0.03	1.38 (1.09-1.75) 0.06	1.42 (1.12-1.81) 0.07	1.46 (1.15-1.86) 0.07

Model 1: unadjusted model
Model 2: Model 1 + age + sex
Model 3: Model 2 + sociodemographic variables (education level & marital status)
Model 4: Model 3 + alcohol consumption + physical activity
Model 5: Model 4 + smoking status
Model 6: Model 5 + diseases (CVD + diabetes)
OR: odds ratio; CI: confidence interval; R^2: Nagelkerke R-squared; W3: Wave 3
Participants with depressive symptoms in Wave 3 were excluded.

When analyzing the influence of oral health and depressive symptoms on each other at Wave 5 and Wave 7, no significant changes were observed.
The results of the logistic regression analyses indicated that individuals with poor self-rated oral health at Wave 3 were 1.80 (95 % CI: 1.46-2.22) times more likely to have depressive symptoms at Wave 5 and/or Wave 7. The odds ratio decreased only slightly in fully adjusted models (OR: 1.69, 95 % CI: 1.38-2.07) (Zwick et al., 2023).

Slightly stronger associations were observed for oral health impairment: those with one or more oral impacts at Wave 3 were 2.36 (95 % CI: 1.79-3.11) times more likely to have depressive symptoms at Wave 5 and/or Wave 7. The odds ratio decreased only slightly in fully adjusted models (OR: 2.19, 95 % CI: 1.62-2.96) (Zwick et al., 2023). The results are presented in Table 11.

Table 11. Logistic regression analysis for the association of oral health at Wave 3 with depressive symptoms at Waves 5 and 7

	Model 1 OR (95 % CI) R^2	Model 2 OR (95 % CI) R^2	Model 3 OR (95 % CI) R^2	Model 4 OR (95 % CI) R^2	Model 5 OR (95 % CI) R^2	Model 6 OR (95 % CI) R^2
Wave 5&7 depressive symptoms						
W3 good self-rated oral health	1	1	1	1	1	1
W3 poor self-rated oral health	1.80 (1.46-2.22) 0.01	1.66 (1.39-1.98) 0.03	1.57 (1.31-1.88) 0.03	1.62 (1.32-1.97) 0.05	1.66 (1.36-2.02) 0.06	1.69 (1.38-2.07) 0.06
Wave 5&7 depressive symptoms						
W3 no oral impacts	1	1	1	1	1	1
W3 ≥ 1 oral impacts	2.36 (1.79-3.11) 0.01	2.35 (1.78-3.09) 0.03	2.34 (1.77-3.09) 0.03	2.22 (1.64-2.99) 0.05	2.18 (1.61-2.94) 0.06	2.19 (1.62-2.96) 0.06

Model 1: unadjusted model
Model 2: Model 1 + age + sex
Model 3: Model 2 + sociodemographic variables (education level & marital status)
Model 4: Model 3 + alcohol consumption + physical activity
Model 5: Model 4 + smoking status
Model 6: Model 5 + diseases (CVD + diabetes)
OR: odds ratio; CI: confidence interval; R^2: Nagelkerke R-squared; W3: Wave 3
Participants with depressive symptoms in Wave 3 were excluded.

Increased depressive symptoms at Wave 3 were associated with an OR of 1.94 (95 % CI: 1.57-2.39) for poor self-rated oral health at Wave 5 or Wave 7. Similar results were found in the fully adjusted models (OR: 1.93, 95 % CI: 1.52-2.44). Similarly, the odds of having ≥ 1 oral impairment at Waves 5 and 7 were significantly higher among participants with elevated depressive symptoms at Wave 3 (OR: 2.04, 95 % CI: 1.64-2.54), even after adjustment for sociodemographic, behavioral and clinical risk factors (OR: 1.86, 95 % CI: 1.45-2.40).

Detailed models are shown in Table 12.

Table 12. Logistic regression analysis for associations of depressive symptoms at Wave 3 with oral health at Waves 5 and 7

	Model 1 OR (95 % CI) R^2	Model 2 OR (95 % CI) R^2	Model 3 OR (95 % CI) R^2	Model 4 OR (95 % CI) R^2	Model 5 OR (95 % CI) R^2	Model 6 OR (95 % CI) R^2
Wave 5&7 self-rated oral health						
W3 No depressive symptoms	1	1	1	1	1	1
W3 Depressive symptoms	1.94 (1.57-2.39) 0.01	2.00 (1.62-2.47) 0.02	1.91 (1.54-2.37) 0.02	2.11 (1.71-2.60) 0.03	1.93 (1.53-2.45) 0.04	1.93 (1.52-2.44) 0.04
Wave 5&7 OIDP						
W3 No depressive symptoms	1	1	1	1	1	1
W3 Depressive symptoms	2.04 (1.64-2.54) 0.01	2.10 (1.68-2.62) 0.02	1.99 (1.59-2.48) 0.02	1.01 (1.49-2.45) 0.02	1.88 (1.47-2.42) 0.03	1.86 (1.45-2.40) 0.03

Model 1: unadjusted model
Model 2: Model 1 + age + sex
Model 3: Model 2 + sociodemographic variables (education level & marital status)
Model 4: Model 3 + alcohol consumption + physical activity
Model 5: Model 4 + smoking status
Model 6: Model 5 + diseases (CVD + diabetes)
OR: odds ratio; CI: confidence interval; R^2: Nagelkerke R-squared; W3: Wave 3; OIDP: Oral Impacts on Daily Performances
Participants with poor oral health in Wave 3 were excluded.

3.6 Summary

In summary, a significant association was found between oral health-related quality of life and depressive symptoms. Both cross-sectional and longitudinal analyses were evaluated for all three key variables. Self-rated oral health and OIDP were associated with the development of depressive symptoms. In addition, current depressive symptoms affected self-rated oral health and OIDP. In the longitudinal analysis, a bidirectional association was found: Individuals with poor oral health and no depressive symptoms at baseline were more likely to report elevated depressive symptoms at 4- and 8-year follow-up than individuals with good oral health at baseline. In addition, individuals with depressive symptoms and good oral health at baseline were more likely to report poor oral health at 4- and 8-year follow-up than participants without depressive symptoms at baseline (Zwick et al., 2023).

Some other parameters including living alone, not having a professional qualification, smoking, low physical activity, and having CVD and/or diabetes contributed to a higher percentage of poor oral health and increased depressive symptoms. After controlling for potential confounders, the association of the key variables remained significant.

4 Discussion

To our knowledge, this is the first study to examine the bidirectional association between depressive symptoms and oral health in a community sample of older adults over an eight-year period.

Our findings are consistent with previous cross-sectional studies that have examined the association between depressive symptoms and oral health (Skoskiewicz-Malinowska et al., 2018; Zhang et al., 2019; Hajek and Konig, 2022; Aldosari et al., 2020). For instance, a study with a sample of 3,075 older adults conducted in Germany reported an association between poorer oral health-related quality of life and higher risk of depression and anxiety (Hajek & Konig, 2022).

Similarly, Aldosari et al. conducted a study of 9,799 participants and found that depressive symptoms were associated with a higher number of missing teeth (Aldosari et al., 2020).

Some longitudinal studies have also examined the association between depressive symptoms and self-rated oral health (Kunrath and Silva, 2021; Ohi et al., 2022; Yamamoto et al., 2017): Ohi et al. found that impaired oral health-related quality of life predicted the development of depressive symptoms within 4 years in a sample of 296 older adults (Ohi et al., 2022). Furthermore, depressive symptoms were more common in people with fewer teeth and more oral health problems in a sample of 14,279 older Japanese people (Yamamoto et al., 2017). What our study adds to these findings is the bidirectional approach and repeated assessment of depressive symptoms and oral health in a large, community-based sample.

The exact mechanisms behind the link between oral health and depression are not yet fully understood. However, it is likely that multiple factors are involved. For example, poor oral health can lead to pain and discomfort (including functional limitations and dietary dissatisfaction due to problems with teeth or dentures), which can affect quality of life and exacerbate depressive symptoms (Zwick et al., 2023).

4.1 Characteristics of oral health

Our results showed that 17.6 % perceived their oral health as poor, and 7.6 % experienced at least one oral impact. Similarly, Dahl et al. found that 28.7 % rated their oral health as poor in a study of 949 individuals (Dahl et al., 2018).
We found that there were no differences in oral health parameters related to age and gender, which is consistent with a previous study of ELSA (Venturelli et al., 2021). In contrast, Lipsky et al. showed that men had poorer oral hygiene and were more likely to develop periodontal disease and oral cancer. This may be due to less frequent dental visits, biological reasons including hormonal differences, and greater tobacco use in men (Lipsky et al., 2021).

Our results showed that current smokers were more likely to have poor oral health (27.3 %) than their nonsmoking counterparts (16.0 %). This is consistent with previous research on this topic, which indicates that cigarette smoking not only increases the risk of oral cavity cancer, but also contributes to gingival and periodontal inflammation, alters the oral microbiome, and reduces salivation (Chaffee et al., 2021).
Nicotine is known to cause vasoconstriction, which leads to decreased gingival perfusion and thus increased susceptibility to inflammatory processes. Patients with periodontitis often have a conspicuous white gingiva, indicating tobacco use. This supports the association between tobacco use and the incidence of periodontitis.

Contrary to expectations, higher alcohol consumption was not related to poorer oral health in our study. This may be due to impaired subjective perception caused by alcohol intake. Self-assessed parameters, including self-rated oral health, should be considered with caution. In contrast, Birková et al. pointed out that oxidative stress can be induced by alcohol and is responsible for inflammatory processes affecting the oral cavity (Birkova et al., 2021). In addition, alcohol abuse can have various negative consequences such as decreased salivation, neglected oral hygiene, and dietary deficiencies leading to dental caries and periodontal disease (Ivoš et al., 2019). The different outcomes can be

explained by the variable we used in our analysis: self-rated oral health and OIDP are subjective measures that may differ from objective clinical observations.

In our study, oral health was found to be worse in people with lower levels of physical activity, lower levels of education, and those living alone. Hajek and Konig also found that low OHRQoL was related to greater loneliness and greater social isolation. One possible explanation for this relationship may be the association between oral health and mental health, such as self-esteem related to oral health and possible shame due to poor oral health (Hajek & Konig, 2021). Tooth loss and impaired oral health function and appearance, can lead to avoidance of communication and social interaction, resulting in feelings of loneliness. In addition, living alone in old age has been shown to be associated with a lower frequency of dental visits (Rouxel et al., 2017).
Farmer et al. showed that lower socioeconomic status, as measured by income and education level was associated with poorer oral health (Farmer et al., 2017). High costs of dental care and low levels of education can lead to missed dental appointments and cause progression of oral disease, resulting in poorer overall health (Walther et al., 2021).
Physical activity can decrease levels of inflammatory markers, that play an important role in the development of oral diseases (Sanchez et al., 2020).

As reported in previous studies, a correlation between CVD (Sanchez et al., 2017) as well as diabetes (Borgnakke, 2019) and oral health was also confirmed in our study.
The correlation between diabetes and oral health is bidirectional. On the one hand, poor oral health status including toothache and tooth loss, can lead to soft food intake and thus poor nutrition. In turn, poor nutrition leads to decreased OHRQoL as well as poorer glycemic control, which results in diabetes (Borgnakke, 2019). On the other hand, people diagnosed with diabetes mellitus have a higher risk of developing periodontal disease, especially gingivitis. Moreover, the severity and progression of periodontitis are worse compared to normoglycemic patients (Borgnakke, 2019). Previous studies have also shown

that periodontal rehabilitation can have a positive influence on glycemic control and lower HbA1c value, which indicates the level of long-term blood glucose. Therefore, the risk of diabetes can be reduced by periodontal treatment (Artese et al., 2015; Poudel et al., 2021).

In addition, cardiovascular disease is linked to oral health. The link between CVD and oral health can be traced back to the entry of bacteria into the bloodstream caused by periodontal lesions. As a result, the body responds with atheroma formation and ultimately an increased risk of CVD (Sanchez et al., 2017). Conversely, proinflammatory cytokines involved in CVD, such as tumor necrosis factor alpha (TNF-α), interleukin 1 (IL-1), and interleukin 6 (IL-6), create a systemic inflammatory state that affects different parts of the body.

Moreover, some medications used to treat atherosclerotic cardiovascular disease can cause xerostomia and hyposalivation, which worsens oral health (Sanchez et al., 2019).

4.2 Characteristics of depression

Our findings showed that 12.9 % were classified as having elevated depressive symptoms. Similarly, Kunrath et. al reported a prevalence of 18.3 % of individuals with depressive symptoms at baseline (Kunrath & Silva, 2021).

As is well known and confirmed in this study, depressive disorders are approximately twice as common in women as in men (Sekiguchi et al., 2020). Sexual hormones play an important role in this disparity. Depending on a woman’s situation (menstruation, pregnancy, menopause, etc.), hormone levels can vary and make her susceptible to depressive episodes. On the other hand, women often have got lower levels of self-confidence and reflective thinking, which also makes them vulnerable to depressive disorders (Garcia-Montero et al., 2022).

Among older people, the onset of depression is often attributed to interference with activities of daily living (ADL) due to declining health status. These physical impairments can result in avoidance of social contacts and associated loneliness as well as depressive symptoms (Kim et al., 2013). The described association

between depressive symptoms and loneliness is consistent with the findings of our study. We found that people living alone were twice as likely (18.2 %) to suffer from depressive symptoms than participants living with a partner (8.9 %). However, social isolation must be distinguished from loneliness. There is a difference between emotional and social loneliness: Missing a specific person can lead to emotional loneliness, while lack of acquaintances and friends leads to social loneliness (Rouxel et al., 2017).

In our study, depressive symptoms were elevated in participants with lower levels of education. This association showed that socioeconomic status is related to depressive symptoms, which has been confirmed in other studies (Garcia-Montero et al., 2022; Kim et al., 2013).

Several studies have documented associations between excessive alcohol consumption (Pedrelli et al., 2016), alcohol dependence (Grant et al., 2021) and major depressive disorder. Nevertheless, our results showed an increased risk of elevated depressive symptoms with lower frequency of drinking alcoholic beverages. This discrepancy may be due to different measures. While our study focused exclusively on the frequency of alcohol consumption, Pedrelli et al. also focused on the amount of alcoholic beverages consumed in a typical day. In addition, this study was conducted with college students, in contrast to the cohort of older adults in our study. Another explanation for the results of our study may be that people tend to suppress their distress by consuming alcoholic beverages.

Mental health and health-related quality of life (HRQoL) also depend on physical activity (PA), according to a Korean study. Regular PA can reduce and prevent stress. As a result, PA may play an important role in the management of depressive episodes (Koo & Kim, 2021). On the other hand, chronic stress may lead to lower levels of PA (Rodriquez et al., 2018). However, chronic stress may mainly affect the lower age group of 50-64 years. Consistent with these associations, our results show a positive correlation between physical inactivity and higher rates of depressive symptoms.

Physical inactivity not only affects mental health, but also other noncommunicable diseases (NCDs) (Geidl et al., 2020). For example, an

increased risk of developing type 2 diabetes mellitus (DM) is associated with physical inactivity and increased depressive symptoms. This can be understood by poor diet, which is common among people with depression and is also considered an important risk factor for DM (Chireh & D'Arcy, 2019). Another explanation for this association is chronic emotional stress, which is associated with both depressive symptoms and DM (Graham et al., 2017).

Diabetes and depression have several common risk factors, one of which is cigarette smoking (Chireh & D'Arcy, 2019). Poor emotional state or psychological stress present in depression may lead to increased tobacco use (Audrain-McGovern et al., 2015). In addition, nicotine delivery can cause changes in the effectiveness of dopamine and serotonin, which are associated with depressive symptoms (Ranjit et al., 2019). Ranjit et al. found out that regular smoking predicted higher depression scores, which is consistent with our findings. In addition, smoking cessation appears to increase positive feelings and subsequently reduce depressive symptoms and improve quality of life (Taylor et al., 2014).

Furthermore, depressive symptoms are bidirectionally related to cardiometabolic abnormalities (Pan et al., 2012). One possible explanation for this relationship is the association between depressive symptoms and cardiovascular disease in obesity. Hormones and inflammatory cytokines, including CRP, produced by adipose tissue may lead to processes that account for cardiometabolic dysregulation and depression. In addition, neuroendocrine dysregulation caused by depression may affect the sympathetic nervous system and thus alter blood pressure regulation. In addition to CVD, glucose metabolism and hence the onset of diabetes have also been implicated in these mechanisms (Freitas et al., 2016). These findings are consistent with our finding that participants with current CVD were more likely to have elevated depressive symptoms.

In our study, people with dementia or Alzheimer's disease were excluded because of the questionable reliability of their responses. It is well known that there is an association between Alzheimer's disease and depression.
In addition, Kim et al. found out that depression can increase Alzheimer's symptomatology. When older people are placed in nursing homes, they may experience a lack of attention from their family members and are therefore at higher risk of developing depressive symptoms. As a result, the progression of Alzheimer's disease may also worsen in institutional care (Kim et al., 2013). Analysis of this correlation was not part of the present study.

4.3 Longitudinal development of key variables

As shown in 3.3, neither depressive symptoms nor oral health parameters were constant over the time.
A possible explanation for the variable occurrence of depressive episodes in older adults may be the varying overall health status and comorbid conditions that affect the mood and well-being of older adults.
Similarly, self-rated oral health and OIDP may be affected by transient toothache. On the other hand, after a period of coping with decayed or missing teeth, newly inserted dentures may positively alter satisfaction with oral conditions.

4.4 Associations between OH and depressive symptoms

4.4.1 Direction of associations

A recently published German study confirmed the association between OHRQoL and depression in adults. The study participants (N = 3,075) were between 18 and 70 years old. This study analyzed not only depressive disorders, but also anxiety disorders and their association with oral health parameters. In contrast, the current work focused only on depressive symptoms and their relation to OHRQoL. However, both studies are similar in the finding that oral health affects probable depression. The included covariates are approximately matched, so the regression analysis is comparable in this respect. Oral health was not assessed

by the OIDP as in our study. Hajek and König used the Oral Health Impact Profile (OHIP-G5), which includes five scales: functional limitation, physical disability, physical pain, psychological discomfort, and social disability. Overall, these aspects are consistent with the scope of the OIDP measures. Physical pain is not explicitly mentioned in the OIDP questions. The items “difficulties eating and enjoying food” and “difficulties sleeping and relaxing” tend to identify possible orofacial pain. Furthermore, in our study, oral health was additionally captured by analyzing self-rated oral health to determine an individual’s self-perception of their general oral health. Since both the CES-D and the PHQ-9 (used in the German study) are based on DSM criteria, the assessment of depression is comparable.

A major difference between Hajek’s study and ours is that he only focused on the cross-sectional relationship, whereas a longitudinal perspective is needed to better understand the causal and temporal relationships.

There is consensus with our study that poorer oral health is associated with increased depressive symptoms. However, our study provides additional evidence from a longitudinal cohort of older adults in the UK.

In contrast to our study, Hajek et al. considered only one direction and used the oral health-related quality of life as the independent variable, in accordance with most previous studies (Hajek & Konig, 2022).

Our study found that depressive symptoms may also influence oral health, which may be due to unhealthy habits (e.g., poor diet, alcohol consumption, smoking, and sedentary lifestyle) or the use of antidepressants, which may cause xerostomia, as explained above.

Previous results from a cross-sectional Chinese study of college students reported an inverse relationship between oral health and depression. The influence of other mental disorders on OHRQoL outcomes, including negative affectivity and somatization, is also mentioned. Oral health was assessed using the 14-item OHIP and depression using the Self-rating Depression Scale (SDS), which are similar to the measures of our study (Zhang et al., 2019). However, the associations may be very different in this age group.

4.4.2 Lifestyle variables

Depression can have a negative impact on oral health, as people with depression are more likely to neglect their oral hygiene (Skoskiewicz-Malinowska et al., 2018) and engage in unhealthy behaviors such as smoking, alcohol consumption, (Stepović et al., 2020) and reduced physical activity, which in turn can contribute to oral health problems (Zwick et al., 2023).
These behaviors, particularly low levels of physical activity, are associated with obesity. Obesity was not described in our study. However, obesity is closely related to the incidence of diabetes and CVD, which are common in older adults and were therefore assessed in our study.

4.4.3 Socioeconomic Status

Previous studies have shown that lower socioeconomic status, as measured by income and education level, is associated with poorer oral health (Farmer et al., 2017) and higher risk of depression (Zwick et al., 2023). In the study by Zhang et al., the number of siblings was presumably collected to assess whether the participating students suffered from loneliness. In our case, marital status was used instead of sibling status, which is more appropriate for research on the elderly. Due to their status as currently studying, the final educational level of the Chinese college students could not be determined, instead, the educational level of the students' parents was assessed (Zhang et al., 2019). Parental education may also play a role in a child's upbringing, influencing both mental health and oral health habits. In our study, the educational level of the participants was collected, which also influences oral and mental health.

4.4.4 Psychosocial well-being

Psychosocial well-being is essential for OHRQoL and the prevention of depression. Loneliness and social isolation are both related to poor mental health and low OHRQoL. While self-esteem may be affected by feelings of embarrassment related to imperfect or damaged teeth, life satisfaction may

decrease (Hajek & Konig, 2022). In addition, poor oral health can lead to social isolation, which is a known risk factor for depression (Zwick et al., 2023). Accordingly, participants in our study who lived alone reported poorer self-rated oral health, greater impact on daily performances and elevated depressive symptoms compared with those who lived with a partner.

4.4.5 Comorbidities

Diabetes and CVD are common comorbidities of poor oral health and depression, as confirmed by our study. Depressive symptoms increase the risk of developing diabetes (Freitas et al., 2016), which is strongly associated with the development of periodontitis (Borgnakke, 2019). Periodontitis has also been identified as a risk factor for CVD (Sanchez et al., 2017), which is often associated with depressive symptoms (Zwick et al., 2023).

Regarding depressive symptoms in older adults, it is essential to consider chronic diseases because of their high prevalence in the elderly and their influence on the biological pathways of the human body. To elucidate, longstanding medical conditions often occur in comorbidity with depressive disorder. The co-occurrence of other diseases with depression can be explained by inflammatory markers such as CRP, which has been found to be elevated in patients with depression. (Au et al., 2015)

Similarly, several comorbidities are associated with oral health problems. For example, rheumatoid arthritis is associated with poor oral health, including periodontitis. This destructive disease is characterized by inflammation of the synovial membranes and chronic pain, and therefore affects the quality of life of affected patients. Orofacial manifestations of the disease include temporomandibular joint disorders (TMD), secondary Sjögren's syndrome (sSS), periodontal and dental disease (Gonzalez-Chavez et al., 2020).
SSS can lead to xerostomia, which affects dental health due to lack of remineralization of affected teeth. Normally, this remineralization is facilitated by salivary minerals.

Second, rheumatoid arthritis can have social consequences and even cause depressive symptoms (Ionescu et al., 2022).

There is evidence that osteoporosis is related to OHRQoL, which can be elucidated by a reduction in bone mineralization, subsequent loss of alveolar supporting tissue, and following edentulism. It has been shown that edentulous patients have a lower OHRQoL, but this can be improved by an appropriate dental prosthesis that restores the oral status (Dikicier et al., 2021).
On this basis, several studies have focused on the measurement of tooth loss (Aldosari et al., 2020; Dahl et al., 2018; Ortiz-Barrios et al., 2019).

However, our study did not focus on rheumatoid arthritis or osteoporosis as comorbidities, as oral function and satisfaction have been shown to improve with prosthetic care.

4.4.6 Other factors associated with outcome variables

Some factors involved in the processes leading to poor oral health and the development of depressive symptoms were not part of our study. Nevertheless, they are worth mentioning with regard to previous studies and future research.

Vitamin D intake is known to be involved in calcium homeostasis and bone mineralization. Therefore, dietary intake, and more importantly, skin exposure to direct sunlight are essential to prevent impaired bone growth and density. When there is an imbalance in the concentration of calcium and phosphate, osteoporosis can be established. Due to limited outdoor activities and subsequent low sun exposure and decreased ability to synthesize calcitriol, older people may suffer from vitamin D deficiency. Osteoporosis, in turn, can adversely affect tooth mobility, as explained above. In addition, calcium and phosphate are important minerals for adequate dental mineralization. A deficiency of these elements in the saliva leads to a decreased remineralization of the teeth and an increased susceptibility to cariogenic acids. In this way, oral health is negatively

affected by a deficiency of essential vitamins and minerals (Antonenko et al., 2015).

On the other hand, vitamin D deficiency has been associated with depressive disorders. Vitamin D synthesis and elimination have been found to occur in the brain. Changes in the hippocampus have been found in animal studies, which may be the reason for imbalance of neuronal stimulation and inhibition pathways in depressive patients. Alleviation of depressive symptoms has been found to be related to vitamin D intake (Garcia-Montero et al., 2022). Thus, vitamin D intake is associated with both oral health and depressive symptoms.

Wave 6 of ELSA included data on vitamin D levels (Steptoe et al., 2013). However, Waves 3, 5, and 7 did not include this measure, therefore this study was not able to assess this variable.

Furthermore, nutrition plays an essential role in an individual's health-related quality of life. The composition of carbohydrates, proteins and fats in the diet is essential for general, oral, and mental health. While a diet rich in refined carbohydrates increases the risk of depressive disorders, the consumption of complete proteins promotes many biological processes. Of course, low-molecular-weight carbohydrates also compromise teeth by providing a substrate for cariogenic bacteria. Fats, in turn, can be divided into harmful and beneficial fats. For example, omega-3 polyunsaturated fatty acids are needed for several bodily functions and can prevent the production of proinflammatory cytokines in depressed patients.

On the other hand, fats in aliments could be considered as a protective coating for teeth against harmful acids and bacteria. Unhealthy fats consist of trans-fatty acids which are found in junk food and have been linked to the development of depression (Garcia-Montero et al., 2022).

Women have different eating habits during the different phases of the menstrual cycle. Therefore, malnutrition should be observed especially in women. A high concentration of estrogen reduces the need for gratification and therefore diminishes the desire of savory foods. In contrast, increased levels of progesterone can induce ravenous appetite and may even cause binge eating.

The latter can result in malnutrition, which can have a negative impact on the dopaminergic system and also cause depressive disorders. In postmenopausal women, the menstrual cycle no longer plays a role. Research in this age group should rather focus on the observed loss of appetite and involuntary weight loss (Garcia-Montero et al., 2022).

Furthermore, the regularity of food intake may affect an individual's health-related quality of life. Zhang et al. assessed the frequency of breakfast consumption (Zhang et al., 2019). Skipping morning meals can lead to low blood glucose levels, which may promote negative feelings and might contribute to depressive mood (Lee et al., 2017). On the other hand, spacing out the meals rather than snacking throughout the day improves oral health. When teeth are frequently exposed to sugars and acids in aliments, they may become demineralized more often and therefore become more susceptible to carious lesions (Lehmann et al., 2012). However, collecting data on breakfast frequency should include asking about the nutritional quality of breakfast. For example, cereals and sweet spreads high in low-molecular-weight sugars are associated with poor oral health and rapid blood glucose lowering. In fact, these records were not part of our study, although they are worth following in future research.

An important factor in poor oral health is halitosis, which can be a consequence of deficient oral hygiene and subsequent oral dysbiosis. However, it may also have other causes, including tonsil calculus and malignant tumors. Problems with chewing, swallowing, and speech, as well as dysgeusia, are associated with salivary gland dysfunction, which can lead to foetor ex ore. Oral malodor can also affect self-confidence by interfering with communication with others, leading to loneliness and depression.

Burning mouth syndrome (BMS) is common in the elderly and is associated with emotional stress and depressive symptoms. It is a burning sensation in the mouth without any clinical or histologic changes of the oral mucosa, and therefore an idiopathic symptom that is still poorly understood. Both psychogenic parameters and multifactorial neuropathy may play a role in the development of BMS. Its relationship with depressive disorders may be understood by an altered

regulation of pain sensation in people with depression. Mental disorders may increase or decrease the neurotransmission of peripheral pain receptors and induce changes in pain perception. Because of the prevalence of BMS (approximately 1-4 % worldwide, often in postmenopausal women), it should be considered when assessing depressive symptoms and oral health in the elderly. Patients may perceive their oral health to be poor because they experience pain in the oral cavity that is not related to any dental or medical condition. People suffering from BMS usually experience lack of understanding from their families and friends, which leads to despair and frustration (Rezazadeh et al., 2021). Nevertheless, our study did not include data on BMS or detailed questions about perceived pain.

Sleep duration and sleep quality are also important factors in depression and Health-Related Quality of Life. Han et al. showed that oral health is also influenced by sleep duration. The Korean study found that men and younger (< 60 years) individuals were more likely to have poor oral health if they slept ≤ 5 or ≥ 9 hours. Sleeping less than 6 hours had a greater impact on the occurrence of poor oral health than longer sleep duration. Insufficient sleep, which impairs the immune system, could make the oral cavity more susceptible to periodontal disease. However, the latter is due to an interaction between bacteria, host, and environmental factors such as salivary flow. Adequate sleep is also important for maintaining mental and physical health. The body of a stressed person produces more stress hormones and pro-inflammatory cytokines, which leads to the proliferation of bacteria in the mouth and consequently to poorer oral health (Han et al., 2021).

Sleep architecture and depression are also bidirectionally related. First, reduced sleep time increases the risk of onset and recurrence of depression in men over the age of 60. Second, depression contributes to shorter sleep duration. Proper sleep quality is essential for the maintenance of cerebral performance as well as the functioning of the immune and endocrine systems. Abnormal sleep duration in individuals with depressive symptoms is related to several complications such as obesity, diabetes, and cardiovascular disease. Furthermore, antidepressants

may affect sleep parameters, and both positive and negative alterations have been reported (Hutka et al., 2021).

We did not include sleep duration as a covariate in our research, because we focused on older adults, whose sleep duration is already reduced by the aging process.

4.5 Strengths and limitations of the study

The longitudinal design, large sample size, assessment of bivariate associations, and inclusion of potentially confounding variables can be considered strengths of the current study.

However, the present study also has some limitations. Depressive symptoms were measured using a self-reported scale rather than clinical measures. The CES-D does not take into account the diagnosis, history, and treatment of depression. A structured clinical interview for depression would provide more information for diagnosis of depression. Unfortunately, such an interview is not available in ELSA. Oral health status was also assessed using a self-report scale with binary response categories, which may introduce reporting bias (Zwick et al., 2023).Therefore, there was no objective assessment of oral health. However, self-rated oral health and the actual clinical situation may differ. In particular, older people may have other health problems that they perceive as having a greater impact on their quality of life. However, the focus of the study was on self-reported Oral Health-Related Quality of Life. Furthermore, subjective self-assessment has been shown to be an appropriate method of measuring OHRQoL (Yamamoto et al., 2017).

ELSA is designed to be a nationally representative sample, but the majority of participants in the current study were Caucasian, which affects generalizability to other ethnic groups. ELSA also includes the UK population, which may not be generalizable to adults in other countries (Zwick et al., 2023).

Attrition is always a problem in large, older cohorts such as ELSA. It is possible that participants with depression are more likely to drop out of the study, which could lead to an underestimation of the underlying associations. In addition, as

with all observational studies, there may be unmeasured or unknown predictors (Zwick et al., 2023).

Moreover, the classification of oral health into “good” and “poor” could be controversial. For example, “fair” oral health was considered to be “poor” oral health. In this regard, it remains difficult to define a threshold. However, our categorization has been used in numerous studies on self-rated oral health.

The OIDP, which was used in our study, is a valuable measure of whether oral health negatively affects a patient’s daily life. The assessment of depressive symptoms was comparable to other studies, and the CES-D as a widely used scale, was appropriate in this case. Because of the specific questions included in the CES-D, personal questionnaires were appropriate.

Similar to other studies (Hajek & Konig, 2022; Venturelli et al., 2021), this study did not include dietary patterns apart from alcohol consumption.

Major comorbidities, including cardiovascular disease and type 2 diabetes mellitus, were included in the analysis. However, osteoporosis, rheumatoid arthritis, Alzheimer’s disease, and other diseases were not included, although they may affect oral health as well as depression.

While we focused on the elderly, maintaining good oral and mental health begins in childhood and should be followed at all stages of life.

4.6 Outlook

Due to the deficiency of individual nutrient intake data in previous publications, further research on this topic should examine the effect of nutrition on oral and mental health. Furthermore, the adverse effects of medications such as antidepressants should be given more attention and research. Treatment should include nutritional and lifestyle counseling, as well as the improvement and elimination of comorbid conditions, so that the body can return to a balanced, inflammation-free state. The complex associations between the key variables may also include other biomarkers and probiotics, which should be analyzed in future studies.

For a more detailed understanding of the correlations between OHRQoL and depressive symptoms, both subjective and objective data collection should be conducted. Further longitudinal studies on this topic are recommended to confirm our findings.

The implications of the present work are to increase education about the detrimental effects of cigarette smoking, sedentary lifestyle, comorbid diseases, and social relationships on general health, including oral health and psychological well-being. This education can take place, inter alia in educational institutions. In addition, appropriate education should be provided to every citizen to enable individuals to achieve good health conditions. In addition, cooperation between dentists and general practitioners should be strengthened in order to improve related symptoms or diseases, such as periodontitis and cardiovascular disease or diabetes. The psychological state seems to be often neglected by dental professionals; this study aimed to counteract these circumstances.

5 Conclusion

In conclusion, this study confirms the existing association between oral health-related quality of life and depressive symptoms in older adults.
In addition to previous studies, longitudinal associations were identified and found to be significant. A higher risk of depressive symptoms due to poor oral health and consequences of depressive disorders on oral health were found.

The present work examines data from 6,790 participants on their oral health status, depressive symptoms, and other sociodemographic and lifestyle variables.
After calculating cross-sectional relationships between the key variables of self-rated oral health, oral impacts on daily performances, and depressive symptoms, longitudinal comparisons were made.

The results showed that both poorer self-rated oral health and at least one oral impact on daily performances were associated with an increased likelihood of developing depressive symptoms.
On the other hand, pre-existing elevated depressive symptoms also resulted in a greater risk of poor self-rated oral health and more OIDPs.
Although lifestyle factors such as cigarette smoking and physical inactivity affect both oral and mental health, these findings remained significant after adjustment for potential confounders.

Nevertheless, there are other factors that affect oral health and psychological integrity that were not represented in our results. For example, nutritional information should be included in future research to provide more detail on potential relationships.
However, we have established that there are several existing linkages in the human body, as well as between individuals and their environment, that may amplify various processes related to oral and mental health.

Both cross-sectional and longitudinal correlations in different directions were evaluated between the mentioned issues. Dental professionals and other medical practitioners should be encouraged to work together and to consider overall health. In addition, individuals should keep in mind that the prevention of many diseases remains the best medicine.

5 Zusammenfassung

Zusammenfassend konnte der Zusammenhang zwischen mundgesundheitsbezogener Lebensqualität und depressiven Symptomen bei älteren Menschen in dieser Studie bestätigt werden. Ergänzend zu früheren Studien wurde auch ein längsschnittlicher Zusammenhang zwischen der Mundgesundheit und depressiven Störungen gefunden und als signifikant bewertet.

Die vorliegende Arbeit enthält die Daten von 6.790 Teilnehmern zum Mundgesundheitsstatus, zu depressiven Symptomen und anderen soziodemographischen Variablen sowie zu Lebensgewohnheiten.
Nach der Berechnung der Querschnittsdaten und der Korrelationen zwischen den Schlüsselvariablen selbst eingeschätzte Mundgesundheit, orale Auswirkungen auf tägliche Leistungen und depressive Symptome wurde ein Längsschnittvergleich durchgeführt.

Die vorgestellten Ergebnisse zeigen, dass sowohl eine schlechtere Mundgesundheit als auch das Vorhandensein von mindestens einer oralen Beeinträchtigung der täglichen Leistungsfähigkeit zu einer erhöhten Wahrscheinlichkeit der Entwicklung depressiver Symptome führt.
Umgekehrt haben Personen, die bereits unter depressiven Symptomen leiden, ein erhöhtes Risiko für eine schlechte Mundgesundheit.
Diese Erkenntnisse blieben auch nach der Anpassung an Störfaktoren signifikant, obwohl sich Gewohnheiten wie Rauchen und Bewegungsmangel sowohl auf die Mundgesundheit als auch auf die psychische Gesundheit auswirken.

Es gibt jedoch einige Faktoren, die sowohl die Mundgesundheit als auch die psychische Gesundheit beeinflussen, die in dieser Forschungsarbeit nicht durch eigene Berechnungen untersucht wurden. Beispielsweise sollte die Erfassung

von Ernährungsparametern Teil zukünftiger Studien sein, da diese eine wesentliche Rolle bei der Entwicklung verschiedener Krankheiten spielen.

Dennoch zeigt diese Studie, dass es eine Reihe von Beziehungen im menschlichen Körper und zwischen einem Individuum und seiner Umwelt gibt, die verschiedene Prozesse bezüglich der Mundgesundheit und dem psychischen Wohlbefinden verstärken können.

Diese Arbeit untersuchte sowohl querschnittliche als auch längsschnittliche Korrelationen in verschiedenen Richtungen zwischen den genannten Parametern. Sie ist sowohl für Zahnärzte als auch für andere Ärzte von besonderer Bedeutung, da sie diese dazu anregt noch enger zusammenzuarbeiten und die allgemeine Gesundheit bei einer Vielzahl von Behandlungen zu berücksichtigen. Sie richtet sich aber auch an die Allgemeinbevölkerung und vermittelt einen wichtigen Grundsatz: Die Prävention vieler Krankheiten ist die beste Medizin.

6 References

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7 Erklärung zum Eigenanteil

Die Arbeit wurde in der Abteilung Population-Based Medicine des Institutes für Gesundheitswissenschaften der Universitätsklinik Tübingen unter Betreuung von Prof. Dr. Norbert Schmitz durchgeführt.
Die Datenerhebung und Konzeption der Studie erfolgte durch Forscher der ELSA, die von dem University College London, dem Insitute of Fiscal Studies und dem National Centre for Social Research entwickelt wurde.
Die statistische Auswertung erfolgte durch mich unter Anleitung und in Absprache mit Prof. Dr. Norbert Schmitz und Dr. Mahdieh Shojaa.
Ich versichere, das Manuskript selbstständig verfasst zu haben und keine weiteren als die von mir angegebenen Quellen verwendet zu haben.

Tübingen, den 31.07.23

Luisa Zwick

8 Veröffentlichungen

Teile der vorliegenden Dissertationsschrift wurden bereits in der folgenden Publikation veröffentlicht:

Zwick, L., Schmitz, N., & Shojaa, M. (2023). Oral health-related quality of life and depressive symptoms in adults: longitudinal associations of the English Longitudinal Study of Ageing (ELSA). *BMC Oral Health*, *23*(1), 1029. https://doi.org/10.1186/s12903-023-03722-4

9 Danksagung

Mein Dank gilt zunächst meinem Doktorvater Prof. Dr. Norbert Schmitz, der mir die Möglichkeit für die Erarbeitung dieser spannenden Thematik gab und mir jederzeit für Fragen zur Seite stand. Vielen Dank für Deine offene und kollegiale Art und die Unterstützung in jeder Phase der Arbeit.

Ein besonderer Dank geht auch an meine Betreuerin Dr. Mahdieh Shojaa, die mich jederzeit geduldig und hilfsbereit bei meiner Arbeit begleitet hat. Außerdem bedanke ich mich bei der gesamten Abteilung der Population-Based Medicine für die gute Zeit und die Unterstützung bei meiner Arbeit.

Weiterhin bedanke ich mich bei dem UK Data Archive für die Bereitstellung der ELSA Daten. Die Gründer der ELSA Datensammlung und des UK Data Archives tragen keine Verantwortung für die Interpretationen, die in dieser Arbeit dargestellt werden.

An dieser Stelle möchte ich mich auch herzlich bei meinen Eltern bedanken, die mir mein gesamtes Studium ermöglichen und mich immer wieder dabei motivieren, meine Ziele zu erreichen.

Außerdem gilt ein herzlicher Dank meiner Schwester Sophie, Dominik und Fabian, die mich stets unterstützen und mir bei Fragen jeglicher Art weiterhelfen.