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### Every smile matters

*Oral health and orofacial pain in older people with dementia in UK care settings*

van de Rijt, L.J.M.

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# 2

The influence of oral health factors  
on the quality of life in older people

*A systematic review*

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## Abstract

### Background and Objectives

The number of people aged 65 years or older is growing substantially. As a result of increased health burden and tooth retention, more oral health problems are expected in this age group. A poor Oral Health-related Quality of Life (OHQoL) can compromise a person's psychological state, social relationships, personal beliefs, and physical health. The aim of this systematic review is to identify oral health factors associated with OHQoL in people aged 65 years or older, and to give a comprehensive overview of the body of literature for each oral health factor separately.

### Research Design and Methods

A comprehensive search was performed in 5 databases. The following terms were used as index terms or free-text words: 'Oral Health', 'Quality of Life', 'Older People'. Two researchers independently assessed studies for eligibility based on pre-defined criteria.

### Results

Of 3,702 references retrieved from the databases, 68 studies were eligible and included (9 RCT's, 6 cohort studies, and 53 cross-sectional studies). All results were reported descriptively. OHQoL in people aged 65 years or older is positively associated with higher number of teeth, higher number of occluding pairs, implant-retained overdentures, and the Shortened Dental Arch concept; and negatively associated with xerostomia, orofacial pain, and poor chewing ability. In the current literature there is no consensus on the association between edentulism, caries, and periodontal conditions and OHQoL.

### Discussion and Implications

Having a functional dentition (either natural or prosthetic) is important for a good OHQoL, whereas painful or functional complaints are associated with impaired OHQoL.

### Keywords

Oral health-related quality of life; Dental status; Dentition

## Introduction

In 2017, the United Nations published a report about global ageing, showing that the older population is expected to increase substantially [1].

Not only will the numbers of older people increase, but since older people are more likely to suffer from comorbid disease [2], ageing of the world population will lead to an increased number of people with multiple comorbid diseases [2]. Nowadays, due to improved dental care during the lifespan, older people tend to retain more natural teeth [3]. Since impaired general health has a negative effect on oral health, and more older people have natural teeth, more oral health problems are expected in this population [2].

Appropriate access to oral health care can improve the overall quality of life, even in older people with multimorbidity [4]. The World Health Organization defines quality of life as 'an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns' [5]. Impaired quality of life can compromise a person's psychological wellbeing, social relationships, personal beliefs, and physical health [5]. To focus on how to improve the quality of life of an older person in dental care, it is important to know which oral health factors contribute to improved quality of life. Only a few previous reviews have reported on oral health factors influencing quality of life in adults [6-9]. Strikingly, with the exception of a single paper, there are no systematic reviews in the existing literature which comprehensively synthesise the associations of oral health factors with quality of life in older people [10]. A person over 65 years old may have different values and perspectives than an 18-year-old adult.

The concept of Oral Health-related Quality of Life (OHQoL) is based on the perspective that oral health conditions and diseases can undermine someone's self-esteem and self-image, can cause other health problems, can discourage social interaction, and can lead to pain, stress or depression [11]. Furthermore, it could influence vital functions, such as swallowing, speaking, and breathing [12]. The most widely used method to assess OHQoL is multiple items questionnaires [11]. They often contain questions regarding a person's perception on physical health, psychological status, and functional capacity [13].

One of the goals in dental care is to improve OHQoL of patients, which requires an understanding of which factors contribute to OHQoL [14]. In adults OHQoL

is affected by impaired oral health [8], including the number of remaining natural teeth, the number of occluding pairs, and the location of remaining teeth [7, 9], and periodontal disease [6].

A systematic review conducted in 2013 on the influence of oral health and literacy on OHQoL, concluded that there is a negative impact of edentulism on OHQoL in people aged 65 years or older [10]. However, in this systematic review, the results of the 11 included studies were summarized separately, and the results were not systematically reported for each oral health factor. With the exception of this single paper, there are no other systematic reviews that describe the associations of oral health factors with OHQoL in older people. Due to global ageing, the proportion of people aged 65 years or older attending dental care clinics will increase substantially. For dental care professionals it is important to know which factors contribute to improved OHQoL, and what they should focus on when treating this specific population. Therefore, the aim of this systematic review is to identify oral health factors associated with OHQoL in people aged 65 years or older, and to give a comprehensive overview of the body of literature for each oral health factor separately.

## Research Design and Methods

### Search strategy

A review protocol was developed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)-statement ([www.prisma-statement.org](http://www.prisma-statement.org)). A comprehensive search was performed in the bibliographic databases PubMed, Embase, EBSCO/CINAHL, EBSCO/PsycINFO, and Wiley/Cochrane Library from inception up to April 3, 2019, in collaboration with a medical librarian. The following terms were used (including synonyms and closely related words) as index terms or free-text words: 'Oral Health', 'Quality of Life', 'Older People'. The search was performed without date or language restriction. After deduplication, all titles were screened and appropriate abstracts reviewed. The full search strategies for all databases can be found in *Appendix 1* of the Supplementary Material.

### Inclusion and exclusion criteria

The titles, abstracts, and full texts were reviewed according to the following inclusion and exclusion criteria. The inclusion criteria were:

- Randomised Clinical Trial (RCT) studies, cross-sectional studies, case-control studies, or cohort studies;
- older people aged 65 years or above;

- participants stratified for oral health factor (e.g., healthy vs. control);
- validated measurement tool for Quality of Life.

Exclusion criteria were:

- age below 65 years old;
- age not specified;
- participants not stratified for oral health factors;
- case report or review;
- no usable data (e.g., qualitative studies).

### Study selection

Titles, abstracts, and full texts were independently screened by a dentist (LR, MSc) and a dental master student (CS, BSc). Conflicts were resolved by consensus meetings between LR, CS, and RW (neurobiologist, PhD). Two papers were in other languages than English and were screened and assessed by a native speaker and dentist. The reference lists of all included studies were screened for additional relevant studies, but none were found.

### Quality assessment

The quality of the included studies was assessed by one reviewer (LR). The quality of the included RCT studies was assessed by one reviewer with the Cochrane Risk of Bias Tool, which assesses RCT studies on selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias [15]. The quality of the cohort studies was assessed with the Newcastle Ottawa Scale (NOS), which assesses cohort studies on selection, comparability, and outcome [16]. Furthermore, the quality of the included cross-sectional studies was assessed with the Appraisal tool for Cross-Sectional Studies (AXIS tool), which assesses cross-sectional studies on reliability and relevance (e.g., selection bias, response bias, and internal consistency) [17].

### Data extraction

Two researchers extracted and reviewed the data from the eligible studies (LR, CS). The following characteristics were extracted from the included studies: (1) design; (2) country; (3) age; (4) population; (5) oral health factor; and (6) outcome tool (validated instrument for quality of life).

The included studies were categorized according to the following oral health factors domains, which were pre-defined based on the literature [18-20]: (1) natural dentition; (2) caries; (3) periodontal conditions; (4) prosthetic status; and (5) other oral health-related factors.

## Analysis

All results were reported descriptively and tabulated. Meta-analysis was considered. However, the studies and results were too heterogeneous (e.g., different study designs and populations, different assessments of the measurements, and different outcome tools) to conduct meaningful meta-analysis.

## Results

### Study selection and characteristics

Of the 3,702 references retrieved from the databases, 68 studies were eligible and included (*Figure 1*). From the 68 studies, 9 were RCT's, 6 were cohort studies, and 53 were cross-sectional studies. Of the included studies, one was in Korean and one was in Portuguese [21, 22]. Characteristics of included studies are described in *Table 1*. The included papers were published from 30 different countries with 49 conducted in community, 9 in institutional care, and 2 in both. Four studies included older people with dementia.

### Quality ratings

Quality ratings are described separately for RCT's, cohort studies, and cross-sectional studies in *Appendices 2, 3, and 4*, respectively. In all RCT some sort of bias was present, five out of six cohort studies were of poor quality according to the NOS, and the quality of the cross-sectional studies ranged from 10 to 20 criteria of the AXIS tool.

### Quality of life outcome tools

Of the 68 included papers, 38 papers used the OHIP, or a variety of the OHIP, to measure OHQoL [23]. Nineteen papers used the GOHAI and nine papers used the Oral Impact on Daily Performance (OIDP) questionnaire to measure OHQoL [24, 25]. Furthermore, four papers used the Euroqol 5 Dimension (EQ-5D) to measure general quality of life [26].

### Results categorized in domains

#### Natural dentition

All reported associations regarding edentulism, number of teeth, number of missing teeth, and number of occluding pairs are shown in *Table 2*. Five studies reported significantly lower OHQoL in edentulous participants than in dentate participants [27-30], two studies demonstrated a positive association between edentate patients in

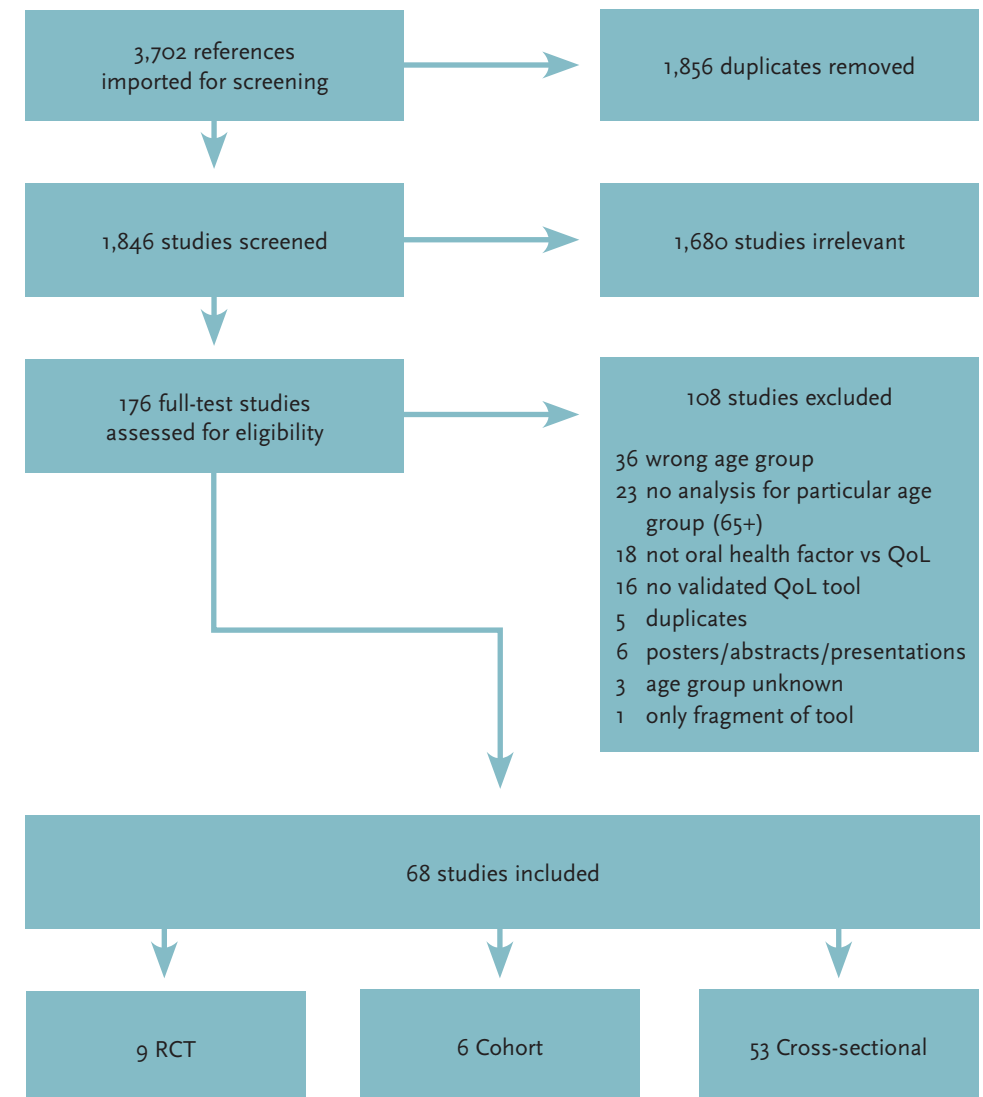


FIGURE 1 | Flow diagram of study selection.

comparison to dentate patients and OHQoL [31, 32], and seven studies reported no significant association between edentulism and OHQoL [33-38]. All studies regarding edentulism were cross-sectional studies. Only two studies, showing either no significant association or a negative association between edentulism and OHQoL, met all quality criteria of the AXIS tool [36, 39]. One cohort study of poor quality showed that participants with permanent tooth loss were most likely to both worsen and improve OHQoL [40].

TABLE 1 | Characteristics of included studies.

| Paper                        | Design | Country                | N    | Age mean (SD)                    | Population  | Oral health factor(s)   | Outcome (tool)   |
|------------------------------|--------|------------------------|------|----------------------------------|---|---|------------------|
| Alshammari et al., 2018      | CS     | Saudi Arabia           | 200  | 69.26 (SE 0.34)                  | elderly patients aged 65+ attending dental clinics                            | NT, prosthetic status, pain   | GOHAI-Ar         |
| Astrom et al., 2018          | Cohort | Sweden                 | 3585 | 70                               | Swedish people born in 1942   | persistent tooth loss, FT   | OIDP             |
| Awad et al., 2003            | RCT    | Canada                 | 60   | 65; 75                           | persons between the ages 65 and 75 who wished to replace their dentures       | IOD   | OHIP, OHIP-EDENT |
| Campos et al., 2017          | Cohort | Brazil                 | 32   | 76.7 (SD 6.3);<br>75.23 (SD 4.4) | partially or completely edentulous elderly individuals with AD and without AD | new CD  | GOHAI            |
| Castrejon-Perez et al., 2017 | CS     | Mexico                 | 655  | 70+                              | home dwelling elders 70+  | xerostomia, prosthetic status, periodontal conditions                           | OHIP-14-SP       |
| Chen et al., 2012            | CS     | Taiwan                 | 400  | 77                               | denture recipients under a new welfare and public health policy               | complete dentures   | OHIP-14          |
| Cho et al., 2018             | CS     | Korea                  | 3034 | 65+                              | elderly people  | function  | EQ-5D            |
| Cicciù et al., 2013          | CS     | Italy                  | 158  | 65-87                            | dentate older people with AD  | periodontal conditions  | OHIP-14          |
| Cornejo et al., 2013         | CS     | Spain                  | 194  | 65+                              | people aged 65 or older in long-stay centers                                  | D vs ED, NT, DMFT, periodontal conditions, prosthetic status, dental appearance | GOHAI            |
| da Silva et al., 2011        | CS     | Brazil                 | 876  | 72.8                             | elderly people  | NT, AOM, prosthetic status  | GOHAI            |
| Dahl et al., 2011            | CS     | Norway                 | 151  | 72.1 (68-77)                     | adults of 68-77 years old   | D vs ED, NT, DT   | OHIP-14          |
| Emami et al., 2009           | RCT    | Canada                 | 255  | 70.0 (SD 4.8)                    | edentulous elders (65+)   | IOD   | OHIP-20          |
| Emami et al., 2010           | RCT    | Canada                 | 173  | 66-88                            | edentulous elders (65+)   | IOD   | OHIP-20          |
| Eric et al., 2012            | CS     | Bosnia and Herzegovina | 261  | 65+                              | community-dwelling adults 65+   | NT, NOP   | OIDP             |
| Eric et al., 2017            | CS     | Bosnia and Herzegovina | 120  | 65+                              | community-dwelling edentulous adults 65+                                      | new CD  | OIDP             |
| Geckili et al., 2011         | Cohort | Turkey                 | 78   | 65-82                            | edentulous complete denture wearers seeking IOD                               | IOD   | OHIP-14          |
| Gerdin et al., 2005          | CS     | Sweden                 | 41   | 83-91                            | old people living at service homes  | xerostomia, hyposalivation  | OHIP-14          |
| Göktürk et al., 2018         | CS     | Turkey                 | 110  | 72.1 (SD 4.33)                   | elderly patients from the periodontology department                           | periodontal conditions  | GOHAI            |
| Ha et al., 2012              | Cohort | Korea                  | 439  | 65-93                            | elderly, who were basic livelihood security recipients (65+)                  | prosthetic status   | OHIP-14          |
| Hassel et al., 2007          | CS     | Germany                | 36   | 75+                              | patients wearing FPD or RPD   | prosthetic status   | OHIP-SUM         |
| Heydecke et al., 2003        | RCT    | Canada                 | 55   | 69.4; 68.9                       | older people seeking denture replacement                                      | IOD, new CD   | OHIP-20          |
| Hoeksema et al., 2017        | CS     | Netherlands            | 1026 | 80 (IQR 77-84)                   | community-living elderly participating in 'Samen ouder' programme             | dentate, CD, IOD  | EQ-5D            |
| Hoeksema et al., 2018        | CS     | Netherlands            | 103  | 79 (72-85)                       | community living older people   | D vs ED   | OHIP-14          |

| Paper                          | Design | Country     | N    | Age mean (SD)                     | Population   | Oral health factor(s)   | Outcome (tool) |
|--------------------------------|--------|-------------|------|-----------------------------------|--|---|----------------|
| Hsu et al., 2014               | CS     | Taiwan      | 332  | 76.0 (SD 0.4)                     | community-dwelling, independently living elderly adults                        | NT, NOP, prosthetic status, function  | GOHAI-T        |
| Jabbour et al., 2012           | RCT    | Canada      | 172  | 71 (SD 4.5)                       | edentulous females and males aged 65+  | IOD, new CD   | OHIP-20        |
| Jensen et al., 2008            | CS     | USA         | 641  | 79.1                              | community-dwelling elderly persons with disabilities                           | NT, xerostomia, CTN   | OHIP-14        |
| Johansson et al., 2012         | CS     | Sweden      | 9813 | 65; 75                            | all 65 and 75 years of age   | xerostomia  | OIDP           |
| Jung et al., 2008              | CS     | Korea       | 268  | 72.27 (SD 5.22)                   | community-dwelling older adults  | NT, orofacial pain  | OHIP-K         |
| Kato et al., 2018              | CS     | Sweden      | 804  | 70, 78, 82, 86, 92                | men aged 70, women aged 70, 78, 82, 86 and 92                                  | NT, periodontal conditions  | OHIP-14        |
| Klotz et al., 2017             | CS     | Germany     | 169  | 82.9 (SD 8.9)                     | nursing home residents with or without dementia                                | NT, prosthetic status   | GOHAI          |
| Klotz et al., 2018             | Cohort | Germany     | 152  | 73.9 (SD 0.9)                     | people born in 1930-1932   | prosthetic status   | GOHAI          |
| Kohli et al., 2017             | CS     | USA         | 177  | 65+                               | institutionalized and community dwelling older adults                          | D vs ED   | OHIP-14        |
| Komagamine et al., 2012        | Cohort | Japan       | 122  | 74.4                              | edentulous patients requiring new CD   | new CD  | OHIP-EDENT     |
| Lee et al., 2012               | CS     | Taiwan      | 947  | 65+                               | all elderly over the age of 65   | D vs ED, prosthetic status, function  | OHIP           |
| Ling et al., 2014              | CS     | New-Zealand | 162  | 82.6 (SD 6.6)                     | older people admitted to older persons' hospital wards                         | D vs ED, root DT  | OHIP-20        |
| Masood et al., 2017            | CS     | UK          | 1277 | 65+                               | older people   | NMT, DT, root DT, PUFA, periodontal conditions, orofacial pain, prosthetic status | OHIP-14        |
| McKenna et al., 2015           | RCT    | Ireland     | 89   | 65+                               | partially dentate older patients   | SDA, RPD  | OHIP-14        |
| McKenna et al., 2018           | RCT    | Ireland     | 89   | 65+                               | partially dentate older patients   | SDA, RPD  | OHIP-14        |
| Meneses-Gómez et al., 2016     | CS     | Colombia    | 342  | 72.6 (SD 5.9)                     | elderly population receiving health care at the public hospital network        | AOM, TMJ, prosthetic status   | GOHAI          |
| Mihara et al., 2018            | CS     | Japan       | 1969 | 69-71, 79-81                      | community-dwelling elderly residents   | NT, function, prosthetic status   | GOHAI          |
| Motallebnejad et al., 2015     | CS     | Iran        | 300  | 71.4 (SD 5.6)                     | elderly population   | D vs ED, prosthetic status, CTN   | OHIP-14        |
| Müller et al., 2013            | RCT    | Switzerland | 34   | 85.0 (SD 6.19);<br>84.1 (SD 5.55) | very old edentulous patients who depend on help for activities of daily living | IOD   | OHIP-EDENT     |
| Nielsen et al., 2016           | CS     | Netherlands | 235  | 73.1 (SD 5.4); 85.4 (SD 7.1)      | care-independent and care-dependent older population                           | DT, prosthetic status, CTN  | GOHAI          |
| Noguchi et al., 2017           | CS     | Japan       | 187  | 77.9 (SD 3.0)                     | elderly 75+ who have pain in general   | NT, DT, FT, periodontal conditions  | GOHAI          |
| Östberg et al., 2010           | CS     | Sweden      | 186  | 80+                               | people with pain problems  | function, dental appearance   | OHIP-14        |
| Paredes-Rodríguez et al., 2016 | CS     | Spain       | 30   | 80.50 (SD 8.93)                   | nursing home residents with or without dementia                                | NT, xerostomia  | OHIP-14        |
| Park et al., 2010              | CS     | Korea       | 156  | 77.4 (SD 6.53)                    | community-dwelling elders  | NT, xerostomia, prosthetic status   | OHIP-14        |
| Pearson et al., 2007           | RCT    | UK          | 133  | 80.7; 79.5                        | older patients requiring CD  | new CD  | OIDP           |

| Paper                               | Design | Country                | N    | Age mean (SD)                | Population                                       | Oral health factor(s)   | Outcome (tool) |
|-------------------------------------|--------|------------------------|------|------------------------------|--|---|----------------|
| Porter et al., 2015                 | CS     | UK                     | 179  | 65-100                       | older residents of nursing homes                 | periodontal conditions, sensitive teeth, orofacial pain, xerostomia | OIDP           |
| Rebelo et al., 2016                 | CS     | Brazil                 | 613  | 69.27 (SD 3.01)              | elderly people                                   | D vs ED, DMFT, prosthetic status                                    | GOHAI          |
| Rodrigues Gomes et al., 2015        | CS     | Portugal               | 207  | 65+                          | older adults with diabetes                       | NT, DT, periodontal conditions, xerostomia                          | OHIP-14        |
| Sáez-Prado et al., 2016             | CS     | Spain                  | 202  | 65+                          | elderly people aged 65 years or more             | NT, NMT, DT, DMFT, FT   | OHIP-14, EQ-5D |
| Santucci et al., 2015               | CS     | Malta                  | 278  | 83.5 (SD 6.5)                | state institutionalized older adults             | NT, NMT, NOP, DT, DMFT, FT, periodontal conditions                  | OHIP-14, GOHAI |
| Shao et al., 2018                   | CS     | China                  | 744  | 69.3 (65-74)                 | elders   | NT, DMFT, root DT, periodontal conditions, prosthetic status        | GOHAI          |
| Sheiham et al., 2001                | CS     | UK                     | 202  | 65+                          | population aged 65 years and older               | D vs ED, NT   | OIDP           |
| Skoskiewicz-Malinowska et al., 2019 | CS     | Poland                 | 500  | 73 (65-99)                   | urban residents at the age of 65+                | oral dryness  | OHIP-14        |
| Slade et al., 1996                  | CS     | Australia, Canada, USA | 1642 | 65+                          | people aged 65 and older                         | NMT, root DT, RR, periodontal conditions                            | OHIP           |
| Souza et al., 2017                  | CS     | Brazil                 | 7619 | 69.09                        | older people                                     | D vs ED, prosthetic status, dental appearance                       | OIDP           |
| Stenman et al., 2012                | CS     | Sweden                 | 561  | 70                           | elderly individuals                              | NT, burning mouth   | OHIP-14        |
| Strömberg et al., 2013              | CS     | Sweden                 | 302  | 65-101                       | homebound elderly                                | D vs ED, NT, DT, RR, periodontal conditions, prosthetic status      | GOHAI          |
| Tsakos et al., 2004                 | CS     | Greece                 | 681  | 71.4 (SD 5.4); 74.5 (SD 6.9) | elderly population                               | NT, NOP, DT, root DT, periodontal conditions, prosthetic status     | OIDP           |
| Wu et al., 2018                     | CS     | Hong Kong              | 195  | 75.3 (SD 6.7)                | community dwelling elders                        | NT, NOP, DT, periodontal conditions                                 | GOHAI          |
| Yen et al., 2015                    | CS     | Taiwan                 | 277  | 76.0                         | elderly individuals                              | NT, AOM, orofacial pain, halitosis, xerostomia, prosthetic status   | GOHAI-T        |
| Yoon et al., 2013                   | CS     | Korea                  | 479  | 74.6                         | community-dwelling elders aged 65 years or above | NMT   | OHIP-14        |
| Yu et al., 2008                     | CS     | China                  | 155  | 80.0 (SD 7.2)                | hospitalised geriatric patients                  | D vs ED, NOP, periodontal conditions, xerostomia                    | GOHAI          |
| Zhou et al., 2012                   | CS     | China                  | 913  | 73 (SD 6)                    | older adults                                     | prosthetic status   | OHIP-14        |
| Zuluaga et al., 2011                | CS     | Spain                  | 215  | 82.9 (SD 7.6)                | institutionalised elderly                        | D vs ED, NT, NOP, DT  | GOHAI          |
| Zusman et al., 2016                 | CS     | Israel                 | 987  | 65+                          | elderly  | prosthetic status, dental appearance                                | OHIP-14        |

NOTE | RCT = randomized controlled trial, CS = cross-sectional, USA = United States of America, UK = United Kingdom, SD = standard deviation, IQR = interquartile range, AD = Alzheimer's Disease, IOD = implant overdenture, FPD = fixed partial denture, RPD = removable partial denture, CD = conventional denture, D = dentate, ED = edentate, NT = number of teeth, NMT = number of missing teeth, DMFT = decayed missing and filled teeth, DT = decayed teeth, NOP = number of occlusal pairs, CTN = clinically assessed treatment need, PUFA = Presence of severely decayed teeth with visible pulpal involvement, Ulceration caused by dislocated tooth fragments, Fistula and Abscess, SDA = shortened dental arch, AOM = abnormalities oral mucosa, TMJ = temporomandibular joint, FT = filled teeth, RR = retained roots, OHIP = Oral Health Impact Profile, GOHAI = Geriatric Oral Health Assessment Index, OIDP = Oral Impact on Daily Performance.



The number of natural teeth was found to be positively associated with OHQoL in twenty-one studies [22, 29, 33, 34, 38, 41-53], with four studies finding no significant association between number of teeth and OHQoL [21, 54-56]. Regarding number of missing teeth, four studies found a significant negative association between number of missing teeth and OHQoL [47, 55, 57, 58], while one study reported no significant association [59]. The study of Santucci et al. was conducted in institutionalised older people, while the other studies were conducted in community-dwelling older people.

One study reported a negative association between unfilled anterior spaces (gap between front teeth) and OHQoL [56]. With regards to occluding pairs (i.e., the number of pairs of opposing lower and upper teeth), six out of eight studies concluded that there was a positive association between the number of occluding pairs and OHQoL [29, 37, 42, 49, 50]. The two studies that did not find an association between the number of occluding pairs and OHQoL, were of poor quality, meeting only 14 and 12 out of 20 criteria of the AXIS tool [54, 55].

#### Summary

There is no consensus on the influence of edentulism on OHQoL in people aged 65 years or older. However, there is overall agreement that a higher number of natural teeth and a higher number of occluding pairs are positively associated with OHQoL.

#### Caries

In *Table 3*, the associations between OHQoL and decayed teeth, Decayed Missing and Filled Teeth (DMFT), filled teeth, root caries, and retained roots are given. Seven studies found no significant association between decayed teeth and OHQoL [22, 29, 34, 45, 47, 60, 61], while four studies found a negative association between decayed teeth and OHQoL [30, 55, 57, 62]. Four out of five studies reported a negative association between DMFT and OHQoL [36, 47, 55, 63]. Regarding filled teeth, three studies reported a negative association with OHQoL [47, 49, 64], while one study reported no significant association [55], and one study reported a positive association [40].

The link between root caries (caries located on the root surface of a tooth) and OHQoL remains unclear: three studies reported a negative association between root caries and OHQoL [58, 63, 65], one study reported a positive association [57],

TABLE 2 | Associations of oral health factors in the natural dentition domain with oral health-related quality of life.

| Paper                          | D vs ED | NT   | NMT | NOP  |
|--------------------------------|---------|------|-----|------|
| Alshammari et al., 2018        | N.S.    |      |     |      |
| Cornejo et al., 2013           | N.S.    | +    |     |      |
| da Silva et al., 2011          |         | +    |     |      |
| Dahl et al., 2011              | N.S.    | +    |     |      |
| Eric et al., 2012              |         | +    |     | +    |
| Ha et al., 2012                |         | +    |     |      |
| Lee et al., 2012               | -       |      |     |      |
| Hoeksema et al., 2017          | +       |      |     |      |
| Hoeksema et al., 2018          | +       |      |     |      |
| Hsu et al., 2014               |         | N.S. |     | N.S. |
| Jensen et al., 2008            |         | +    |     |      |
| Jung et al., 2008              |         | +    |     |      |
| Kato et al., 2018              |         | +    |     |      |
| Klotz et al., 2017             |         | +    |     |      |
| Kohli et al., 2017             | N.S.    |      |     |      |
| Masood et al., 2017            |         |      | -   |      |
| Mihara et al., 2018            |         | +    |     |      |
| Motallebnejad et al., 2015     | +       |      |     |      |
| Noguchi et al., 2016           |         | +    |     |      |
| Paredes-Rodríguez et al., 2016 |         | +    |     |      |
| Park et al., 2010              |         | N.S. |     |      |
| Rebelo et al., 2016            | N.S.    |      |     |      |
| Rodrigues-Gomes et al., 2015   |         | +    |     |      |
| Saez-Prado et al., 2016        |         | +    | -   |      |
| Santucci et al., 2015          |         | N.S. | -   | N.S. |
| Shao et al., 2018              |         | +    |     | +    |
| Sheiham et al., 2001           | N.S.    | +    |     |      |
| Slade et al., 1996             |         |      | -   |      |
| Souza et al., 2017             | -       |      |     |      |
| Stenman et al., 2012           |         | N.S. |     |      |

| Paper                  | D vs. ED | NT | NMT  | NOP |
|------------------------|----------|----|------|-----|
| Strömberg et al., 2013 | +        | +  |      |     |
| Tsakos et al., 2004    |          | +  |      | +   |
| Wu et al., 2018        |          | +  |      | +   |
| Yen et al., 2015       |          | +  |      |     |
| Yoon et al., 2013      |          |    | N.S. |     |
| Yu et al., 2008        | N.S.     |    |      | +   |
| Zuluaga et al., 2012   | +        | +  |      | +   |

NOTE | D = dentate, ED = edentate, NT = number of teeth, NMT = number of missing teeth, NOP = number of occluding pairs, + = positive association, - = negative association, N.S. = no significant association.

and another one found no significant association between root caries and OHQoL [49]. Retained roots (partial root structure that remains in the jaw following fracture or severely damage by caries) were negatively associated with OHQoL, according to two studies [30, 58].

One study found a negative association between presence of severely decayed teeth, ulceration caused by dislocated tooth fragments, fistula, and abscesses and OHQoL [57]. All studies on the influence of caries on OHQoL were cross-sectional studies, varying with a quality rating from 12 to 20 on the AXIS tool. The different findings of the studies cannot be explained by the overall difference in quality.

### Summary

There is no consensus on the negative association between caries and OHQoL.

### Periodontal conditions

Associations between pocket depth, mobility, bleeding, gingivitis, periodontitis, and abnormalities of the oral mucosa and OHQoL are given in *Table 4*. Three studies reported a negative association between pocket depth and OHQoL [55, 58, 63], one study reported a negative association between mobility and bleeding and OHQoL [66], and one study reported a negative association between gingivitis and OHQoL [37]. Two studies found a negative association between periodontitis and OHQoL [67, 68]. One study reported a positive association between a healthy periodontium and OHQoL [69].

TABLE 3 | Associations of oral health factors in the caries domain with oral health-related quality of life.

| Paper                        | DT   | DMFT | FT   | root caries | RR |
|------------------------------|------|------|------|-------------|----|
| Astrom et al., 2018          |      |      | +    |             |    |
| Cornejo et al., 2013         |      | N.S. |      |             |    |
| Dahl et al., 2011            | N.S. |      |      |             |    |
| Ling et al., 2014            |      |      |      | -           |    |
| Masood et al., 2017          | -    |      |      | +           |    |
| Niesten et al., 2016         | N.S. |      |      |             |    |
| Noguchi et al., 2016         | N.S. |      | -    |             |    |
| Rebelo et al., 2016          |      | -    |      |             |    |
| Rodrigues-Gomes et al., 2015 | N.S. |      |      |             |    |
| Saez-Prado et al., 2016      | N.S. | -    | -    |             |    |
| Santucci et al., 2015        | -    | -    | N.S. |             |    |
| Shao et al., 2018            |      | -    |      | -           |    |
| Slade et al., 1996           |      |      |      | -           | -  |
| Strömberg et al., 2013       | -    |      |      |             | -  |
| Tsakos et al., 2004          | N.S. |      | -    | N.S.        |    |
| Wu et al., 2018              | -    |      |      |             |    |
| Zuluaga et al., 2012         | N.S. |      |      |             |    |

NOTE | DT = Decayed Teeth, DMFT = Decayed Missing and Filled Teeth, FT = Filled Teeth, RR = retained roots, + = positive association, - = negative association, N.S. = no significant association.

On the other hand, more studies found no significant association between pocket depth [45, 57, 62], mobility [49], bleeding [57, 62], gingivitis [70], or periodontitis [22, 70] and OHQoL. Additionally, two out of three studies found a negative association between abnormalities of the oral mucosa (e.g., ulcers, lichen planus, candidiasis) and OHQoL [63, 71].

Other studies found no significant association between periodontal inflammation [59], and need for periodontal treatment and OHQoL [33]. All studies regarding periodontal conditions were cross-sectional studies.

TABLE 4 | Associations of oral health factors in the periodontal conditions domain with oral health-related quality of life.

| Paper                        | Pocket depth | Mobility | Bleeding | Gingivitis | Periodontitis | AOM  |
|------------------------------|--------------|----------|----------|------------|---------------|------|
| Castrejon-Perez et al., 2017 |              |          |          | N.S.       | N.S.          |      |
| da Silva et al., 2011        |              |          |          |            |               | -    |
| Göktürk et al., 2018         |              |          |          |            |               | -    |
| Kato et al., 2018            |              |          |          |            |               | -    |
| Masood et al., 2017          | N.S.         |          | N.S.     |            |               |      |
| Meneses-Gomes et al., 2016   |              |          |          |            |               | N.S. |
| Noguchi et al., 2016         | N.S.         |          |          |            |               |      |
| Porter et al., 2015          |              | -        | -        |            |               |      |
| Rodrigues-Gomes et al., 2015 |              |          |          |            | N.S.          |      |
| Santucci et al., 2015        | -            |          |          |            |               |      |
| Shao et al., 2018            | -            |          |          |            |               | -    |
| Slade et al., 1996           | -            |          |          |            |               |      |
| Strömberg et al., 2013       |              |          |          |            |               | +    |
| Tsakos et al., 2004          |              | N.S.     |          |            |               |      |
| Wu et al., 2018              | N.S.         |          | N.S.     |            |               |      |
| Yu et al., 2008              |              |          |          |            |               | -    |

NOTE | AOM = abnormalities oral mucosa, + = positive association, - = negative association, N.S. = no significant association.

### Summary

There is no consensus on the negative association between periodontal conditions and OHQoL. From the 18 included studies, eight studies reported a negative association, one study reported a positive association, and nine studies reported no significant association.

### Prosthetic status

Table 5 shows the associations between the prosthetic status and OHQoL. Four studies found a positive association between the use of removable dentures and OHQoL [28, 32, 53, 71], six studies reported negative associations [48, 57, 59, 72, 73], and three other studies found no significant associations [33, 52, 54]. Only one of these studies, reporting no significant association, was a cohort study [52]. All other studies were cross-sectional studies. A negative significant association between OHQoL and non-functional dentures (dentures without stability, retention, and extension) was reported by two studies [53, 70]. Another cross-sectional study reported a negative association between OHQoL and dentures causing ulcers or bad breath [74].

One cohort study of good quality found an association between type of dental prosthesis and OHQoL, indicating a greater OHQoL in participants with a fixed dental prosthesis than those who wore removable dental prosthesis and conventional dentures [53].

Moreover, after insertion of a new conventional denture, most studies, of which two RCT's, reported a positive association between new dentures and OHQoL [52, 75-79], except for one RCT, which mentioned no significant association [80].

Seven studies, of which five were RCT's, found statistically significant positive correlations between implant-retained overdentures in comparison with conventional dentures and OHQoL [27, 77, 80-84]. Also, implant-retained overdentures compared with new conventional prostheses showed positive correlations with OHQoL, according to two RCTs [83, 85]. One cross-sectional study reported no significant differences in OHQoL between patients with implant-retained overdentures and dentate patients [27].

Furthermore, only one study reported positive associations between OHQoL and characteristics of the removable partial denture (RPD), such as: aesthetics, retention, and fit [86]. This is in contrast to fixed partial dentures, where no significant association between OHQoL and aesthetics was found [86]. One study found positive associations between OHQoL and the aesthetics and speech function of the conventional denture [78]. For maxillary denture retention and mandibular denture stability, positive associations were found with OHQoL as well [87]. McKenna et al. conducted a RCT, showing that, regarding tooth replacement strategies for partially dentate people, treatment according to the Shortened Dental Arch (SDA) concept resulted in better OHQoL than treatment with RPD after 1-year and 2-year follow-up [88].

TABLE 5 | Associations of oral health factors in the prosthetic domain with oral health-related quality of life.

| Paper                        | IOD vs CD | IOD vs new CD | Denture treatment need | PD vs CD | Using dentures | New CD |
|------------------------------|-----------|---------------|------------------------|----------|----------------|--------|
| Awad et al., 2003            | +         |               |                        |          |                |        |
| Campos et al., 2017          |           |               |                        |          |                | +      |
| Castrejon-Perez et al., 2017 |           |               | -                      |          |                |        |
| Cornejo et al., 2013         |           |               | N.S./-                 |          | N.S.           |        |
| da Silva et al., 2011        |           |               | -                      |          | +              |        |
| Emami et al., 2009           | +         |               |                        |          |                |        |
| Emami et al., 2010           | +         | +             |                        |          |                |        |
| Eric et al., 2017            |           |               |                        |          |                | +      |
| Geckili et al., 2011         | +         |               |                        |          |                |        |
| Ha et al., 2012              |           |               |                        | N.S.     | N.S.           | +      |
| Heydecke et al., 2003        | +         |               |                        |          |                | N.S.   |
| Hoeksema et al., 2017        | +         |               |                        |          |                |        |
| Hsu et al., 2014             |           |               |                        |          | N.S.           |        |
| Jabbour et al., 2012         | +         |               |                        |          |                | +      |
| Klotz et al., 2017           |           |               |                        | N.S.     | +              |        |
| Komagamine et al., 2012      |           |               |                        |          |                | +      |
| Masood et al., 2017          |           |               |                        |          | -              |        |
| Mihara et al., 2018          |           |               |                        |          | -              |        |
| Meneses-Gomes et al., 2016   |           |               | N.S.                   |          |                |        |
| Motallebnejad et al., 2015   |           |               |                        |          | +              |        |
| Müller et al., 2013          |           | +             |                        |          |                |        |
| Nielsen et al., 2016         |           |               |                        | N.S.     |                |        |
| Park et al., 2010            |           |               |                        | N.S.     |                |        |
| Pearson et al., 2007         |           |               |                        |          |                | +      |
| Rebelo et al., 2016          |           |               | -                      |          |                |        |
| Shao et al., 2018            |           |               | -                      |          |                |        |
| Souza et al., 2017           |           |               |                        |          | +              |        |
| Strömberg et al., 2013       |           |               |                        |          | -              |        |
| Tsakos et al., 2004          |           |               | -                      |          |                |        |

| Paper               | IOD vs CD | IOD vs new CD | Denture treatment need | PD vs CD | Using dentures | New CD |
|---------------------|-----------|---------------|------------------------|----------|----------------|--------|
| Yen et al., 2015    |           |               | -                      | N.S. / - |                |        |
| Yoon et al., 2013   |           |               |                        |          | -              |        |
| Zhou et al., 2012   |           |               |                        |          | -              |        |
| Zusman et al., 2016 |           |               |                        |          | -              |        |

NOTE | IOD = implant-retained overdenture, CD = conventional denture, PD = partial denture, + = positive association, - = negative association, N.S. = no significant association.

### Summary

There is no consensus of the influence of the use of dentures on OHQoL. Being satisfied with the dentures, proper function of the dentures, and no need for denture treatment, were positively associated with OHQoL. Several RCT's show a positive effect of implant-retained overdentures on OHQoL, and one RCT shows a positive correlation of the SDA concept compared to RPD.

### Other oral-health related factors

The associations of other oral health factors that may have an influence on OHQoL are presented in *Table 6*. Most (8 out of 10) included studies found statistically significant negative associations between xerostomia and OHQoL scores [21, 22, 46, 66, 70, 89, 90]. There was no statistically significant association between hyposalivation and OHQoL [89]. One study found a significant negative association between OHQoL and clinical symptoms of oral dryness [91].

One study reported no significant associations between OHQoL and orofacial pain, in contrast to four other studies that found negative associations [44, 51, 57, 66]. The study that reported no significant association, had the lowest quality rating (14/20) [51].

Furthermore, negative associations between OHQoL and the following oral health factors were reported by cross-sectional studies: presence of symptoms in the temporomandibular joint [92], sensitive teeth [66], halitosis [51], clinically assessed treatment need [28, 43, 60], and a poor opinion of their dental appearance [32, 33, 56, 92, 93]. There was no association between OHQoL and burning mouth [56]. Moreover, three studies found positive associations between OHQoL and chewing

TABLE 6 | Associations of remaining oral health factors with oral health-related quality of life.

| Paper                          | Xerostomia | Orofacial pain | Chewing function |
|--------------------------------|------------|----------------|------------------|
| Alshammari et al., 2018        |            | –              |                  |
| Castrejon-Perez et al., 2017   | –          |                |                  |
| Cho et al., 2018               |            |                | +                |
| Gerdin et al., 2005            | –          |                |                  |
| Hsu et al., 2014               |            |                | +                |
| Jensen et al., 2008            | N.S.       |                |                  |
| Johansson et al., 2012         | –          |                |                  |
| Jung et al., 2008              |            | –              |                  |
| Masood et al., 2017            |            | –              | N.S.             |
| Östberg et al., 2011           |            |                | +                |
| Paredes-Rodríguez et al., 2016 | –          |                |                  |
| Park et al., 2010              | –          |                |                  |
| Porter et al., 2015            | –          | –              |                  |
| Rodrigues-Gomes et al., 2015   | –          |                |                  |
| Yen et al., 2015               | N.S.       | N.S.           |                  |
| Yu et al., 2008                | –          |                |                  |

NOTE | + = positive association, – = negative association, N.S. = no significant association.

ability [54, 93], but one study found no significant association [31]. One study reported a significant positive association between occlusal force and OHQoL [94].

#### Summary

OHQoL is associated with xerostomia, but no association was found with hyposalivation. Furthermore, orofacial pain and poor chewing ability were negatively associated with OHQoL.

## Discussion and Implications

The aim of this systematic review was to identify oral health factors associated with OHQoL in people aged 65 years or older, and to give a comprehensive overview of the body of literature for each oral health factor separately. We found higher number of natural teeth, higher number of occluding pairs, being satisfied with dentures, proper function of dentures, and not having a need for denture treatment were positively associated with OHQoL. Implant-retained overdentures compared to conventional dentures, and SDA concept compared to RPD, resulted in a better OHQoL in people aged 65 years or older. Xerostomia, orofacial pain, and poor chewing ability were found to be negatively associated with OHQoL. There is no consensus in the current literature regarding the association between OHQoL and caries, periodontal conditions, and edentulism.

### Natural dentition

Another systematic review concluded that edentulism in older people is associated with a poor quality of life [10]. However, they described the results of 11 papers separately, without clearly describing on what their final conclusion was based [10]. In our systematic search, it was found that most studies did not find a significant association between edentulism and OHQoL in people aged 65 years or older, and that there were two studies that reported a better OHQoL in edentate participants, due to the absence of dental problems that can only occur in natural teeth [31, 32]. The overall consensus on the negative effect of tooth loss has also been reported in the adult population [7, 9]. A systematic review on qualitative studies shows that tooth loss is not only associated with diminished oral function, but is also associated with less self-esteem and loss of social status [95].

### Caries

In the current literature, there is no consensus on the influence of caries on OHQoL in people aged 65 years or older. Impaired OHQoL due to caries may be caused by pain, poor aesthetics, or halitosis [55]. However, it is important to acknowledge that carious lesions do not always cause pain or may not be in the aesthetic zone, and as such, does not influence self-rated OHQoL.

### Periodontal conditions

We found no consensus on the associations between periodontal conditions and OHQoL. Another systematic review found periodontal diseases have a negative impact on quality of life in adults, depending on the severity of the periodontal disease [6]. However, periodontal disease is recognised as a ‘silent’ disease, causing only a

few or no symptoms, which could explain the results of the studies that did not find an association between periodontal conditions and OHQoL. Although periodontal disease may not directly lead to impaired OHQoL, it can ultimately lead to loss of teeth, and therefore have a negative impact on OHQoL in older people [96].

### Prosthetic status

A previous review found a positive association between OHQoL and implant-retained overdentures compared to conventional dentures in the adult population [97]. We showed similar results for people aged 65 years or older. Implant-retained overdentures have better stability and retention, which supports patients' satisfaction [83]. This results in better chewing ability and improvement in aesthetics, speech, food choice, and social activity [80]. Dissatisfaction with conventional dentures is the most common reason to fit implant-retained overdentures, which could also explain the better OHQoL of implant-retained overdentures compared to conventional dentures [84].

Furthermore, regarding tooth replacement strategies for partially dentate people, the Shortened Dental Arch concept compared to Removable Partial Dentures resulted in a better OHQoL in people aged 65 years or older in this study. These results are in contrast with another review, which concluded that the SDA concept appears to be as feasible as RPD in terms of OHQoL in adults [98]. A recently conducted RCT showed no differences in chewing capacity between patients with SDA or RPD [99]. Besides, patients often indicate that they do not want to have removable dentures [100]. The shortened dental arch concept can therefore be a good strategy to prevent overtreatment and discomfort of removable dentures, while preserving a functional dentition [88].

### Other oral-health related factors

Xerostomia is negatively associated with OHQoL, according to a few reviews [18-20]. Xerostomia impacts on difficulties in swallowing and chewing, burning sensation, pain in salivary glands, and speech difficulties [18].

Furthermore, our review shows that orofacial pain has a negative influence on OHQoL in people aged 65 years or older. In adults, besides dental pain, negative associations were reported between temporomandibular disorders and OHQoL [101]. Pain is known to have a negative impact on a person's physical and mental state, and social functioning [102].

Chewing ability has previously been reported as significantly related to lower OHQoL scores [103]. In our review, poor chewing ability was also found to be negatively associated with OHQoL in people aged 65 years or older. This could be explained by diminished food intake and different food intake, which is caused by poor chewing ability [104].

### Quality assessment

From the 68 studies, 9 were RCT's, 6 were cohort studies, and 53 were cross-sectional studies. The RCT studies reported on the influence of implant-retained overdentures, conventional dentures, and the SDA concept on OHQoL, while the cohort studies reported on the influence of implant-retained overdentures, (new) conventional dentures, and fixed or removable dentures on OHQoL. All other oral health factors were described in cross-sectional studies. It is important to acknowledge that results reported by cross-sectional studies cannot be used to determine cause and effect. However, cross-sectional studies are commonly used to determine factors that associate with a certain health related problem, in this case OHQoL. Most studies showed methodological flaws and some sort of bias. Performance and detection bias were often present in the RCT studies. According to the NOS, only one cohort study was of good quality and from the 53 cross-sectional studies, only three studies met all 20 criteria of the AXIS tool [66].

### Strengths & Limitations

This is the first systematic review on OHQoL for people aged 65 years or over including all oral health-related factors. Strengths include unrestricted literature searches, no language limitations, and study selection performed independently by two researchers.

Nonetheless, the sample size in each study varied greatly, from 32 participants in one study to a national survey (9,813 participants) study. Due to different study designs and populations, different assessments of the measurements, and different outcome tools, no meta-analysis could be performed. Furthermore, some studies did not adjust for confounders (e.g., age, gender, educational level, frailty, and general health) and the non-response rate was often not described, resulting in an increased risk for selection bias. In this review, we considered 65 years as the cut off point for older people. It is important to acknowledge, however, that in other countries younger individuals could be considered as older people. Most of the included studies were cross-sectional. Future research with longer follow-ups and RCTs are needed to understand causal associations.

## Clinical Implications

As people age, their perceptions and values with respect to quality of life may change [56], and it is important to adjust the dental care accordingly. This review shows that to preserve a good OHQoL in dentate people aged 65 years or older, it is important to prevent tooth loss to preserve a good oral health-related quality of life. However, it should be acknowledged that more oral health problems can occur in dentate older people, due to impaired oral self-care and increased comorbid diseases [2]. This review shows that it remains unclear whether being dentate in people aged 65 years or older is preferable in terms of OHQoL than being edentate. People aged 65 years or older might benefit more from well-functioning dentures than from being dentate. More research is needed to determine at what point (e.g., number of teeth, missing front teeth) having well-functioning dentures is preferred over being dentate in terms of OHQoL. Furthermore, dental care in this population must focus on being free of pain and retain proper chewing ability. The results of the included studies are at population level, which should not mask the diversity on individual level. It is therefore recommended to evaluate each person's perceptions and wishes separately, to achieve the best possible treatment choice.

## Conclusion

This is the first systematic review on OHQoL for people aged 65 years or over including all oral health-related factors. Having a functional dentition (either natural or prosthetic) is important for a good OHQoL, whereas painful or functional complaints are associated with impaired OHQoL.

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APPENDIX 1 | Full search strategies for all databases.

PubMed Session Results (03 Apr 2019)

| Search | Query  | Items found |
|--------|--|-------------|
| #4     | #1 AND #2 AND #3   | 1,413       |
| #3     | “Aged”[Mesh] OR “Geriatric Dentistry”[Mesh] OR “Dental Care for Aged”[Mesh] OR elder*[tw] OR eldest[tw] OR frail*[tw] OR geriatri*[tw] OR old age*[tw] OR oldest old*[tw] OR senior*[tw] OR senium[tw] OR very old*[tw] OR septuagenarian*[tw] OR octagenarian*[tw] OR octogenarian*[tw] OR nonagenarian*[tw] OR centarian*[tw] OR centenarian*[tw] OR supercentenarian*[tw] OR older people[tw] OR older subject*[tw] OR older patient*[tw] OR older age*[tw] OR older adult*[tw] OR older man[tw] OR older men[tw] OR older male*[tw] OR older woman[tw] OR older women[tw] OR older female*[tw] OR older population*[tw] OR older person*[tw] | 3,121,040   |
| #2     | “Quality of Life”[Mesh] OR life qualit*[tiab] OR “quality of life”[tiab] OR “qol”[tiab] OR “hrql”[tiab] OR “hrqol”[tiab] OR living qualit*[tiab] OR “quality of living”[tiab]  | 299,734     |
| #1     | “Oral Health”[Mesh] OR oral health[tiab] OR periodontal health[tiab] OR periodontal status[tiab]   | 32,625      |

Embase.com Session Results (03 Apr 2019)

| Search | Query  | Items found |
|--------|--|-------------|
| #4     | #1 AND #2 AND #3   | 1,420       |
| #3     | ‘aged’/exp OR elder*:ab,ti,kw OR eldest:ab,ti,kw OR frail*:ab,ti,kw OR geriatri*:ab,ti,kw OR ‘old age*’:ab,ti,kw OR ‘oldest old*’:ab,ti,kw OR senior*:ab,ti,kw OR senium:ab,ti,kw OR ‘very old*’:ab,ti,kw OR septuagenarian*:ab,ti,kw OR octagenarian*:ab,ti,kw OR octogenarian*:ab,ti,kw OR nonagenarian*:ab,ti,kw OR centarian*:ab,ti,kw OR centenarian*:ab,ti,kw OR supercentenarian*:ab,ti,kw OR ‘older people’:ab,ti,kw OR ‘older subject*’:ab,ti,kw OR ‘older patient*’:ab,ti,kw OR ‘older age*’:ab,ti,kw OR ‘older adult*’:ab,ti,kw OR ‘older man’:ab,ti,kw OR ‘older men’:ab,ti,kw OR ‘older male*’:ab,ti,kw OR ‘older woman’:ab,ti,kw OR ‘older women’:ab,ti,kw OR ‘older female*’:ab,ti,kw OR ‘older population*’:ab,ti,kw OR ‘older person*’:ab,ti,kw | 3,142,637   |
| #2     | ‘quality of life’/exp OR ((life OR living) NEAR/3 qualit*):ab,ti,kw OR qol:ab,ti,kw OR hrql:ab,ti,kw OR hrqol:ab,ti,kw   | 535,127     |
| #1     | ‘dental health’/exp OR ‘oral health’:ab,ti,kw OR ‘periodontal health’:ab,ti,kw OR ‘periodontal status’:ab,ti,kw  | 29,748      |

## Wiley / Cochrane Library Session Results (03 Apr 2019)

| Search | Query  | Items found |
|--------|--|-------------|
| #4     | #1 AND #2 AND #3   | 96          |
| #3     | (elder* or eldest or frail* or geriatri* or (old NEXT age*) or (oldest NEXT old*) or senior* or senium or (very NEXT old*) or septuagenarian* or octagenarian* or octogenarian* or nonagenarian* or centarian* or centenarian* or supercentenarian* or (older NEXT people) or (older NEXT subject*) or (older NEXT patient*) or (older NEXT age*) or (older NEXT adult*) or (older NEXT man) or (older NEXT men) or (older NEXT male*) or (older NEXT woman) or (older NEXT women) or (older NEXT female*) or (older NEXT population*) or (older NEXT person*)):ab,ti,kw | 70,163      |
| #2     | ((life or living) near/3 qualit*) or qol or hrql or hrqol):ab,ti,kw  | 96,090      |
| #1     | ((oral NEXT health) or (periodontal NEXT health) or (periodontal NEXT status)):ab,ti,kw  | 3,015       |

## CINAHL (Ebsco) Session Results (03 Apr 2019)

| Search | Query   | Items found |
|--------|---|-------------|
| S4     | S1 AND S2 AND S3  | 693         |
| S3     | (MH "Aged+") OR (MH "Dental Care for Aged") OR TI (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") OR AB (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") OR SU (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") | 780,706     |

| Search | Query  | Items found |
|--------|--|-------------|
| S2     | (MH "Quality of Life") OR TI (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol) OR AB (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol) OR SU (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol)                     | 149,670     |
| S1     | (MH "Oral Health") OR TI ("oral health" OR "periodontal health" OR "periodontal status") OR AB ("oral health" OR "periodontal health" OR "periodontal status") OR SU ("oral health" OR "periodontal health" OR "periodontal status") | 16,223      |

## PsycINFO (Ebsco) Session Results (03 Apr 2019)

| Search | Query  | Items found |
|--------|--|-------------|
| S4     | S1 AND S2 AND S3   | 80          |
| S3     | TI (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") OR AB (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") OR KW (elder* OR eldest OR frail* OR geriatri* OR "old age*" OR "oldest old*" OR senior* OR senium OR "very old*" OR septuagenarian* OR octagenarian* OR octogenarian* OR nonagenarian* OR centarian* OR centenarian* OR supercentenarian* OR "older people" OR "older subject*" OR "older patient*" OR "older age*" OR "older adult*" OR "older man" OR "older men" OR "older male*" OR "older woman" OR "older women" OR "older female*" OR "older population*" OR "older person*") | 171,270     |
| S2     | DE "Quality of Life" OR TI (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol) OR AB (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol) OR KW (((life OR living) N3 qualit*) OR qol OR hrql OR hrqol)   | 79,750      |
| S1     | DE "Oral Health" OR TI ("oral health" OR "periodontal health" OR "periodontal status") OR AB ("oral health" OR "periodontal health" OR "periodontal status") OR KW ("oral health" OR "periodontal health" OR "periodontal status")   | 1,556       |

APPENDIX 2 | Methodological quality assessment of the included RCT studies with the Cochrane Risk of Bias tool.

| Paper                 | Selection bias | Performance bias | Detection bias | Attrition bias | Reporting bias | Other bias |
|-----------------------|----------------|------------------|----------------|----------------|----------------|------------|
| Awad et al., 2003     | -              | +                | +              | -              | -              | +          |
| Emami et al., 2010    | -              | +                | +              | -              | -              | +          |
| Emami et al., 2009    | -              | +                | +              | -              | -              | +          |
| Heydecke et al., 2003 | -              | +                | +              | -              | -              | +          |
| Jabbour et al., 2012  | -              | +                | +              | -              | -              | +          |
| McKenna et al., 2015  | -              | +                | -              | -              | -              | -          |
| McKenna et al., 2018  | -              | +                | +              | -              | -              | -          |
| Müller et al., 2013   | -              | +                | +              | +              | -              | -          |
| Pearson et al., 2007  | -              | +                | -              | -              | -              | -          |

NOTE | RCT = randomized controlled trial, + = bias is present, - = bias is not present.

APPENDIX 3 | Methodological quality assessment of the included cohort studies with the NOS.

| Paper                   | Selection |       |       |       | Compa-rability |   | Outcome |       |   | Total score  | Quality rating |
|-------------------------|-----------|-------|-------|-------|----------------|---|---------|-------|---|--------------|----------------|
|                         | 1         | 2     | 3     | 4     | 5              | 6 | 7       | 8     |   |              |                |
| Astrom et al., 2018     | a (1)     | a (1) | c     | a (1) | b (1)          | c | a (1)   | c     | 5 | poor quality |                |
| Campos et al., 2017     | b (1)     | a (1) | a (1) | a (1) | c              | c | a (1)   | a (1) | 6 | poor quality |                |
| Geckili et al., 2011    | b (1)     | a (1) | a (1) | a (1) | c              | c | a (1)   | a (1) | 6 | poor quality |                |
| Ha et al., 2012         | b (1)     | a (1) | a (1) | b     | a (1)          | c | b       | c     | 4 | poor quality |                |
| Klotz et al., 2018      | a (1)     | a (1) | a (1) | a (1) | b (1)          | c | a (1)   | b (1) | 7 | good quality |                |
| Komagamine et al., 2012 | b (1)     | a (1) | a (1) | a (1) | b (1)          | c | b       | c     | 5 | poor quality |                |

NOTE | NOS = Newcastle-Ottawa Scale, ( ) = number of stars; Good quality: 3 or 4 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome domain; Fair quality: 2 stars in selection domain AND 1 or 2 stars in comparability domain AND 2 or 3 stars in outcome domain; Poor quality: 0 or 1 star in selection domain OR 0 stars in comparability domain OR 0 or 1 stars in outcome domain.

APPENDIX 4 | Methodological quality assessment of the cross-sectional studies with the Appraisal tool for Cross-Sectional Studies (AXIS tool).

| Paper                        | Q1  | Q2  | Q3  | Q4  | Q5  | Q6  | Q7  | Q8  | Q9  | Q10 | Q11 | Q12 | Q13 <sup>a</sup> | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 <sup>a</sup> | Q20 | AXIS Score/20 |
|------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------------------|-----|-----|-----|-----|-----|------------------|-----|---------------|
| Alshammari et al., 2018      | yes | yes | yes | yes | no  | no  | no  | yes | yes | yes | yes | no  | ?                | no  | yes | yes | yes | yes | no               | yes | 14            |
| Castrejon-Perez et al., 2017 | yes | yes | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | yes | no               | yes | 17            |
| Chen et al., 2012            | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | no  | ?                | yes | 18            |
| Cho et al., 2018             | yes | yes | yes | yes | yes | ?   | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | no               | ?   | 15            |
| Cicciù et al., 2013          | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | yes | yes | no               | yes | ?   | yes | yes | yes | no               | yes | 18            |
| Cornejo et al., 2013         | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes              | no  | yes | yes | yes | yes | no               | yes | 18            |
| Dahl et al., 2011            | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes              | yes | yes | yes | yes | no  | ?                | yes | 17            |
| da Silva et al., 2011        | yes | yes | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | ?                | yes | 16            |
| Eric et al., 2012            | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | yes | ?                | yes | 17            |
| Eric et al., 2017            | yes | yes | yes | yes | no  | yes | no  | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | yes | ?                | yes | 16            |
| Gerdin et al., 2005          | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | yes | yes | yes              | yes | yes | yes | yes | no  | no               | yes | 17            |
| Göktürk et al., 2018         | yes | yes | yes | yes | no  | no  | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | no               | yes | 15            |
| Hassel et al., 2007          | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | yes | ?                | ?   | 17            |
| Hoeksema et al., 2017        | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes              | yes | yes | yes | yes | yes | yes              | yes | 18            |
| Hoeksema et al., 2018        | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | yes | no               | yes | 20            |
| Hsu et al., 2014             | yes | yes | yes | yes | no  | no  | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | ?                | yes | 14            |
| Jensen et al., 2008          | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | ?                | yes | yes | yes | yes | yes | yes              | yes | 18            |
| Johansson et al., 2012       | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | yes | yes | yes              | no  | yes | yes | yes | no  | ?                | yes | 15            |
| Jung et al., 2008            | yes | yes | no  | yes | no  | yes | yes | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | yes | ?                | ?   | 15            |
| Kato et al., 2018            | yes | yes | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | no               | yes | 17            |
| Klotz et al., 2017           | yes | yes | yes | yes | no  | yes | no  | yes | yes | yes | yes | yes | yes              | yes | yes | yes | yes | yes | ?                | yes | 16            |
| Kohli et al., 2017           | yes | yes | yes | yes | no  | yes | no  | yes | yes | yes | yes | yes | yes              | yes | yes | yes | yes | yes | no               | yes | 17            |
| Lee et al., 2012             | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | yes | yes | yes              | no  | yes | yes | yes | no  | yes              | ?   | 14            |
| Ling et al., 2014            | yes | yes | no  | yes | no  | yes | no  | yes | yes | yes | yes | yes | yes              | no  | yes | yes | yes | yes | yes              | yes | 14            |
| Masood et al., 2017          | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | no  | no               | ?   | 18            |
| Meneses-Gómez et al., 2016   | yes | yes | no  | yes | no  | yes | no  | yes | yes | yes | yes | yes | yes              | no  | yes | yes | yes | yes | ?                | yes | 14            |
| Mihara et al., 2018          | yes | yes | yes | yes | yes | no  | no  | yes | yes | yes | yes | no  | no               | no  | yes | yes | yes | yes | no               | yes | 16            |
| Motallebnejad et al., 2015   | yes | yes | no  | no  | yes | yes | yes | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | no  | ?                | ?   | 14            |
| Niستن et al., 2016           | yes | yes | yes | yes | no  | no  | no  | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | no  | no               | yes | 15            |
| Noguchi et al., 2016         | yes | yes | yes | yes | no  | no  | no  | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | yes | no               | yes | 16            |

| Paper                               | Q1  | Q2  | Q3  | Q4  | Q5  | Q6  | Q7  | Q8  | Q9  | Q10 | Q11 | Q12 | Q13 <sup>a</sup> | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 <sup>a</sup> | Q20 | AXIS Score/20 |
|-------------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------------------|-----|-----|-----|-----|-----|------------------|-----|---------------|
| Östberg et al., 2011                | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | no  | no               | yes | 19            |
| Paredes-Rodríguez et al., 2016      | yes | yes | no  | no  | no  | no  | no  | yes | yes | yes | yes | no  | ?                | no  | yes | yes | no  | no  | no               | yes | 10            |
| Park et al., 2010                   | yes | yes | yes | yes | no  | no  | yes | no  | yes | yes | yes | yes | yes              | no  | yes | yes | yes | no  | no               | yes | 14            |
| Porter et al., 2015                 | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | yes | no               | yes | 20            |
| Rebello et al., 2016                | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | yes | no               | yes | 20            |
| Rodrigues Gomes et al., 2015        | yes | yes | yes | yes | no  | no  | yes | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | yes | no               | ?   | 16            |
| Sáez-Prado et al., 2016             | yes | yes | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | no  | no               | yes | 16            |
| Santucci et al., 2015               | yes | yes | yes | yes | no  | no  | no  | yes | yes | yes | yes | no  | ?                | no  | yes | yes | yes | no  | no               | ?   | 12            |
| Shao et al., 2018                   | yes | yes | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | no               | no  | yes | yes | no  | yes | no               | ?   | 16            |
| Sheiham et al., 2001                | yes | yes | no  | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes              | yes | yes | yes | yes | no  | ?                | ?   | 15            |
| Skoskiewicz-Malinowska et al., 2019 | yes | yes | yes | yes | no  | yes | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | ?                | yes | 15            |
| Slade et al., 1996                  | yes | yes | no  | yes | yes | yes | no  | yes | yes | yes | yes | yes | yes              | yes | yes | yes | yes | yes | ?                | ?   | 15            |
| Souza et al., 2017                  | yes | yes | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | ?                | yes | 16            |
| Stenman et al., 2012                | yes | yes | yes | yes | yes | yes | no  | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | yes | ?                | yes | 17            |
| Strömberg et al., 2013              | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | no  | no               | yes | 19            |
| Tsakos et al., 2004                 | yes | yes | no  | yes | yes | yes | no  | yes | yes | yes | yes | no  | no               | no  | yes | yes | yes | no  | no               | ?   | 14            |
| Wu et al., 2018                     | yes | yes | yes | yes | no  | no  | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | no               | yes | 15            |
| Yen et al., 2015                    | yes | yes | no  | yes | no  | no  | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | no               | yes | 14            |
| Yoon et al., 2013                   | yes | yes | no  | yes | yes | no  | yes | yes | yes | yes | yes | yes | no               | yes | yes | yes | yes | yes | ?                | yes | 17            |
| Yu et al., 2008                     | yes | yes | yes | yes | no  | no  | yes | yes | yes | yes | yes | yes | yes              | yes | yes | yes | yes | yes | ?                | yes | 16            |
| Zhou et al., 2012                   | yes | yes | no  | yes | yes | yes | no  | yes | yes | yes | yes | yes | no               | no  | yes | yes | yes | yes | ?                | yes | 16            |
| Zuluaga et al., 2011                | yes | yes | yes | yes | yes | no  | no  | yes | yes | yes | yes | yes | ?                | no  | yes | yes | yes | yes | ?                | yes | 15            |
| Zusman et al., 2016                 | yes | yes | yes | yes | yes | yes | yes | yes | yes | no  | yes | yes | yes              | no  | yes | yes | yes | no  | ?                | yes | 15            |

NOTE | Q = Question, ? = unclear. a = Item is reverse scored (i.e., no is a positive).

- Q1 Were the aims/objectives of the study clear?  
 Q2 Was the study design appropriate for the stated aim(s)?  
 Q3 Was the sample size justified?  
 Q4 Was the target/reference population clearly defined? (Is it clear who the research was about?)  
 Q5 Was the sample frame taken from an appropriate population base so that is closely represented the target/reference population under investigation?  
 Q6 Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?  
 Q7 Were measures undertaken to address and categorise non-responders?  
 Q8 Were the risk factor and outcome variables measured appropriate to the aims of the study?  
 Q9 Were the risk factors and outcome variables measured correctly using instruments/measurements that had been trialled, piloted or published previously?

Q10 Is it clear what was used to determined statistical significance and/or precision estimates? (e.g. p-values, confidence intervals)

Q11 Were methods (including statistical methods) sufficiently described to enable them to be repeated?

Q12 Were the basic data adequately described?

Q13 Does the response rate raise concerns about non-response bias?

Q14 If appropriate, was information about non-responders described?

Q15 Were the results internally consistent?

Q16 Were the results presented for all the analyses described in the methods?

Q17 Were the authors' discussion and conclusions justified by the results?

Q18 Were the limitations of the study discussed?

Q19 Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?

Q20 Was ethical approval or consent of participants attained?