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Association between periodontal disease and age-related cognitive impairment: a narrative review

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Abstract

Background Previous studies have shown associations between periodontal disease and age-related cognitive impairment. However, little is known about the different cognitive functions that may be affected in patients with periodontal disease.

Methods We reviewed the recent literature to better understand the bidirectional relationship between cognitive function and periodontal disease, and to explore the cognitive assessments that may be useful when investigating this relationship. We also reviewed the literature around improving periodontal health in older adults presenting with cognitive impairment, which may improve their cognition.

Results There is a bidirectional relationship between periodontal disease and cognitive impairment. We also found that visuospatial function, attention, memory, and language are important cognitive domains that may be impaired in older people with periodontal disease, possibly because these factors are associated with the ability to adequately brush one's teeth. Furthermore, we noted that the choice of cognitive assessment may be particularly important when studying cognitive function in relation to periodontal health. To improve periodontal health in older people with cognitive impairment, partner-assisted interventions, adequate toothbrushing, and the use of a powered toothbrush have all been proposed. The early initiation of regular oral care visits, education for individuals, improving cooking skills, and dietary/caloric restrictions may also contribute to improving periodontal health.

Conclusions The bidirectional nature of the relationship between periodontal health and cognitive function is important for older adults presenting with cognitive impairment. Furthermore, improvements in periodontal health may help to improve cognitive impairment. The appropriate assessment of cognitive function will contribute to preserving and improving oral health in older people with periodontal disease.

Keywords Cognitive impairment, Dementia, Periodontal disease, Oral health, Oral hygiene

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Background

Periodontal disease is characterised by chronic inflammation of the periodontium that can currently be successfully controlled, meaning that teeth can be retained for life [1]. Periodontal diseases include gingivitis, which is a superficial and reversible inflammation of the gum that results in swelling and bleeding [2]. Periodontal disease is often accompanied by the loss of the periodontal ligament and alveolar bone, and eventually the loss of teeth. Severe periodontal disease is widespread, with a global prevalence of approximately 19% in people aged 15 years and older, representing more than 1 billion cases worldwide [2]. The incidence of severe periodontal disease starts in late adolescence, peaks around 55 years of age, and remains high until old age [2]. Periodontal disease is particularly prevalent in people who do not receive regular periodontal care [3]. Other risk factors for developing periodontal disease include ageing, male sex, vascular disease, smoking, diabetes, medication, systemic diseases, genetics, bone mineral density disorders, lower income, lower education, and stress [3–5].

Cognitive impairment is characterised by objective declines in at least one cognitive domain, such as executive functioning, memory, attention, language, abstract reasoning, or visuospatial skills. Cognitive impairments such as memory loss and loss of executive functions can appear at different times during disease development, in the journey along a continuum that ends in dementia [6]. Dementia is the most severe level of cognitive impairment and is defined by cognitive deficits that impair daily functioning and lead to a loss of independence [7]. Moreover, dementia places a large economic burden on individuals and societies [8]. Similar to dementia, mild cognitive impairment (MCI) is characterised by objective cognitive impairment. However, in contrast to dementia, the day-to-day functioning of individuals with MCI remains largely intact and independence is preserved [7, 9]. Globally, 15.6% of community-dwelling adults aged over 50 years have MCI [10]. Some individuals experience a subjective decrease in cognitive function despite cognitive performance showing no evidence of objective cognitive impairment in neuropsychological testing or daily functioning [6]. The term "subjective cognitive decline", as a possible step before MCI, was coined by researchers to describe this condition [6, 7]. Around 20% of individuals with subjective cognitive decline progress to MCI [6].

Recently, investigations into the concept of an Alzheimer's disease continuum have become more focused on whether the continuum is unidirectional across all steps, or whether it may be bidirectional. For example, although it is currently impossible to revert dementia, subjects with MCI can reportedly revert to normal cognitive functioning [6]. To reduce the overall risk of dementia using several strategies, it has been recommended that cardiovascular and cerebrovascular risk factors, such as high blood pressure, should be managed from early adult life onward to reduce the risk of infarcts and white matter lesion accumulation; controlling for depression and the provision of adequate learning opportunities from childhood may also be important [11]. In addition, an Alzheimer's disease-modifying drug has been developed [12]. The main target of this drug is individuals with early Alzheimer's disease (MCI or mild dementia caused by Alzheimer's disease). Hence, therapeutic interventions for individuals with MCI may be able to delay or reduce the onset of dementia.

Ageing has been well established to promote the deterioration of cognitive function [13], and other risk factors for cognitive impairment include smoking, depression, obesity, low levels of physical activity, vascular diseases, and low levels of education [4, 10]. Poorer cognitive function is associated with depression, social withdrawal, and restricted spatial mobility, and generally has a negative impact on quality of life [14]. Importantly, because many people with MCI will go on to develop dementia, the prevention and/or treatment of cognitive impairment at this early stage may lead to lower rates of dementia in the ageing population [9].

Many studies have described a relationship between periodontal disease and cognitive impairment [15–20]. Specifically, periodontal disease is associated with a higher risk of cognitive impairment. However, in relevant studies, a wide range of cognitive testing methods have been used. Furthermore, the lack of self-care (including less frequent tooth brushing and fewer visits to the dentist) that often accompanies cognitive impairment may lead to the development of periodontal disease [21].

The specific relationship between periodontal disease and cognitive impairment remains somewhat unclear; the use of different methods to assess cognitive impairment may have contributed to the inconsistent findings that have been reported [4]. Notably, different cognitive functions may be affected in patients with periodontal disease [4]. A standardised assessment protocol is therefore required for measuring cognitive impairment in relation to periodontal disease. Thus, the aims of the present review are to summarise the ways in which different cognitive testing methods may affect research into the bidirectional relationship between cognitive impairment and periodontal disease, and to provide a better understanding of how improving dental health might also improve cognitive function in older adults presenting with cognitive impairment.

Methods

Search strategy and selection criteria

We searched the PubMed database using the keywords "periodontal disease" and "cognitive impairment". We checked for related studies using keywords such as "cognitive testing", "cognitive domains", "oral health", and "frailty". We included human studies that were written in English and published in the last 20 years to provide a review of the most recent literature, updated to August 2024. Studies were included if they investigated the associations between periodontal disease and cognitive function, the ways to assess different cognitive domains, and/or possible improvements in oral health in individuals with cognitive impairment. We also manually checked the references of included articles to identify any other relevant studies, which were also included in this narrative review.

Results

Assessing cognitive impairment

Many cognitive tests exist and are commonly used in both research and clinical settings. Although some tests measure cognitive function as a whole, such as the Mini-Mental State Examination, Montreal Cognitive Assessment, and Mini-Cog, others measure different aspects of cognition. Cognitive domains can be classified in many different ways; for example, by the process that is involved, on the basis of brain regions, or using a hierarchical approach [22]. Each type of cognitive domain has different associated tests. The most commonly defined cognitive domains of executive functioning, memory, attention, language, abstract reasoning, and visuospatial skills can be assessed using various evaluation methods (Table 1). For example, the Verbal Fluency Test Category/Letters, Clock Drawing Test, and Trail Making Test-B are commonly used to test executive functioning [23], whereas the Wechsler Memory Scale-Revised, Rey Auditory Verbal Learning Test, Rivermead Behavioral

Table 1 Commonly used tests for measuring cognitive function over different domains

Cognitive domain	Test	Duration (minutes)	Benefits	Limitations
Global cognition	Mini-Mental State Examination	5–10	Rapid; requires no equipment or training; widely accepted; available in many languages	Does not easily identify mild cognitive changes; has age/education/ culture biases
	Montreal Cognitive Assessment	10–15	Rapid; requires no equipment or training, widely accepted; sensitive to mild changes	Scores in the specific domains do not correlate well to domain-specific impairments in other tests
Executive functioning	Clock Drawing Test	1–2	Very rapid; requires no equipment or training	Relatively low sensitivity and specificity for mild cognitive impairments; also measures visuospatial skills
	Trail Making Test-B	< 5	Very rapid; requires no equipment or training; widely accepted	Scores may improve with practice; needs constant attention from clinician while being administered
Memory	Wechsler Memory Scale-Revised	130–190	Widely accepted; available in many languages; relatively comprehensive	Relatively long and complex; participants may tire or get frustrated before finishing
	Rivermead Behavioral Memory Test	25–30	Requires no training or equipment; relatively simple scoring method; tasks resemble everyday life	Relatively low sensitivity; scores are affected by age and intellectual ability
Attention	Digit Span Forward	1–3	Very rapid; requires no equipment or training; easy to administer	Not specific to attention only; differences exist depending on the language used
	Trail Making Test-A	< 5	Very rapid; requires no equipment or training; widely accepted	Scores may improve with practice; needs constant attention from clinician while being administered
Language	Boston Naming Test	30–45	Widely used; adequate sensitivity; scores correlate with structural language-related features in neuroimaging	Relatively complex and long; participants may tire or get frustrated before finishing
	Controlled Oral Word Association	5–10	Rapid; easy to administer; requires no training or equipment	May also measure executive function; relatively low sensitivity for mild changes
Abstract reasoning	Shipley-2 Abstraction Test	20–25 (full test)	Requires no training or equipment; easy to administer	May not be specific to abstract reasoning only; scores are affected by intellectual ability
	Conceptual Level Analogy Test	20	Relatively sensitive; shorter versions can be used	Relatively long; not very widely used; scores are affected by age, education, and intellectual ability
Visuospatial skills	Clock Drawing Test	1–2	Very rapid; requires no equipment or training	Relatively low sensitivity and specificity for mild cognitive impairments; also measures executive functioning
	Rey-Osterrieth Complex Figure Copy Test	35	Simple to administer; requires no equipment or training; can be used in a digital format; adequate sensitivity	May be affected by coordination; also measures memory, attention, and concentration

Memory Test, California Verbal Learning Test, Free and Cued Selective Reminding Test, and Brief Memory and Executive Test evaluate abilities in the memory domain. To test attention, the Digit Span Forward, Digit Span Backward, and Trail Making Test-A are recommended [23]; the Boston Naming Test and Controlled Oral Word Association both assess language [24]. The Shipley-2 Abstraction Test, Gorham's Proverbs Test, Conceptual Level Analogy Test, and Verbal Concept Attainment Test are all used to test abstract reasoning [24], whereas the Clock Drawing Test and Rey-Osterrieth Complex Figure Copy Test [24] can be used to evaluate visuospatial abilities.

Many factors should therefore be considered when choosing a cognitive testing method. For example, it may be important to reflect on the precise domains of cognitive function that are being measured, the subjectiveness of test results, the specificity and sensitivity of each testing method, and the possible effects of patient age, education, socioeconomic status, and/or cultural background on test results [24, 25]. Psychological tests of emotion and/or behaviour may also be useful for identifying individuals with cognitive impairment, although more research is needed in this field [26].

Another important factor that may be associated with cognitive function tests is the presence of sensory disorders. For example, hearing loss is associated with an increased risk of age-related cognitive decline [27–30]. Moreover, a dual sensory impairment—defined as the combined presence of hearing and visual impairments—is reportedly a risk factor for dementia [30, 31]. Thus, screening for these factors may be helpful when cognitive function tests are used.

Cognitive function tests and periodontal disease

In a large meta-analysis of the relationship between periodontal disease and cognitive decline/dementia, the authors noted that most of the included studies used only one testing method to assess cognitive function. The most common method was the Mini-Mental State Examination, although many different testing methods were used (namely, recall tests, digit symbol substitution test, modified Telephone Interview for Cognitive Status, Montreal Cognitive Assessment, word fluency, clock drawing test, and spatial coping test) [4]. Recently published studies of the relationship between periodontal disease and cognitive impairment have similarly used a large range of tests of cognitive function [32–35]. The use of many different testing methods makes it difficult to compare results between studies.

A very recent investigation used a variety of tests to investigate the relationship between periodontal disease and a range of different cognitive functions; the authors identified specific cognitive impairments in the domains of episodic memory and spontaneous retrieval, rather than global impairments [36]. In another recent study, researchers used the Mini-Mental State Examination, Clinical Dementia Rating scale, Alzheimer's Disease Assessment Scale-Cognitive Subscale, Frontal Assessment Battery, Raven's Coloured Progressive Matrices, and the Logical Memory subtests of the Wechsler Memory Scale-Revised to assess cognitive function over specific domains in people with periodontal disease. They identified specific deficits in visuospatial function, attention, word recall and recognition, and the ability to follow commands in these individuals [37]. Therefore, it seems that there may be a specific set of cognitive impairments that occur in people with periodontal disease. Future studies should thus use testing methods that are able to pick up these specific deficits, rather than simply using global tests of cognition.

A standardised set of methods for measuring cognitive impairment in patients with periodontal disease is likely to lead to a better understanding of the shared mechanisms of these pathologies, which in turn will lead to better diagnosis, treatment, and prevention. We propose that a set of tests that measure visuospatial function, attention, memory, and the ability to follow commands (i.e., language) may be optimal for evaluating cognitive impairment in individuals with periodontal disease (Fig. 1).

Relationship between periodontal disease and cognitive impairment

Although it was originally assumed that cognitive impairment leads to behavioural changes that make individuals more susceptible to oral health issues, recent studies have noted that periodontal disease can also lead to a greater risk of cognitive impairments and/or dementia [38–41]. Similarly, a longitudinal study has demonstrated a positive reciprocal association between cognitive impairment and oral health in older adults [42]. There is therefore a bidirectional relationship between periodontal disease and cognitive impairment [16, 43].

In addition, both periodontal disease and cognitive impairment have common underlying features. For example, both are generally accompanied by high levels of systemic inflammation and oxidative stress [44–46]. Although small carious lesions do not cause bacteraemia, caries closer to the pulp can cause an inflammatory response [47, 48]. The periodontium generates a protective immune response retarding the ingress of bacteria and bacterial byproducts. Carious pulpal exposure provides a direct pathway to bone without an epithelial immune response [48]. Apical infections in bone cause significant, irreversible bacteraemia and an inflammatory response unless treated endodontically or by extraction [48]. The presence of teeth with carious pulpal exposures

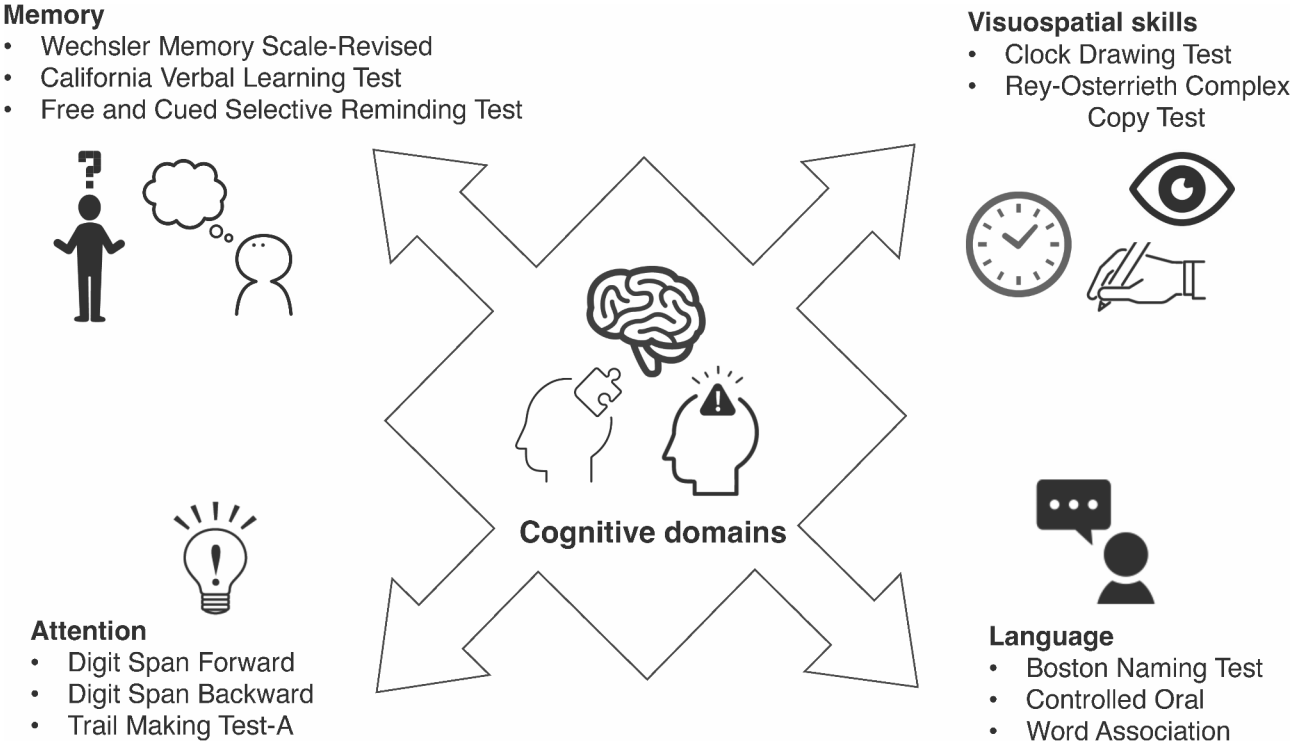

Fig. 1 Recommended standardised testing methods for cognitive impairments in individuals with periodontal disease

and retained roots is common in older adults, particularly in those prescribed polypharmacy with a high anti-cholinergic burden causing salivary gland hypofunction. Hyposalivation of salivary glands results in dry mouth, leading to dental caries, intraoral infection, orofacial pain, problems with speaking and swallowing, and diminished oral health-related quality of life [49]. This situation is exacerbated when older adults cannot maintain their own oral health and become dependent on their caregivers.

Reactive oxygen species are then generated and cause oxidative damage to the tissue. Oxidative stress plays an important role in the impact of periodontal disease on systemic diseases, such as cardiovascular disease [44]. Similar to periodontal disease, dementia is associated with a systemic inflammatory response. For example, inflammation such as activated microglia within and surrounding senile plaques is part of the underlying pathophysiology of Alzheimer's disease [50]. Moreover, *Porphyromonas gingivalis*, a keystone pathogen in the development of periodontal disease, increases the risk of Alzheimer's disease through its pro-inflammatory effects [51]. Thus, the underlying features of both periodontal disease and cognitive impairment can lead to or worsen the two disorders (Fig. 2).

Improving oral health in individuals with cognitive impairment

Interestingly, a recent study has reported that adequate toothbrushing in older adults without cognitive impairments might prevent cognitive decline [52], indicating that improved dental health may lead to improved cognitive outcomes. Although older adults without cognitive impairment may be able to maintain self-care abilities such as brushing their teeth, multiple tooth loss, infrequent toothbrushing, and delayed dental visits are all factors that are associated with cognitive impairment [52]. Furthermore, older adults presenting with impaired activities of daily living, such as individuals who are unable to toilet themselves for cognitive or physical reasons, feed themselves, have weak grip strength, or lack the mobility required to reach a bathroom will be unable to maintain their own oral health and are dependent on caregivers. Under these conditions, periodontitis and carious lesions will dramatically worsen. Thus, assessment of activities of daily living in older adults is important as well as assessing their cognitive function.

Another study revealed that oral hygiene care may play a positive role in maintaining cognitive levels in older adults with dementia [53]. Subjective memory impairment is also associated with poorer oral health-related quality of life [54]. In addition, unhealthy lifestyle patterns such as physical inactivity, smoking, alcohol consumption, shorter sleep duration, and an absence of oral

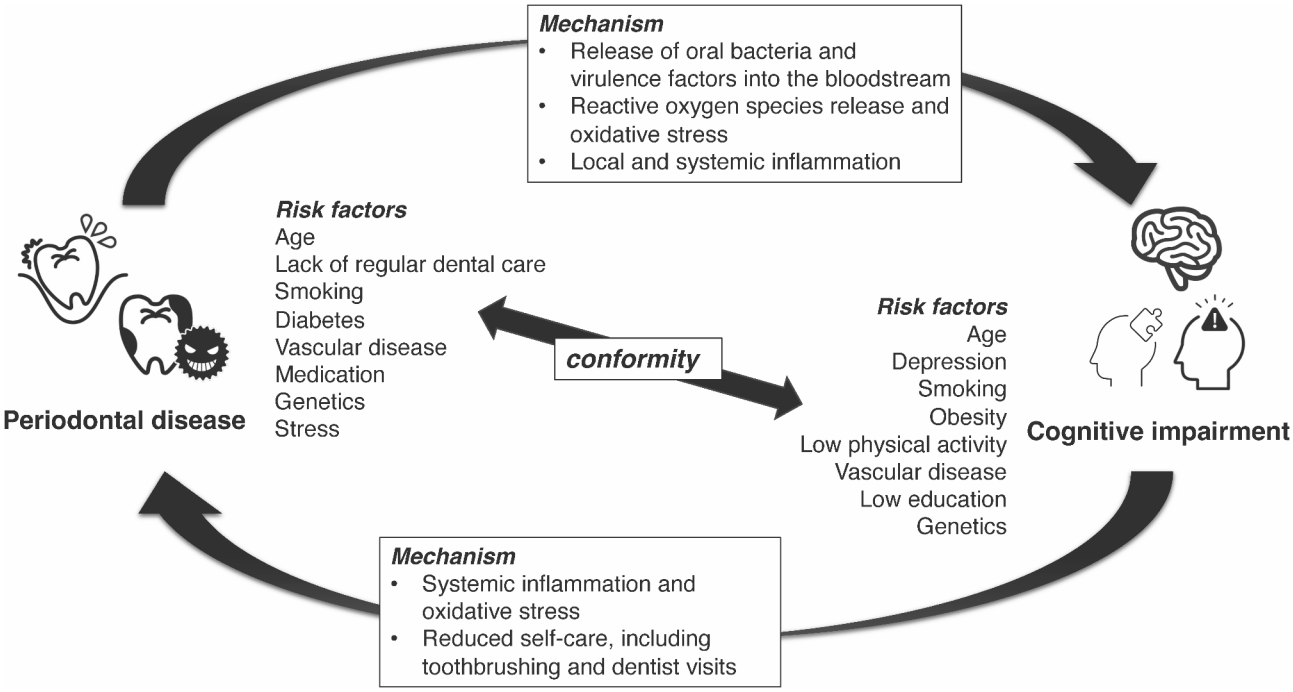

Fig. 2 Schema of the bidirectional relationship between periodontal disease and cognitive impairment

examinations are associated with an increased risk of periodontal disease [55].

Individuals with cognitive impairment and dementia are less likely to use dental services [21]. This may be remedied with clinical support—for example, by having general medical practitioners regularly recommend the use of dental services in their consultations with patients, via the use of technology-based notifications or reminders for people with cognitive impairments, or by improving caregiver knowledge regarding the importance of oral health. Furthermore, it should be noted that individuals presenting with severe dementia should be an important target for oral health care because such individuals often lose the ability to care for their oral health. For example, a major issue of individuals living with dementia involves challenging and care-resistant behaviours. Improved family support and person-centred care may be a solution for reducing these behaviours [56]. Moreover, many barriers to accessing care continue to exist, including the cost of dental treatments, a lack of transportation, psychosocial factors including anxiety or depression, and the accessibility and availability of oral health providers [57]. People living with dementia may also be overly optimistic about their oral health conditions and dental needs [57]. Hence, the early initiation of regular oral care visits and education for individuals at the stage of MCI—before their cognitive impairment worsens—may also be important [57]. A clinical study has also mentioned the importance of developing good oral hygiene practices in the earlier stages of cognitive impairment [56].

There is a range of other published methods that may be useful for improving oral health in individuals with cognitive impairment. For example, partner-assisted interventions, in which a caregiver is trained to facilitate good oral hygiene, reportedly have positive outcomes for improving oral health in individuals with mild dementia or cognitive impairment [56]. Moreover, both adequate toothbrushing [52, 58] and the use of a powered toothbrush [59, 60] have been proposed as simple methods for improving oral health, and thus possibly cognition, in adults with cognitive impairment. Improving cooking skills [61] and dietary/caloric restrictions [62] can also contribute to oral health, because some nutrient patterns are associated with better cognitive function and delayed brain ageing [63]. Socioeconomic status, such as low household income and rural residence, is also a risk factor for poor oral health care [57]. Regular and routine scaling treatment is suggested for older adults because regular scaling can reduce the incidence of dementia [40]. Tongue pressure [64], inadequate chewing function [65], and edentulism [66] are also risk factors for cognitive impairment. In addition, a recent systematic review revealed the efficacy of nonsurgical periodontal therapy for treating periodontitis in patients with concurrent systemic conditions [67]. However, two systematic reviews have highlighted the lack of high-quality evidence to support the use of oral health interventions in people with cognitive impairment [68, 69], indicating that more research is needed in this area.

Another notable ageing-related factor that may be associated with periodontal disease is frailty [70, 71]. In particular, the concept of oral frailty—an age-related decline in oral function that is driven by a series of dysfunctions that deteriorate oral health—has recently been proposed [72–74]. Much recent research has therefore focused on the prevention and management of frailty [75], because frailty is associated with decreased swallowing function [71] and increased costs of care services [76].

Together, these findings indicate that improving oral health in older adults presenting with cognitive impairment may lead to an improved diet and quality of daily living, and might also contribute to improved cognitive function and a reduced risk of dementia and/or frailty.

Concomitant strategies targeting periodontal disease and cognitive impairment

The initiating causes for cognitive impairment in domains that show impairments later in life (visuospatial, attention, memory, the ability to follow commands, language, and executive function) occur relatively early in the lifespan. Periodontal disease may also occur early in life and continue until cognitive impairments become tangible. Preventive periodontal treatment thus needs to encompass the entire lifetime to reduce pathogenic organisms and prevent their inflammatory byproducts from entering the bloodstream. These preventive periodontal interventions early in life are likely to have more profound, long-term beneficial effects than preventive measures taken once the signs and symptoms of cognitive decline have become tangible. Intrinsically, the strategy for preventing periodontal disease is important per se; however, multilateral evaluations—including cognitive assessments—will increase the benefits for the early detection and/or prevention of periodontal disease.

Limitations and future directions

The present review has some limitations. For example, the reviewed studies were heterogeneous, potential sources of bias were not clearly noted, and there were relatively few related studies. In addition, we searched relevant articles in just one electronic database (PubMed) because this study was designed as a narrative review rather than a systematic review or meta-analysis (which require the use of multiple databases). Searching multiple databases may increase the quality of this review; however, we found sufficient articles in the present review to draw a conclusion. Moreover, we did not systematically count the number of relevant articles. Finally, to make our proposed standard assessment protocol for cognitive function in patients with periodontal disease [37] more clinically relevant, the generalisation of these findings to other cohorts is needed, and a longitudinal assessment is required.

Precision periodontal care from omics discoveries has recently been proposed [77]. More research is therefore needed to improve the quality of evidence regarding the relationship between periodontal disease and cognitive impairment. The present review also highlights the large number of different tests that have been used to investigate the association between periodontal disease and cognitive impairment. Further research is required to construct a standardised method for assessing cognitive impairment in individuals with periodontal disease.

Gaps also remain in our clinical understanding of the methods and benefits of improving oral health in individuals with cognitive impairment. Prevention and management, improving health and care service provision, and improving daily life may also contribute to oral health. In addition, the effects of periodontal *Bacillus* [78] and microbial biomarkers [79] have recently become a research focus, and the optimal countermeasure for periodontal *Bacillus* should be explored in the future.

Conclusion

The bidirectional nature of the relationship between periodontal health and cognitive function is important in older adults presenting with cognitive impairment. Improvements in periodontal health in such individuals may help to improve their cognitive impairment. The appropriate assessment of cognitive function will contribute to preserving and improving oral health in older people with periodontal disease.

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Author contributions

NS: conception, original draft preparation, project administration, funding acquisition. KM: critical revision and funding acquisition. AT: critical revision and supervision. TS: funding acquisition and supervision. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable. Clinical trial number: not applicable.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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