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SYSTEMATIC REVIEW

The association between the number of teeth and frailty among older adults: a systematic review and meta-analysis

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Abstract

Background Tooth loss is common among the elderly and often correlates with aging. Existing studies on the link between tooth loss and frailty in older adults yield inconsistent results. This systematic review and meta-analysis aims to clarify the relationship.

Methods A comprehensive search of PubMed, Web of Science, Embase, and Cochrane Library was conducted to find observational studies on tooth count and frailty in older adults. Study quality was assessed using the Newcastle-Ottawa scale. Heterogeneity was evaluated using Cochran's Q and I^2 statistics, and subgroup analyses identified factors influencing outcomes. Publication bias and sensitivity analysis confirmed result stability.

Results From 1,903 articles, 22 comprising 25 studies with 36,406 participants were included. The meta-analysis showed a pooled odds ratio (OR) of 0.98 (95% CI: 0.97−0.99) for tooth count and frailty. Individuals with 20 or fewer teeth had a higher risk of frailty (pooled OR = 1.99, 95% CI: 1.57−2.53). The highest frailty risk was observed in Japan (pooled OR = 3.02), followed by China (2.27), the UK and USA (1.90), and other regions (1.25). Subgroup analyses revealed no significant differences by country, study design, setting, adjustment model, or frailty assessment tool ($P > 0.05$).

Conclusions There is a significant association between tooth count and frailty, particularly in those with 20 or fewer teeth. Policymakers should prioritize oral health within aging populations by promoting early preventive care and education to mitigate frailty risk. Robust, large-scale studies are needed to guide evidence-based interventions and public health policy.

Keywords Teeth · Frailty · Older adults · Systematic review · Meta-analysis

Introduction

Frailty is a prevalent geriatric syndrome characterized by a diminished physiological reserve, rendering older adults more susceptible to adverse health outcomes such as falls, hospitalizations, and disability [1]. More alarmingly, frailty can significantly elevate the risk of mortality in this population [2]. Various clinical variables have been identified as risk factors for frailty, including advanced age, malnutrition, social isolation, sedentary behavior, low vitamin D levels, and poor oral health [3]. Among these factors, oral health is increasingly garnering attention within the geriatric field.

Oral health is a crucial determinant of overall health, wellbeing, and quality of life for older individuals [4]. However, as people age, they often encounter oral health issues such as xerostomia (dry mouth), periodontal disease, and dental caries, which can adversely affect their nutritional status and potentially lead to the development of frailty.

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Several studies have documented the association between oral health status and frailty, highlighting that poor oral health, tooth loss, xerostomia, and masticatory dysfunction are significant risk factors for frailty [5–9]. A recent meta-analysis by Kojima et al. demonstrated a significant association between self-reported masticatory dysfunction and frailty (pooled OR = 1.83, 95% CI: 1.55–2.18) [7], underscoring the critical role of masticatory function in the onset of frailty. Notably, the number of natural teeth is a primary determinant of masticatory function [10]. However, Kojima's meta-analysis included only four studies, relied on self-reported measures of masticatory dysfunction, and did not specifically address the relationship between tooth loss and frailty.

To date, numerous studies have investigated the relationship between the number of teeth and frailty, yielding mixed results [5, 6, 9, 11–29]. Some studies have found no significant association [9, 11, 24, 25, 27], while others have reported a significant association between tooth loss and frailty [5, 12, 16, 29]. Therefore, elucidating the relationship between tooth count and frailty in older adults is of paramount importance. This study aims to examine the potential association between dental health and frailty in the elderly population, with a specific focus on determining whether a reduced number of teeth is associated with an elevated risk of frailty within this demographic.

Methods

Search strategy and protocol

We systematically searched PubMed, Web of Science, Embase, and Cochrane Library from their inception to June 2024, utilizing both MeSH terms and keywords (oral health OR teeth OR tooth; frail*; Older people OR older adults OR elderly OR the aged). The detailed search strategy is provided in the supplementary file1. Our review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Supplementary Table 1). The study protocol has been registered with PROSPERO (CRD42023431843).

Inclusion and exclusion criteria

Studies were included if they met the following criteria: (1) observational study design (e.g., cross-sectional, cohort, case-control); (2) reported data on the relationship between tooth count and frailty; and (3) involved older adults aged 60 years or above. Based on previous research, tooth loss was defined as having 20 or fewer teeth [30].

Selection process

Two authors (ZXM and CSM) independently screened the studies. Duplicate records were removed using EndNote X9 software. Titles, abstracts, and full texts were reviewed to exclude irrelevant studies. Any disagreements were resolved by consensus with a third author (TLT). Ultimately, 22 articles consisting of 25 studies were included in the analysis. The selection flow chart is depicted in Supplementary Fig. 1.

Data extraction

Authors (ZXM, CSM) extracted the following data from the included studies: age, percentage of female participants, year of publication, country, prevalence of frailty, tooth count, sample size, and combined effect data (e.g., OR, RR, HR, 95% CI). Disagreements between authors were resolved through discussion with a third author (TLT).

Quality assessment

The quality of the included studies was evaluated by four authors (CSM, TLT) using the Newcastle-Ottawa Scale (NOS). This scale assesses cohort study quality based on three criteria: selection of the cohort, comparability of the cohorts, and outcome assessment [20]. Scores range from 0 to 9, with 7–9 indicating high quality, 4–6 indicating moderate quality, and below 4 indicating low quality.

Statistical analysis

Data analyses were performed using R 3.4 and Stata software. Heterogeneity among studies was assessed using Cochran's Q and I^2 statistics. An I^2 value below 50% indicated moderate to low heterogeneity, and a fixed-effect model was applied. An I^2 value of 50% or higher indicated substantial heterogeneity, necessitating a random-effects model. We extracted OR, RR, HR, and their 95% confidence intervals (CIs) from the fully adjusted models of the original studies. RR and HR were converted to OR using the formula: OR = RR / (1 - P0 + (P0 * RR)), where P0 is the baseline risk (risk of the event in the control group). HR was treated as equivalent to RR, following previous meta-analyses [31]. If the original studies did not present an effect size for the association between tooth loss and frailty, we calculated the crude OR. Meta-analysis was employed to combine the effect sizes of dental variables (number of teeth or tooth loss) and frailty. Subgroup analyses were conducted based on country, study design, settings, type of adjusted model, and frailty assessment tools to identify whether these characteristics influenced the overall outcomes. Publication

bias was assessed using funnel plots and Begg's test. Sensitivity analysis was also conducted to verify the robustness of the results.

Results

Study selection

The study selection process for our meta-analysis is summarized in Supplementary Fig. 1. From an initial total of 1,903 studies identified across the databases, 322 duplicate records were removed using EndNote X9 software, leaving 1,581 studies for screening. Following the review of titles and abstracts, 65 articles underwent full-text review. Of these, 43 articles were excluded due to lack of relevant outcomes, being review articles or abstracts, and other reasons; detailed exclusion information is provided in Supplementary Table 2. Ultimately, 22 articles encompassing 25 studies met the inclusion criteria and were incorporated into the final analysis [5, 6, 9, 11–29].

Study characteristics

Table 1 provides a summary of the 25 included studies, which were published between 2012 and 2024. These studies involved a total of 34,670 participants from eight countries, with sample sizes ranging from 160 to 5,698 individuals. The mean age of participants varied from 60 to 87.6 years. Seventeen studies were cross-sectional [6, 9, 11–29], while eight were longitudinal [5, 12, 17, 19, 22, 24, 25]. The majority of studies were conducted in Asia, with seven in Japan [6, 15, 17, 23, 24, 26] six in China [5, 14, 21, 22, 28, 29], one spanning the UK and Japan [9], four in both the UK and USA [19, 20], and seven in other countries [11–13, 16, 18, 25, 27]. Twenty-one studies were conducted solely in community settings [5, 6, 9, 11–29], while one was conducted in both community and hospital settings15. Seven different assessments were used to define frailty in the included studies, including the Frailty Index [5, 14–16, 18, 22, 28], Physical Frailty Phenotype (PFP) [6, 9, 11–13, 15, 17, 19, 20, 25, 27, 29], and others [21, 23, 24, 26]. Seventeen studies provided the definition of tooth loss [5, 6, 9, 13–15, 17, 19, 20, 22, 23, 25, 27, 29]. Supplemental Table e3 provided the different adjusted confounding factors in each studies.

Meta-analysis of the association between number of teeth and frailty in older populations

Our meta-analysis revealed a negative association between the number of teeth and frailty in older populations, with an odds ratio (OR) of 0.98 (95% CI: 0.97 − 0.99, I^2 = 67%, $p < 0.01$) (Fig. 1). Specifically, individuals with fewer than 20 teeth exhibited an OR of 1.99 (95% CI: 1.57 − 2.53, I^2 = 89%, $p < 0.01$) (Fig. 2).

Subgroup analyses of tooth loss and frailty

Subgroup analyses by country

Our findings indicate a geographical variation in the risk of frailty associated with having with 20 or fewer teeth Japan showed the highest predisposition to frailty (pooled OR = 3.02, 95% CI: 1.64–5.55, I^2=76%) compared to China (pooled OR = 2.27, 95% CI: 1.38–3.76, I^2=97%), the United Kingdom and United States (pooled OR = 1.90, 95% CI: 1.43–2.52, I^2=19%), and other countries (pooled OR = 1.25, 95% CI: 1.15–1.36, I^2=33%) (Fig. 3).

Subgroup analyses by different frailty definitions

There were observed variations in frailty risk associated with suboptimal dentition across different frailty definitions. Studies using the Frailty Index reported a pooled OR of 1.84 (95% CI: 1.09–3.11, I^2=96%), while those using the Frailty Phenotype yielded an OR of 2.03 (95% CI: 1.52–2.71, I^2=72%). However, the differences across frailty definitions were not statistically significant ($P = 0.72$) (Supplementary Fig. 2).

Subgroup analyses by different settings

A statistically significant correlation was identified across various settings. In community environments, the pooled OR for frailty risk in individuals with 20 or fewer teeth was 1.96, compared to 2.77 in combined community and hospital settings (1.96, 95% CI: 1.53–2.51, I^2=89%; versus 2.77, 95% CI: 2.22–9.09, I^2=4.7%). However, the difference between these settings did not achieve statistical significance ($P = 0.36$) (Supplementary Fig. 3).

Subgroup analyses by study design

Using a random-effects model, the pooled OR in cross-sectional studies indicated a statistically significant increase in frailty risk associated with having with 20 or fewer teeth (pooled OR = 2.23, 95% CI: 1.57–3.16, I^2=91%). This aligns with findings from cohort studies (OR = 1.64, 95% CI: 1.26–2.13, I^2=78%). The differences in outcomes across study designs did not reach statistical significance ($P = 0.17$) (Supplementary Fig. 4).

Table 1 The baseline characteristic of including studies($n=25$)

Reference ID	Author/years	Country	Frailty	Male (%)	*n*	Prevalence	Design	Average age	Setting	Definition for tooth loss	NOS score
25	Ramsay 2018	UK	PFP	—	1622	19%	longitudinal	79.2(4.8)	community	<=20 natural teeth	4
17	Iwasaki 2018	Japan	PFP	181 (56.2%)	322	14.90%	longitudinal	≥75	community	<20 natural teeth	7
14	Gu 2019	China	Frailty index	1751 (48.2%)	3635	27.68%	cross-sectional	84.3(9.9)	community	<=20 natural teeth	4
15	Hakeem 2020b	Japan	Frailty index	257 (72.2%)	356	43.50%	cross-sectional	67.2(6.5)	community and hospital	<=20 natural teeth	4
15	Hakeem 2020a	Japan	PFP	257 (72.2%)	356	43.50%	cross-sectional	67.2(6.5)	community and hospital	<=20 natural teeth	4
29	Zhang 2020	China	PFP	1687(41.78%)	4037	6.70%	cross-sectional	67.8(5.9)	community	<=20 natural teeth	4
27	Valdez 2020	Australia	PFP	—	601	19.30%	cross-sectional	≥70	community and hospital	<=20 natural teeth	5
9	Albani 2021	UK and Japan	PFP	559(40.07%)	1395	24.80%	cross-sectional	85(0.6)and 87(2.2)	community	<=20 natural teeth	3
11	Castrejon 2012	Mexico	PFP	327(46.78%)	699	15.02%	cross-sectional	77.9(6.3)	community		4
12	Castrejon 2017	Mexico	PFP	115 (48.5%)	237	14.80%	longitudinal	76.4(5.2)	community		6
26	Stake 2019	Japan	FRAIL scale	173(37.04%)	467	10.06%	cross-sectional	71.6(7.1)	community		5
21	Kuo 2021	China	Osteoporotic Fracture index	288(31.89%)	903	14.60%	cross-sectional	77.4 (7.1)	community		5
24	Ohara 2022	Japan	revised J-CHS	245(40.2%)	609	17.90%	longitudinal	73(69–77)	community		7
16	Hakeem 2021	USA	Frailty index	1132(47.8%)	2368	38.7%	cross-sectional	>=60	community		4
23	Miyano 2022	Japan	SOF	44(27.5%)	160	26.9%	cross-sectional	82 (79–86)	community	<20 natural teeth	3
18	Kang 2022	Korea	Frailty index	1311(43.44%)	3018	25.90%	cross-sectional	>=65	community and hospital		4
28	Zhang 2022	China	Frailty index	154 (42.2%)	365	71.20%	cross-sectional	87.6 (9.5)	community		3
19	Kimble 2023(BRHS)	UK and USA	PFP	/	649	/	longitudinal	76.3(3.2)	community	<=20 natural teeth	4
19	Kimble 2023(HABC)	UK and USA	PFP	/	1389	/	longitudinal	74.2(4.5)	community	<=20 natural teeth	4
13	Andrade 2013	Brazil	PFP	40.3%	1374	8.5%	cross-sectional	/	community	<=20 natural teeth	5
22	Lin 2024	China	Frailty index	42.2%	5698	/	longitudinal	83.0(11.1)	community	<20 natural teeth	7

Table 1 (continued)

Reference ID	Author/years	Country	Frailty	Male (%)	*n*	Prevalence	Design	Average age	Setting	Definition for tooth loss	NOS score
5	Zhang 2023	China	Frailty index	49.52%	1155	22.9%	longitudinal	74.93 ± 10.7	community	<=20 natural teeth	6
6	Hayashi 2024	Japan	PFP	/	267	37.4%	cross-sectional	/	community	<20 natural teeth	5
20	Kimble 2023 BRHS	UK AND USA	PFP	/	1013	17.9%	cross-sectional	85 ± 5	community	<=20 natural teeth	4
20	Kimble 2023 HABC	UK AND USA	PFP	49.7%	1975	4.9%	cross-sectional	75 ± 3	community	<=20 natural teeth	4

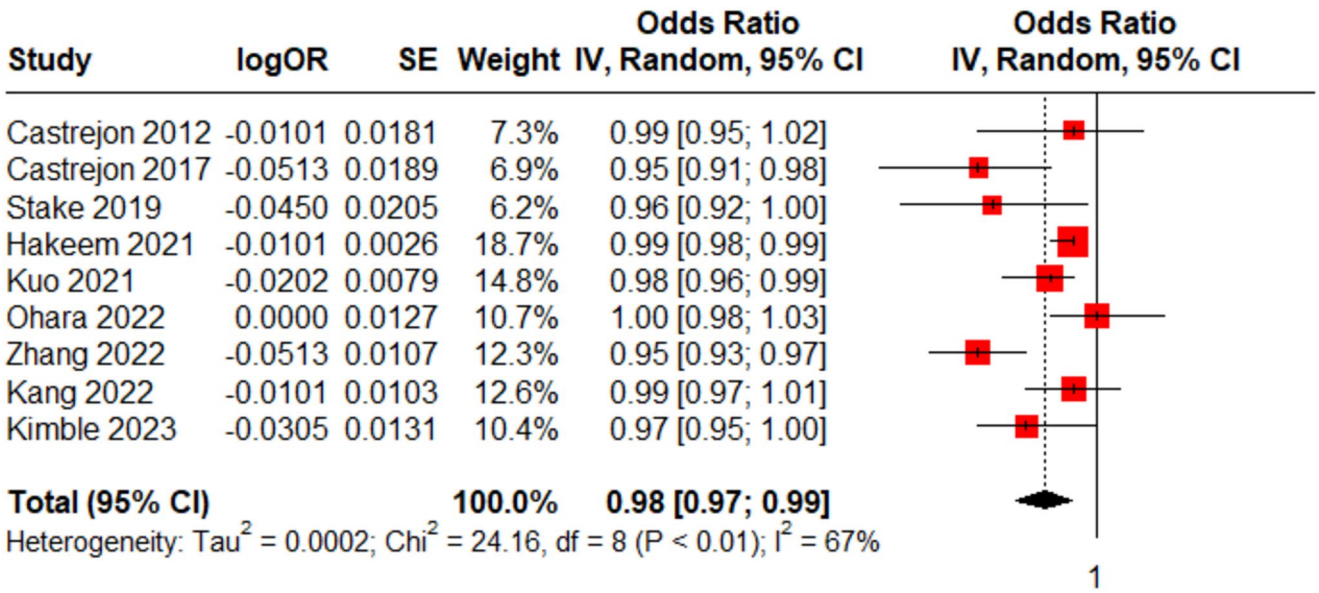

Fig. 1 Meta-analysis for the association between the number of teeth and frailty among older adults

Subgroup analyses by the type of adjusted model

The meta-analysis was stratified into two groups based on whether confounding factors were adjusted. Individuals with 20 or fewer natural teeth had a higher risk of frailty than their counterparts (pooled OR = 1.68, 95% CI: 1.31–2.16, I^2=79%) in the adjusted model. In the unadjusted model, the pooled OR was 2.43 (95% CI: 1.60–3.67, I^2=80%). Subgroup analyses revealed no statistically significant differences between these groups (P = 0.14) (Supplementary Fig. 5).

Quality assessment of the studies

Table 1 summarizes the quality assessment of the included studies. According to the Newcastle-Ottawa Scale, the risk of bias ranged from 3 to 7 on a 0 to 9 scale, with three studies classified as high quality and 15 as moderate quality.

Publication bias

A funnel plot was constructed to investigate publication bias, revealing symmetry. Begg's test did not indicate significant publication bias (P = 0.3870) (Supplementary Fig. 6).

Sensitivity assessment

Omitting any single study from the analysis did not result in a statistically significant change in the pooled OR, which ranged from 1.90 (95% CI: 1.50–2.41) to 2.08 (95% CI: 1.63–2.65). This consistency suggests stability in the results (Supplementary Fig. 7).

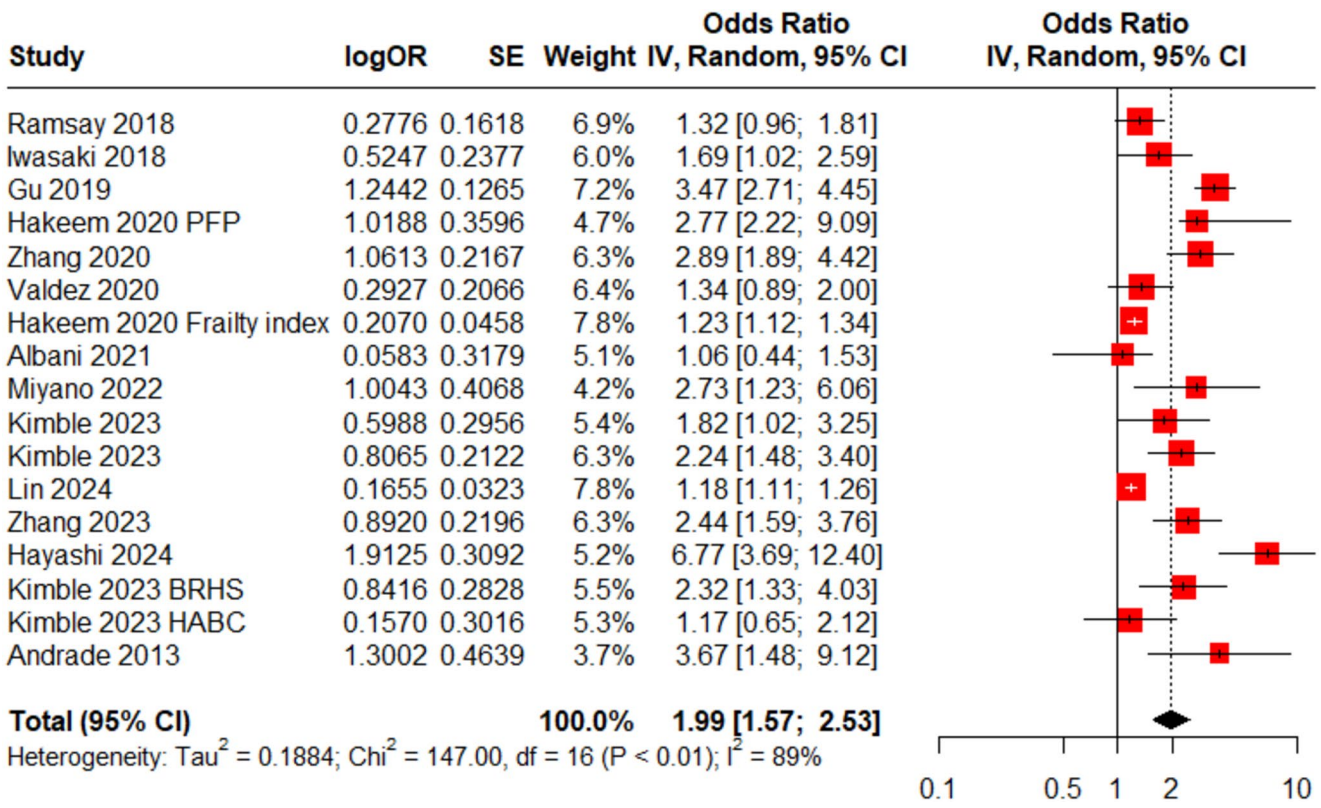

Fig. 2 Meta-analysis for the association between lower number of teeth(less than 20 teeth) and frailty among older adults

Discussion

The primary objective of this meta-analysis was to evaluate the relationship between tooth count and frailty among older adults by synthesizing findings from existing studies. Our analysis reveals a significant negative correlation between the number of teeth and frailty. Specifically, individuals with fewer than 20 teeth exhibited a higher risk of frailty compared to those with more than 20 teeth. This is the first meta-analysis to offer a comprehensive examination of this relationship, underscoring the critical role of tooth retention in preventing frailty in older adults.

Oral health is a significant public health concern, particularly for the elderly. Prior to this study, only one systematic review, by Kojima et al., addressed the association between masticatory dysfunction and frailty [7]. Their review found that older individuals with masticatory dysfunction had approximately a 1.83-fold increased risk of frailty compared to those with normal masticatory function, emphasizing the importance of masticatory ability. Our findings corroborate this, as tooth count directly influences masticatory function. Thus, a reduced number of teeth can elevate the risk of frailty among older adults, aligning with Kojima's conclusions [7].

The mechanisms linking tooth loss to frailty are multifaceted and include nutritional, inflammatory, neurological, and psychological pathways [32]. Tooth loss impairs masticatory function, potentially leading to inadequate intake of essential nutrients such as proteins and vitamins, thereby increasing the risk of frailty [33, 34]. Additionally, periodontitis, a common cause of tooth loss, elevates systemic inflammatory markers like IL-6 and CRP, which are associated with muscle mass reduction and decreased physical activity—both of which contribute to frailty [35]. Neurologically, dental injury can affect proprioceptive nerves, impairing balance and increasing frailty risk due to reduced mobility [32]. Psychologically, tooth loss may impact self-esteem and social interactions, potentially leading to isolation and depression [36], both recognized risk factors for frailty. While some studies have proposed theories or models to explain these mechanisms [11, 37], further research, including animal studies, is needed to fully elucidate this complex clinical phenomenon. Given these insights, it is imperative for healthcare providers to prioritize oral health in older adults. Regular dental check-ups, timely treatment of periodontal disease, and interventions to preserve natural teeth or provide functional prosthetics are crucial.

The implications of our findings for medical practice are significant. While the association between age and tooth loss remains ambiguous, frailty is known to be age-related. Since the aging process cannot be halted, addressing tooth loss becomes crucial. However, many patients with dental

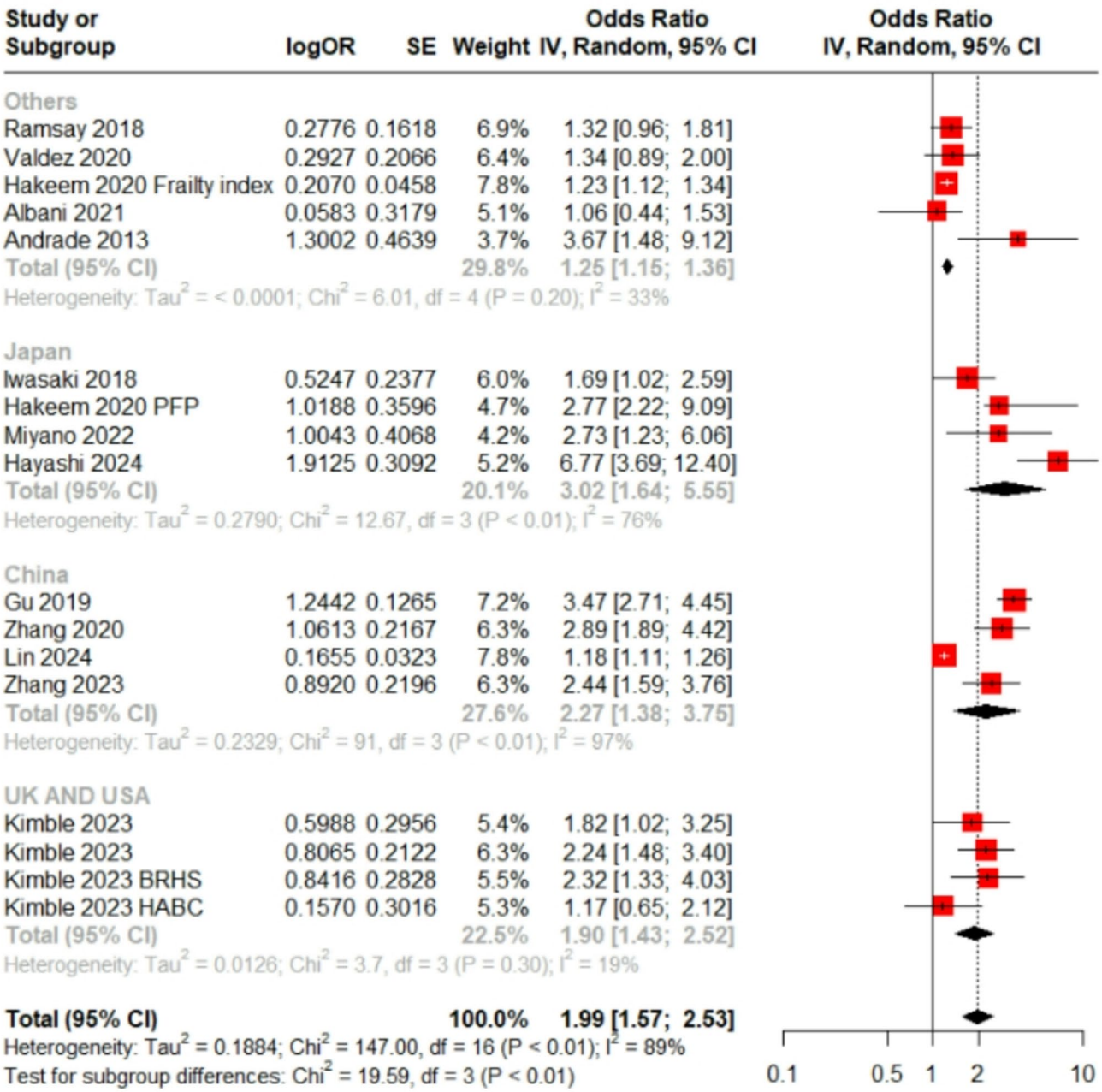

Fig. 3 subgroup analysis for the association between tooth loss and frailty among older adults by country

and periodontal problems do not seek regular dental care, with two-thirds of edentulous patients not visiting the dentist regularly or at all [38]. Current frailty management focuses primarily on nutrition, exercise, and medication [39]. Our study highlights that preserving natural teeth is essential for preventing the occurrence and progression of frailty. Additionally, ensuring adequate nutrition through dietary counseling and addressing psychological impacts through social support and mental health services are vital. By integrating dental care into routine geriatric assessments and preventive health strategies, clinicians can play a crucial role in mitigating the onset and progression of frailty.

Our meta-analysis presents several strengths. It is the first to comprehensively summarize the evidence on the relationship between tooth count and frailty. We included all available observational studies with large sample sizes and conducted multiple methodological analyses, including subgroup analyses, sensitivity analyses, and publication bias tests, suggesting that the observed associations are robust. We also examined the relationship between tooth count and frailty from both continuous and categorical perspectives.

However, there are limitations to this meta-analysis. First, the overall number of studies and follow-up periods were limited, restricting our ability to explore the long-term effects of tooth loss on frailty comprehensively. Second, the majority of data originated from Asian countries, which may not fully represent the global situation due to uneven data distribution across regions. Third, the frailty assessments included in the literature predominantly refer to physical frailty, with limited information on the impact of tooth loss on other forms of frailty, such as cognitive and social frailty. Fourth, the variability in frailty assessment methods across studies introduces potential bias and inconsistency, affecting the reliability of our findings. The cut-off points for classifying frailty also varied, which may influence the analysis and outcomes. Future research should aim to standardize frailty assessment methods and cut-off points to ensure more consistent and comparable results. Meta-analyses using uniform criteria should be conducted once sufficient original studies with standardized measures are available.

Conclusion

Our meta-analysis identifies a notable association between tooth loss and frailty, demonstrating that older adults with 20 or fewer teeth face a substantially higher risk of frailty. This underscores the critical role of oral health in the prevention of frailty in the elderly. Nevertheless, establishing causation remains a key objective, necessitating further research. Future investigations should focus on elucidating the causal mechanisms underlying this association and assessing the effectiveness of targeted dental interventions in reducing frailty risk.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40520-025-03053-0.

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Author contributions XMZ, SMC and LTT contributed to drafting, revising and finalizing the manuscript. XHX and XJW initiated the study concept and design. XMZ performed the research strategy, data extraction and analyzed data. SMC and LTT were responsible for quality bias assessment.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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