

Introduction

The rapid aging of the global population poses significant challenges for oral health, particularly among socioeconomically disadvantaged older adults in rural areas. By 2050, the global population aged 60 and older is projected to surpass 2.1 billion, more than doubling from 1.0 billion recorded in 2020 [1]. Aging is closely linked to declining oral health, which affects over 57% of older adults worldwide [2]. This issue is especially severe in developing countries, where the prevalence of oral disorders continues to rise. Within these nations, socioeconomically disadvantaged groups, particularly those in rural areas, experience disproportionate barriers due to unequal access to oral health services and limited health literacy [3]. In China, where the population aged 60 and older is expected to reach 487 million by 2050, oral health concerns are especially pressing [4]. Between 1990 and 2019, China has recorded the largest global increase in the prevalence of oral disorders and related disability-adjusted life years [5]. Over 210 million individuals aged 55 and older suffer from oral disorders, with a prevalence exceeding 54.3% [6].

Oral health, dietary quality, and nutritional status will be assessed using validated tools, including the 5-item Oral Health Impact Profile (OHIP-5), the number of missing teeth, the Simplified Healthy Eating Index (SHEI) and dietary patterns, and the Short-Form Mini Nutritional Assessment (MNA-SF). The analysis will explore the associations between oral health and dietary quality using both a priori and a posteriori dietary assessment approaches, with robustness checks performed through index transformation methods. Similarly, the association between oral health and nutritional status will be exam

well as on the biological and preventive preservation of natural teeth [3131]

method minimizes the weighted sum of absolute residuals, making it more resilient to outliers and deviations from normality [43]. Robustness tests were additionally conducted using categorical independent variables in each analysis. First, the inter-group difference test—used by bootstrap methods (repeated 500 times)—examined whether the average marginal effects differed significantly by care arrangements and family poverty status. A significance level of 0.05 was set for all statistical tests.

Results

Descriptive statistics

Table 1 described the descriptive characteristics of the 310 rural older adults in the study. The majority were male (83.23%), with a mean age of 71.48 years ($SD=6.96$). Nearly half (41.94%) of the welfare recipients were

bachelors, and an equal proportion (41.94%) were illiterate. A total of 34.19% of participants utilized public nursing home services, and 61.29% were living in extreme poverty. Despite 92.90% having pension coverage, the monthly pension amount was only \$17.03 per person, markedly lower than the rural per capita consumption expenditure of \$214.94 per month [26], highlighting significant financial constraints. In terms of health, 68.71% reported having at least one chronic disease, and 19.68% had a disability. Regarding health behaviors, 46.13% were current smokers, and 34.52% were current drinkers.

The average OHIP-5 score was 5.78 out of 20 ($SD=5.59$), indicating a moderate level of oral problems. Among the five dimensions, the most common issues were difficulty chewing (Mean=1.40, $SD=1.47$) and uncomfortable to eat (Mean

The association between oral health and dietary patterns
In addition to examining dietary quality, an exploratory analysis was conducted to assess the relationship between oral health and dietary patterns. The Kaiser-Meyer-Olkin measure for sampling adequacy of 13

Dietary patterns	Quantile			
	Q1	Q2	Q3	Q4
Panel A. OHIP-5 score				
Eggs-bean products pattern	Ref.	0.001 [-0.029,0.031]	0.009 [-0.013,0.030]	-0.003 [-0.022,0.017]
Fresh fruit-dairy products-nut products pattern	Ref.	0.016 [-0.011,0.043]	0.014 [-0.011,0.039]	-0.003 [-0.032,0.026]
Fresh vegetable-meat pattern	Ref.	-0.035** [-0.059,-0.010]	-0.033*** [-0.049,-0.016]	-0.041*** [-0.063,-0.018]
Garlic-mushroom or algae pattern	Ref.	-0.002 [-0.027,0.024]	0.016 [-0.011,0.042]	0.019 [-0.013,0.050]
Panel B. Difficulty chewing (frequent)				
Eggs-bean products pattern	Ref.	-0.012 [-0.152,0.128]	0.020 [-0.063,0.103]	-0.043 [-0.125,0.039]
Fresh fruit-dairy products-nut products pattern	Ref.	0.030 [-0.059,0.118]	0.002 [-0.097,0.102]	-0.044 [-0.164,0.076]
Fresh vegetable-meat pattern	Ref.	-0.106** [-0.181,-0.031]	-0.103*** [-0.162,-0.043]	-0.124** [-0.197,-0.050]
Garlic-mushroom or algae pattern	Ref.	-0.017 [-0.114,0.080]	0.036 [-0.085,0.158]	0.033 [-0.110,0.175]
Panel C. Painful aching (frequent)				
Eggs-bean products pattern	Ref.	-0.022 [-0.147,0.103]	0.020 [-0.074,0.114]	0.009 [-0.076,0.094]
Fresh fruit-dairy products-nut products pattern	Ref.	0.071 [-0.054,0.196]	0.083 [-0.014,0.181]	0.094 [-0.021,0.209]
Fresh vegetable-meat pattern	Ref.	-0.077 [-0.175,0.021]	-0.133*** [-0.197,-0.069]	-0.162** [-0.261,-0.063]
Garlic-mushroom or algae pattern	Ref.	-0.005 [-0.126,0.115]	0.088 [-0.010,0.187]	0.019 [-0.098,0.136]
Panel D. Uncomfortable to eat (frequent)				
Eggs-bean products pattern	Ref.	0.035 [-0.103,0.174]	0.024 [-0.060,0.109]	-0.008 [-0.096,0.080]
Fresh fruit-dairy products-nut products pattern	Ref.	0.069 [-0.021,0.159]	0.059 [-0.028,0.146]	0.007 [-0.092,0.106]
Fresh vegetable-meat pattern	Ref.			

Dietary patterns	Quantile
	Q1

Heterogeneity analysis

Table 5 presented subgroup analyses examining the associations between oral health, adherence to a healthy diet, and nutritional status. In Panel A, no significant interactions were observed between oral problems and either SHEI score or MNA-SF score, suggesting consistent results across public nursing home and home-based care settings (inter-group difference test, $p > 0.05$). Panel B also showed no significant differences in oral problems and SHEI score or MNA-SF score by family poverty status (inter-group difference test, $p > 0.05$).

Discussion

This study investigates the relationship between oral health, dietary quality and nutritional status among socioeconomically disadvantaged older adults in rural western China—a population representing some of the nation's most vulnerable individuals. To our knowledge, this represents the first comprehensive analysis of how poor oral health is linked to dietary quality and nutritional challenges in this underserved, resource-limited setting. The findings reveal a high prevalence of both poor oral health and inadequate nutrition in this population. Specifically, impaired oral health, characterized by oral problems and the number of missing teeth, is associated with unhealthy dietary patterns, including reduced intake of essential food groups such as fresh vegetable and meat. Moreover, poor oral health directly correlates

with compromised nutritional status, highlighting its critical role in shaping nutritional well-being in this vulnerable population.

Firstly, this study underscores significant oral health disparities and poor nutritional status among socioeconomically disadvantaged older adults in rural China.

The surveyed welfare recipients, heavily reliant on public support, exhibited low educational attainment and lack of family support, with 41.94% illiterate and 41.94% unmarried, nearly half of the participants experienced oral problems and had malnutrition risk or malnutrition. The findings align with previous research, revealing pronounced rural-urban disparities in oral health, worsened by low socioeconomic status [21]. With an average OHIP-5 score of 5.78 and 14.08 missing teeth—both higher than those of the general rural population [44, 45]—this underscores the greater oral health burden faced by this group. Similar trends are observed in other developing countries, such as Rwanda and Afghanistan, where low education, limited income, and disabilities restrict access to dental care [3]. For state-designated vulnerable individuals, including those living in extreme poverty or receiving subsistence allowances, the lack of stable income and residence in under-developed areas further compound their ability to manage unexpected costs, such as healthcare expenses and high transportation costs to access distant dental services [46]. Despite high rates of missing teeth and oral problems, rural older

socioeconomically disadvantaged adults report low self-

Table 5 Heterogeneity analysis

Variables	SHEI score			MNA-SF score		
	Nursing home care	Home-based care	P-value	Nursing home care	Home-based care	P-value
Panel A						
OHIP-5 score	-0.034 (0.047)	-0.066 (0.042)	0.662	-0.020 (0.030)	-0.057* (0.026)	0.338
Total number of missing teeth	-0.002 (0.024)	-0.017 (0.027)	0.673	-0.027 (0.015)	-0.052** (0.016)	0.234
Panel B						
OHIP-5 score (0.016)	-0.054 (0.039)	-0.046	0.896	-0.040	-0.050	0.826

malnutrition or being malnourished than those with adequate dentition [60].

WHO highlights significant disparities in oral health, dietary quality and nutritional status, particularly pronounced among socioeconomically disadvantaged populations, where poor oral health is closely linked to nutritional deficiencies and multimorbidity [61, 62]. For example, studies in marginalized communities, such as those in Karachi, show a strong association between oral health and increased comorbidity linked to nutritional deficiencies [9]. Our findings emphasize the complex interplay between oral health, dietary quality, and nutritional status among socioeconomically disadvantaged older adults in rural China, an area with relatively limited research. Specifically, tooth loss, difficulty chewing, and uncomfortable to eat are key contributors to dietary quality and nutritional status, while uncomfortable to eat is less recognized in general populations [63]. These individuals are more likely to suffer from untreated dental issues, which impair their ability to consume nutrient-rich foods like fruits, vegetables, and protein-rich items. Socioeconomic barriers, including low income and social isolation, limited health literacy, and financial constraints, exacerbate these issues by restricting access to dental care and nutritious food [11, 64]. Research shows that individuals facing severe socioeconomic challenges are 7 to 9 times more likely to avoid necessary dental treatment, further worsening oral health [65]. This convergence of poor oral health, inadequate nutrition, and socioeconomic challenges severely impacts the overall health and quality of life of these at-risk populations.

Indeed, heterogeneity analysis finds no significant differences in the impact of oral health on adherence to a healthy diet and nutritional status across care arrangements or family poverty status. While public nursing homes may offer a broader variety of foods, severe oral problems drive both home-based and public nursing home residents to prioritize softer, easier-to-chew foods

[66], nullifying any notable difference in the oral health-nutrition relationship between these groups. Similarly, poverty status does not significantly modify this relationship in this context. Regardless of whether they reside in rural communities or public nursing homes, socioeconomically disadvantaged older adults exhibit comparable levels of poor oral health and nutritional status [59]. Shared poverty-related barriers, such as limited access to dental care and nutrient-rich foods, constrain nutritional improvements across these groups, obscuring any distinct effects of poverty alone.

This study has several limitations. First, the cross-sectional design restricts causal inference; future research employing longitudinal data or experimental designs could provide stronger causal evidence. Second, the focus on older adults in western rural China may limit the generalizability of findings; cross-regional comparisons could enhance external validity. Cross-regional comparisons, including studies in other regions of China or internationally, could enhance external validity and provide a broader understanding of the associations between oral health, dietary quality, and nutritional status. Third, reliance on self-reported measures of oral health and nutritional status, particularly regarding missing teeth and denture presence, may introduce biases. While self-reports are common in large-scale surveys, they can be affected by recall bias and may not accurately reflect true health status. This study only assessed denture presence, without examining type or usage habits. Future studies could incorporate objective assessments, such as oral exams or clinical evaluations to improve measurement accuracy. Lastly, the relatively small sample size limits the statistical power of our analyses and may impact the generalizability of our results. Although our sample is representative of socioeconomically disadvantaged older adults in rural China, a larger sample size would allow for more robust conclusions and a deeper understanding of the nuances within this population. Future studies with

larger and more diverse samples could strengthen the findings and provide more reliable evidence on the relationship between oral health, dietary quality and nutritional status.

Despite its limitations, this study makes important contributions to the literature. It sheds light on the significant disparities in oral health, dietary quality and nutritional status among socioeconomically disadvantaged older adults in rural areas. Additionally, by adopting a multidimensional perspective, it provides a deeper understanding of how poor oral health affects both dietary quality and nutritional status, particularly in vulnerable populations.

Conclusions

In summary, this study suggests a significant association between oral health, dietary quality and nutritional status among socioeconomically disadvantaged older adults in rural western China. Poor oral health appears to be associated with reduced adherence to a healthy diet, particularly lower consumption of fresh vegetables and meat, which may negatively impact nutritional status. Given the findings, targeted interventions to improve oral health may help enhance dietary intake and nutritional status for older adults in resource-limited settings.

Abbreviations

OHIP-5	5-item Oral Health Impact Profile
SHEI	Simplified Healthy Eating Index
PCA	Principal Component Analysis
MNA-SF	



