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ORIGINAL ARTICLE

Sociomedical and oral factors affecting masticatory performance in an older population

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Abstract

Objectives To assess the sociomedical and oral factors affecting masticatory performance in a community-dwelling older population.

Materials and methods Community-dwelling persons over 60 years were investigated using medical and dental oral interviews, oral and denture examination (natural teeth, tooth mobility, number of occluding tooth pairs, and removable dentures' prevalence and quality), and evaluation of masticatory performance using a mixing ability test.

Results A total of 130 participants with a mean age of 73.9±8.5 years were recorded. Fifty-eight (44.6%) used various types of removable prostheses. Twenty were edentulous and used a pair of complete dentures. Univariate analyses revealed statistically significant associations ($p \leq 0.05$) between masticatory performance and aging, marital status, subjective chewing ability, use of removable dentures, use of various combinations of complete dentures, pain caused by maxillary denture, number of teeth, tooth mobility, posterior chewing pairs, all chewing contacts natural or prosthetic, retention of mandibular partial dentures, and dentures' occlusion. The multivariable quantile regression analysis revealed that fewer natural teeth (95% CI: −0.02–0.01, $p<0.001$), being edentulous and using a pair of complete dentures (95% CI: 0.09–0.35, $p=0.001$), and larger percentage of severely mobile teeth (95% CI: 0.07–0.82, $p=0.020$) were associated with lower masticatory performance.

Conclusions Poor masticatory performance in older adults was associated with fewer teeth, being edentulous and using a pair of complete dentures, and increased prevalence of severe tooth mobility.

Clinical relevance Retaining the natural dentition and preventing and treating periodontal disease are important measures to maintain masticatory performance in older adults.

Keywords Older adults · Oral health · Masticatory performance · Tooth loss · Dentures · Tooth mobility

Introduction

Mastication is a complex sensorimotor task conducted by the coordinated activity of the facial muscles, the elevator and suprahyoidal muscles, teeth, lips, cheeks, palate, tongue, salivary glands, and temporomandibular joints under the control of the central nervous system [1–3]. It is one of the most important functions of the stomatognathic system including the procedure of fragmenting the food into chewable portions by the incisors, transporting it into the oral cavity, fragmenting it into smaller pieces by the teeth, and moistening it with saliva in order to be safely swallowed [1–3].

Various terms and test methods have been used to analyze the masticatory function. Among them, masticatory performance investigates the individual's ability to fragment or mix a specimen of test food (natural food of artificial

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test material) after a predetermined number of masticatory cycles [4]. The term "masticatory performance" must be accompanied by a description of the method employed [4].

Masticatory performance, examined by various assessment tests, has been associated with a large variety of oral and general factors, including the number of teeth [5], the use and quality of removable dentures [5–7], periodontal disease [8, 9], the level of saliva secretion [5, 10], bite force [10], aging [11, 12], or gender [12]. Masticatory impairment has also been associated with systemic diseases such as cerebrovascular accident [13], cognitive impairment [14, 15], and rheumatoid arthritis [16]. An impairment in masticatory performance in older adults may affect dietary choices [17] and lead to malnutrition and increased risk for frailty. Therefore, the assessment of masticatory performance in older people is becoming increasingly important, particularly when protein-energy malnutrition, dysphagia, sarcopenia, and frailty are implicated [18–21].

Several objective methods have been used to evaluate masticatory performance; the most common ones include comminution tests and mixing ability tests [4]. The comminution tests measure the particle size of specific test foods, natural or artificial, after a specific number of chewing cycles [4, 5]. The mixing ability tests evaluate the form and color of a bolus, after chewing artificial food for a specific number of chewing strokes [4]. These tests include the usage of color-changing chewing gum or two-colored chewing gum or wax [4], and the outcome is evaluated visually or opto-electronically [22]. Two-colored chewing gums have been successfully used in various populations, such as denture wearers [23, 24], implant overdenture users [23], and patients recovering from a stroke [25] to assess masticatory function. Mixing ability tests are appropriate for a rapid assessment of masticatory performance and are easy to perform in geriatric wards, nursing homes, or medical and dental offices [4]. They are suitable for patients with dysphagia [25], like patients with a history of cerebrovascular accident or amyotrophic lateral sclerosis due to the lower aspiration risk, and for people with dementia [26] and impaired dentition, such as complete denture wearers [23, 24, 27, 28].

There are very few studies investigating masticatory performance using standardized mixing ability tests in older European community-dwelling adults taking into consideration the simultaneous correlations and individual effects of many social, medical, and oral factors. Therefore, this study aimed to investigate masticatory performance in an older functionally independent European population using a mixing ability test and identify the effect of various demographic, social, medical, dental, and denture-related factors.

Materials and methods

Study population

The study population consisted of older adults who visited the Municipal Open Care Community Centers for Older People in regions of different socioeconomic stratification in Metropolitan Athens, Greece, which were preselected by the researchers. The members of these centers were informed by the social workers about the scope and methodology of the study, and those who volunteered to participate signed appropriate written consent forms.

The recruitment of the participants was performed according to the following inclusion criteria: being over 60 years of age, being able to speak and understand the Greek language, and not reporting any urgent oral problem at the time of the investigation potentially affecting the masticatory function. The exclusion criteria were having cognitive or sensory problems affecting the ability to effectively communicate with the investigators. The examination was performed in private rooms, such as medical or administration offices.

The appropriate sample size was determined using the G*Power 3.1.9.2 software, which pointed at 123 participants [power of $1 - \beta$ (beta error) = 0.80, α (alpha error) =0.05]. The investigation was approved by the National and Kapodistrian University of Athens, School of Dentistry Ethics and Research Committee (418/2019).

The study included oral interviews using structured questionnaires, oral examinations, and recordings of masticatory performance. One trained dentist conducted all the recordings.

Interview

The interview recorded sociodemographic and medical information (based on ICD-10 classification), drug intake (ATC group classification), smoking history, and body mass index (BMI). A detailed dental history was obtained including dental visitation and oral hygiene habits, subjective assessment of oral health (5-point Likert scale), and recording of the Xerostomia Index [29]. Self-assessment of masticatory function was performed using four questions: "can you chew well all your food?" (5-point Likert scale), "can you chew steak?" (yes/no), "can you chew almonds?" (yes/no), "can you chew oranges?" (yes/no). Specific questions were asked regarding use of dentures and related problems, such as denture dislocation during speech, denture dislocation during mastication, and pain caused by denture use (always, sometimes, never).

Oral examination

The oral examination included the recording of natural teeth and the number of posterior and anterior occluding tooth contacts with both natural and prosthetic teeth. Tooth mobility was recorded using the handles of two dental tools according to Miller's classification (grades 1–3) [30]. The number of teeth with mobility #2 or #3 was measured and included in the analysis as "teeth with increased mobility," expressed as a percentage of the total number of remaining teeth. The quality of removable dentures (partial or complete) in terms of retention, stability, vertical dimension of occlusion, and occlusion was recorded. The Modified Kapur Scale score was calculated for the retention and stability of complete dentures [31]. The dentures' occlusion was examined by asking the patients to clench the teeth, and the researcher recorded if the posterior teeth met in occlusion. Neuromuscular control of dentures was investigated by asking the participants to gently open the mouth; if the maxillary denture fell or the mandibular rose, it has been evaluated as lacking neuromuscular control [32].

Assessment of masticatory performance

Evaluation of masticatory performance was carried out with a two-color chewing gum mixing test (Hue-check Gum©, Orophys GmbH, Bern, Switzerland). This gum consists of a blue and a pink part which should be wetted with water outside the mouth and stuck together before chewing. Gum wetting prevents the gum from sticking to dentures, especially in case of complete denture wearers. The gum was chewed for 20 cycles. Saliva was then removed, and the bolus was placed in a transparent plastic bag which was flattened to a wafer of 1mm thickness [33, 34]. The degree of gum color mixing indicated the individual's masticatory performance. The plastic bag with the wafer was then scanned, and both sides were analyzed jointly using the View Gum software program (dHAL Software, Kifissia, Greece) that calculates the variance of the hue (VOH) component representing the measure of color-mixing, with higher VOH values indicating lower masticatory performance [22].

Statistical analysis

Data analysis was performed anonymously. Statistical analyses included descriptive statistics, univariate quantile regression analyses, and Kruskal-Wallis one-way analysis of variance on ranks. Independent variables that were statistically significantly associated with masticatory performance were included in a multivariable quantile regression analysis with backward elimination of nonsignificant predictors [35] (deletion criterion $p>0.10$) [36]. The analysis was performed using statistical software (STATA 16®, StataCorp, College Station, Texas, USA).

Results

A total of 130 people participated in this study with a mean age of 74±8.4 years (range: 60–93 years). Their sociodemographic characteristics are shown in Table 1. The most common diseases were endocrine, nutritional, and metabolic disorders (69.2%); diseases of the circulatory system (66.2%); and diseases of the musculoskeletal system and connective tissue (25.4%) (data not shown). Only 12.3% were active smokers, and 21% received more than four drugs per day (polypharmacy).

Sociodemographic actors and masticatory performance

The association between masticatory performance and various sociodemographic factors is presented in Table 1. The only parameters that were statistically significantly associated with impaired masticatory performance were increasing age ($p=0.002$) and marital status (being widowed compared to unmarried) ($p=0.004$). Masticatory performance was lower in women, those with lower education, and those living alone, but without reaching statistical significance. BMI, active smoking, number of medications per day, medical diseases, and various medication intakes were also not significantly associated with masticatory performance.

Subjective oral health indicators and masticatory performance

As far as the subjective oral health indicators are concerned, self-assessment of masticatory function ($p=0.001$), the ability to chew steak ($p=0.024$), and the ability to chew almonds ($p=0.015$) were significantly associated with masticatory performance. All participants reported that they could chew orange ($p>0.05$). Participants with a higher XI score (more xerostomia symptoms) showed lower masticatory performance but not to a statistically significant level. Last dental visit within the last year was marginally significantly associated with better masticatory performance ($p=0.073$) (Table 2). Only one subjective complaint, pain caused by the maxillary denture, was statistically significantly associated

Table 1 The association between sociodemographic factors and masticatory performance

	Masticatory performance (variance of the hue)						
	n (%)	Mean	SD	Median	Quantiles 25%	75%	*p*-value*
Sociodemographic factors							
Gender							0.438
Female	97 (74.6%)	0.28	0.21	0.21	0.09	0.41	
Male	33 (25.4%)	0.23	0.18	0.17	0.06	0.39	
All	130 (100%)	0.27	0.21	0.19	0.09	0.40	
Age (years)							0.002
60–74 years	69 (53.1%)	0.22	0.19	0.14	0.08	0.33	
75–84 years	43 (33.1%)	0.28	0.20	0.25	0.12	0.40	
≥85 years	18 (13.8%)	0.41	0.23	0.36	0.2	0.66	
Marital status							0.004 **
Married	63 (48.5%)	0.23	0.19	0.16	0.08	0.36	
Widowed	60 (46.2%)	0.32	0.22	0.27	0.14	0.47	
Unmarried	3 (2.3%)	0.04	0.01	0.04	0.03	0.05	
Divorced	4 (3.1%)	0.19	0.10	0.15	0.11	0.29	
Education (years)							0.315
≤6 years	60 (46.5%)	0.32	0.22	0.24	0.14	0.47	
7–12 years	29 (22.3%)	0.25	0.22	0.17	0.08	0.41	
>12 years	41 (31.5%)	0.2	0.17	0.15	0.05	0.34	
Living alone							0.300
Yes	53 (40.8%)	0.29	0.21	0.22	0.10	0.42	
No	77 (59.2%)	0.25	0.20	0.17	0.09	0.39	

*p-value derived from univariate quantile regression

**p-value derived from Kruskal-Wallis test

Table 2 The association between subjective oral health indicators and oral hygiene habits and masticatory performance

	Masticatory performance (variance of the hue)						
	n (%)	Mean	SD	Median	Quantiles 25%	75%	*p*-value*
Subjective oral health indicators							
Last dental visit							0.073
Less than 12 months	59 (45.4%)	0.24	0.19	0.17	0.08	0.34	
12 months and over	71 (54.6%)	0.29	0.22	0.22	0.09	0.42	
Dental hygiene frequency							0.373
At least once per day	115 (88.5%)	0.27	0.21	0.20	0.09	0.40	
Less often than once per day	15 (11.5%)	0.22	0.19	0.18	0.07	0.31	
Xerostomia Index							0.202
≤75th percentile	98 (75.4%)	0.25	0.19	0.19	0.09	0.38	
>75th percentile	32 (24.6%)	0.31	0.26	0.23	0.06	0.56	
Self-assessment of masticatory function							0.001
Very good/good	111 (85.4%)	0.24	0.19	0.17	0.09	0.36	
Moderate/poor/very poor	19 (14.6%)	0.40	0.23	0.37	0.21	0.65	
Chewing steak							0.024
Yes	113 (86.9)	0.25	0.19	0.18	0.09	0.36	
No	17 (13.1%)	0.40	0.25	0.38	0.17	0.67	
Chewing almonds							0.015
Yes	116 (89.2%)	0.24	0.19	0.17	0.09	0.37	
No	14 (10.8%)	0.44	0.20	0.41	0.24	0.63	

*p-value derived from univariate quantile regression

with masticatory performance (p=0.05). Subjective complaints for dislocation of complete and partial dentures during speech and mastication were not associated with masticatory performance (p>0.05).

Use of removable dentures and masticatory performance

Table 3 presents the association between removable denture use and masticatory performance. A total of 44.6% of the participants used complete or partial dentures and, among them, 15.4% a pair of complete dentures. All edentulous persons used complete dentures. Significant impairment in masticatory performance was recorded in all indicators related to complete dentures use, either in the maxilla or in the mandible or both jaws. On the other hand, no statistically significant impairment was recorded in partial dentures users.

Dental indicators and masticatory performance

Most dental indicators negatively affected masticatory performance. These include being edentulous, (p<0.001), having fewer teeth (p<0.001), having many teeth with mobility grade #2 and #3 (p=0.011), having fewer posterior chewing pairs (p=0.005), and fewer chewing contacts in general, either natural or prosthetic (p=0.013). Only the number of anterior chewing pairs was not significantly associated with masticatory performance (p>0.05) (Table 4).

Quality of dentures and masticatory performance

The quality of dentures as examined by the researcher did not reveal any significant association with masticatory performance (p>0.05), with the exception of poor mandibular partial denture retention (p=0.033) and dentures' occlusion (p=0.029) that were significantly associated with lower masticatory performance. It should be noted that all

Table 3 The association between removable denture use and masticatory performance

	Masticatory performance (variance of the hue)						
	n (%)	Mean	SD	Median	Quantiles 25%	75%	*p*-value*
Removable dentures use							
Use of removable denture**							<0.001
Yes	58 (44.6%)	0.38	0.22	0.36	0.20	0.53	
No	72 (55.4%)	0.17	0.15	0.14	0.07	0.22	
Use of complete denture**							<0.001
Yes	32 (24.6%)	0.5	0.2	0.49	0.32	0.68	
No	98 (75.4%)	0.19	0.14	0.16	0.08	0.27	
Use of partial denture**							0.066
Yes	31 (23.8%)	0.27	0.18	0.27	0.10	0.38	
No	99 (76.2%)	0.26	0.22	0.18	0.09	0.41	
Maxillary complete denture**							<0.001
Yes	27 (20.8%)	0.51	0.20	0.51	0.32	0.68	
No	103 (79.2%)	0.20	0.16	0.16	0.08	0.31	
Mandibular complete denture**							<0.001
Yes	25 (19.2%)	0.54	0.18	0.59	0.40	0.70	
No	105 (80.8%)	0.20	0.15	0.16	0.08	0.31	
Maxillary partial denture**							0.205
Yes	22 (16.9%)	0.28	0.19	0.27	0.10	0.36	
No	108 (83.1%)	0.26	0.21	0.18	0.09	0.41	
Mandibular partial denture**							0.107
Yes	19 (14.6%)	0.29	0.17	0.31	0.12	0.41	
No	111 (85.4%)	0.26	0.21	0.19	0.09	0.40	
Pair of complete dentures							<0.001
Yes	20 (15.4%)	0.56	0.16	0.62	0.45	0.71	
No	110 (84.6%)	0.21	0.17	0.16	0.08	0.33	

*p-value derived from univariate quantile regression

**May include dentate people and denture wearers

Table 4 The association between dental status and masticatory performance

	Masticatory performance (variance of the hue)						
	n (%)	Mean	SD	Median	Quantiles 25%	75%	*p*-value*
Dental status							
Dentate status							<0.001
Dentate	110 (84.6%)	0.21	0.17	0.16	0.08	0.33	
Edentulous	20 (15.4%)	0.55	0.16	0.55	0.44	0.68	
Number of teeth							<0.001
0	20 (15.4%)	0.54	0.17	0.55	0.44	0.68	
1–10	21 (16.2%)	0.31	0.21	0.31	0.12	0.41	
11–20	30 (23.1%)	0.28	0.18	0.23	0.13	0.37	
>20	59 (45.4%)	0.15	0.12	0.11	0.06	0.19	
Tooth mobility							0.011
>10% mobility II+III	16 (14.5%)	0.33	0.23	0.26	0.16	0.53	
≤ 10% mobility II+III	94 (85.5%)	0.19	0.15	0.16	0.08	0.31	
Anterior chewing pairs							0.952
<3	19 (14.6%)	0.26	0.20	0.18	0.09	0.41	
≥3	111 (85.4%)	0.27	0.21	0.2	0.09	0.40	
Posterior chewing pairs							0.005
≤4	26 (20%)	0.34	0.21	0.31	0.17	0.53	
5–6	49 (37.7%)	0.27	0.21	0.25	0.09	0.37	
7–10	55 (42.3%)	0.22	0.20	0.16	0.07	0.41	
All chewing pairs (natural and prosthetic)							0.013
≤6	14 (10.8%)	0.37	0.23	0.35	0.17	0.62	
7–10	36 (27.7%)	0.28	0.20	0.25	0.11	0.40	
>10	80 (61.5%)	0.24	0.20	0.17	0.08	0.35	

*p-value derived from univariate quantile regression

denture wearers had successful neuromuscular control of their dentures.

Multivariable analysis

All the above-mentioned parameters that were statistically significantly associated with masticatory performance were included in a multivariable quantile regression analysis (Table 5). Smaller number of natural teeth (95% CI: −0.02 to −0.01, $p<0.001$), being edentulous and using of a pair of complete dentures (95% CI: 0.09–0.35, $p=0.001$), and larger percentage of severely mobile teeth (95% CI: 0.07–0.82, $p=0.020$) were associated with lower masticatory performance.

Discussion

The univariate analyses in the present study revealed several general and oral factors that negatively affected masticatory performance in this functionally independent older population, including increasing age, being widowed, complaining

Table 5 Multivariable quantile regression derived coefficients (β) and *P*-values for masticatory performance (variance of the hue) as dependent variable

Predictor variables	β	SE	*p*-value*	95% confidence interval
Natural teeth (number)	−0.01	0.00	<10−^{3}	−0.02 to −0.01
Pair of complete dentures				
No	Reference			
Yes	0.21	0.06	0.001	0.09–0.35
Mobility (%)	0.44	0.18	0.020	0.07–0.82

*Final multivariable model resulting by backward elimination of nonsignificant predictors (deletion criterion $p>0.10$)

for poor chewing ability, using complete dentures, complaining for pain due to maxillary denture use, being edentate, having fewer natural teeth and fewer occluding pairs of teeth (natural and prosthetic) particularly in the posterior area of the dental arch, and having many teeth with increased mobility. The medical conditions and the medication intake did not affect masticatory performance nor did the quality of the dentures used. However, when a multivariable analysis was performed, only fewer natural teeth, the use of a pair of complete dentures (as an indirect indication of edentulousness), and the increased percentage of mobile teeth remained statistically significantly associated with lower masticatory performance.

The significant effect of the number of remaining natural teeth on masticatory performance agrees with previous findings [5, 37, 38]. If having more than 20 teeth was the baseline, the masticatory performance of those with 11–20 teeth was almost two times lower, of those with 1–10 teeth three times lower, while of the edentulous ones using complete dentures five times lower. Those with more than 10 occluding tooth contacts had almost twice higher masticatory performance values compared to those with less than six. However, although many previous studies have associated the number of chewing pairs with masticatory performance [10, 15, 37], the present investigation revealed a relevant association only in the univariate analyses.

Edentulousness is still common among older populations with increased variation between countries and regions [39]. In 2015, complete tooth loss affected almost 276 million people worldwide [40], while the prevalence of edentulousness in people aged over 65 years in Europe varied between 4 and 45% in 2017 [41]. Furthermore, a 20-teeth functional dentition is still uncommon among community-dwelling older people, especially in those over 75 years of age, with potential negative effects on their masticatory function [42, 43].

Edentulousness and the associated rehabilitation with complete dentures led to decreased masticatory performance, in comparison to natural dentition or rehabilitation with partial dentures and implant fixed or removable prostheses [6, 15, 23]. Complete denture wearers have lower maximum bite forces [6, 23], they tend to chew for longer periods with an increased number of chewing strokes at a decreased rate, and they often swallow bigger food particles compared to the dentate adults [5, 44, 45]. Some of the reasons explaining their lower masticatory performance include their reduced maximum bite forces and masticatory muscle activity, the poor retention and stability of dentures, and the associated pain in the oral tissues [5, 44].

The condition of removable dentures has also been associated with masticatory performance in many studies using various evaluation methods [15, 46]. Replacement of poorly fitted dentures with new ones has been reported to positively affect maximum bite force [47] and masticatory performance [12, 48]. However, in the present investigation, only pain caused by a maxillary denture had negatively affected masticatory performance in the univariate analyses. Both subjective and objective denture quality indicators, including patients' complaints about dislocation during function and objective evaluation of retention, stability, and occlusion, were thoroughly investigated and were not found to significantly affect masticatory performance in the multivariable analysis. This finding may be associated with the successful neuromuscular adaptation to the use of the removable prostheses that was recorded by the examiner and prompts the clinicians to use denture construction techniques that promote it in older dental patients. However, the loss of all natural teeth, even when complete dentures are used, and irrespective of their technical characteristics and the level of neuromuscular adaptation, is an important predictor of poor masticatory performance.

Tooth mobility was another oral health indicator with a significantly negative impact on masticatory performance in the present study, which is particularly important considering the large number of older persons that now retain many periodontally compromised teeth. Periodontal disease is highly prevalent among older adults [49]. In 2015, more than half a billion people globally had severe periodontal disease [40]. Although a reduction in the prevalence of severe periodontitis in industrialized countries has been recorded, the burden of periodontitis is still prevalent, and the tissue damage caused is irreversible and cumulative over lifetime [49]. Periodontal disease impairs masticatory performance, probably due to the reduction of masticatory activity and occlusal forces resulting from the compromised periodontal support [8, 9, 50–52]. Also, the electromyographic activity of anterior temporalis and masseter muscles was lower in patients with chronic periodontitis compared to the periodontally healthy ones [53]. Consequently, periodontal status and the related tooth mobility should be considered when evaluating masticatory function among older adults, and masticatory function may be included in the periodontal disease treatment planning and outcomes [8, 50].

The multivariable analysis did not reveal any age or gender effects on masticatory performance in contrast to some previous studies [11, 12]. Likewise, the Xerostomia Index was not significantly associated with masticatory performance although higher scores (more xerostomia symptoms) were associated with lower performance. Mixing ability tests are less dependent on the saliva flow rate, which is of particular importance when administering the test in geriatric patients who frequently suffer from xerostomia.

Finally, the significant association between self-assessment of masticatory function and masticatory performance in the univariate analysis was not maintained in the

multivariable analysis. This is a common finding in several studies as older adults, and particularly complete denture wearers, often overestimate their subjective masticatory function [4, 5, 54].

It should be noticed that the effect of masticatory performance on eating habits of older adults is still under investigation. Eating patterns are of a multifactorial nature, and the exact role of mixing ability on dietary choices should be further explored [42]. However, it has been previously shown in a study on the same older population that increased masticatory performance was an independent predictor of better adherence to the Mediterranean diet [17].

There are some limitations in the present study related to the characteristics of the test material and the methodology applied jeopardizing the comparisons with other studies that used different testing methods. Another limitation of this study is the selection of a functionally independent older population living in the community, restricting the generalization of the findings to functionally dependent older population groups. Moreover, the study recorded only tooth mobility and did not investigate other periodontal indicators that may had affected masticatory performance.

Further studies should be conducted in frail older adults living in institutional or home care to investigate any variation in the independent factors affecting masticatory performance. Moreover, cut-off values for masticatory deficiency should be determined using standardized techniques to enable comparisons among different investigations.

Conclusion

Within the limitations of the present study, lower masticatory performance was statistically significantly associated with fewer teeth, being edentulous and using a pair of complete dentures and increased prevalence of severe tooth mobility in a functionally independent community dwelling older population. Preventive strategies, such as retaining the natural dentition and managing periodontal disease, may be beneficial to improve or maintain masticatory performance in older adults, but longitudinal studies are necessary to clarify the causative associations.

Declarations

Ethical approval All procedures performed involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration.

Conflict of interest The authors declare no competing interests.

Informed consent Informed consent was obtained from all individual participants included in the study.

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