Table 4 Comparisons of handgrip strength and one-leg standing time with eyes open between before and after intervention.

		Handgrip strength (kg)			*One-leg standing time with eyes open (s)*		
		Mean ± SD			*Mean ± SD*		
Masticatory ability	*n*	*Before*	*After*	*p-values*[a]	*Before*	*After*	*p-values*[a]
Participants with dental treatment (n = 121)							
Total	121	28.0 ± 7.5	27.4 ± 7.7	0.047	33.0 ± 33.3	29.9 ± 34.4	0.106
Impaired	12	24.7 ± 6.8	22.6 ± 6.9	0.005	21.0 ± 27.4	15.7 ± 20.6	0.182
Unchanged	91	29.3 ± 7.3	28.7 ± 7.7	0.066	37.8 ± 34.6	32.1 ± 34.8	0.029
Improved	18	23.4 ± 6.8	24.2 ± 5.9	0.117	16.5 ± 21.2	28.1 ± 38.9	0.029
Participants without dental treatment (n = 33)							
Total	33	26.9 ± 7.7	26.4 ± 6.7	0.734	30.7 ± 30.0	23.0 ± 27.4	0.088
Impaired	3	21.0 ± 8.5	23.8 ± 6.3	0.109	14.9 ± 5.3	30.0 ± 32.4	0.285
Unchanged	28	27.6 ± 7.6	26.6 ± 6.8	0.205	29.8 ± 27.1	22.1 ± 28.4	0.066
Improved	2	26.0 ± 8.8	28.0 ± 8.5	0.157	68.0 ± 73.5	25.0 ± 0.0	0.655

[a]*p*-values were evaluated with the Wilcoxon signed rank sum test.

Table 5 Correlations between changes in handgrip strength and one-leg standing time with eyes open, and those in masticatory ability.

	Changes in handgrip strength between before and after – intervention (kg)[a]		*Changes in one-leg standing time with eyes open between before and after intervention (S)*[b]	
	r	*p-value*	*r*	*p-value*
Participants with dental treatment (n = 121)				
Changes in masticatory ability[c]	0.30	0.001	0.21	0.020
Participants without dental treatment (n = 33)				
Changes in masticatory ability[c]	−0.09	0.635	−0.26	0.146

r: Spearman rank correlation coefficient.
[a]Q–P; P = handgrip strength (kg) before intervention, Q = those after intervention.
[b]*S–R*; *R*= one-leg standing time with eyes open (s) before intervention, *S*=those after intervention
[c]Y–X; X = Categories of masticatory ability before intervention, Y = categories of masticatory ability after intervention., Categories of masticatory ability were created as follows: Poor = 0, Fair = 1, Good = 2.

and there was a significant positive correlation between changes in masticatory ability and handgrip strength. Therefore, it is possible that the improvement in masticatory ability may contribute to controlling the age-related decline in muscle strength. These findings are supported by previous studies that reported a significant positive relationship between perceived chewing ability and muscle strength of the body among the elderly[10,11].

One-leg standing time with eyes open decreased significantly in subjects with unchanged masticatory ability after the intervention. Subjects with impaired masticatory ability only showed a decreasing tendency in one-leg standing time, probably because the number of participants (n = 12) was too small to reach significance. This decline was thought to be mainly an age-related change. The significant increase in one-leg standing time with eyes open among those with improved masticatory ability suggested that improvement in balance function was accompanied by improvement in masticatory ability. This suggestion was further confirmed by the findings in terms of the significant positive correlation and independent relationships between changes in masticatory ability and one-leg standing time with eyes open. The present findings are consistent with those of epidemiological studies on the relationships between

Table 6 Multivariate logistic regression models for improvement in each parameter of physical performance in the participants with dental treatment (n = 121).

	Dependent variables					
	Improvement in handgrip strength[a]			*Improvement in one-leg standing time*[b]		
	OR	*95% CI*	*p-values*	*OR*	*95% CI*	*p-values*
Gender						
Female	1.00 (reference)			1.00 (reference)		
Male	0.87	0.36–2.10	0.759	1.90	0.79–4.56	0.153
Age						
65–74	1.00 (reference)			1.00 (reference)		
75–84	0.87	0.35–2.20	0.779	0.78	0.33–1.88	0.587
Occluding pairs of natural teeth						
Lost support	1.00 (reference)			1.00 (reference)		
Partial support	2.90	0.84–10.10	0.093	1.71	0.53–5.48	0.368
Full support	5.02	1.15–21.90	0.032	3.13	0.79–12.39	0.104
Need for dental treatment						
Periodontal disease						
Needless	1.00 (reference)			1.00 (reference)		
Needed	0.84	0.23–3.00	0.784	0.37	0.11–1.25	0.109
Dentures						
Needless	1.00 (reference)			1.00 (reference)		
Needed	3.26	0.98–10.75	0.053	1.33	0.42–4.17	0.624
Changes in masticatory ability						
Impaired	0.00[c]			0.63	0.14–2.77	0.541
Unchanged	1.00 (reference)			1.00 (reference)		
Improved	2.44	0.75–7.93	0.139	4.05	1.25–13.16	0.020

OR, odds ratio; CI, confidence interval.
[a]Improved (n = 43, 35.5%) vs. unchanged (n = 15, 12.4%) or impaired (n = 63, 52.1%).
[b]Improved (n = 45, 37.2%) vs. unchanged (n = 5, 4.1%) or impaired (n = 71, 58.7%).
[c]There were no persons with impaired masticatory ability among those with improved handgrip strength.

chewing ability and balance function, as well as a clinical trial on the influence of improved dental functional occlusion on the occurrence of falls in elderly with dementia[10,11,13].

According to the related literature, physical performance such as muscle strength and balance function can be influenced by a variety of factors including ageing, the presence of physical diseases (including neurological) and psychological status in older adults[16–19]. Although the participants enrolled had some chronic medical disease, all of them were kept under good medical control. They had no difficulties in activities of daily living and could live independently, as none of them were certificated for care-needs in the LTCI[14] during the follow-up period. It has been shown that masticatory ability was significantly associated with physical performance such as muscle strength and balance function after adjusting for some demographic and general health status[9–11]. Therefore, improved masticatory ability may influence physical performance positively as shown in the present study.

The relationships between chewing ability and physical performance can be explained by several possible underlying mechanisms. First, it has been shown that chewing ability is significantly related to nutritional intake and nutritional status[20–22] and that nutritional status is a significant contributing factor to physical performance, especially muscle strength[23–25], thereby suggesting that chewing ability may positively influence physical performance. Second, muscle strength and balance function may be influenced by orofacial sensory inputs from the trigeminal nerve, that is, epithelial mechanoreceptors and periodontal mechanoreceptors, temporomandibular joint receptors, jaw-closing muscle spindles and Golgi tendon organs[26–32]. Therefore, it is possible that these peripheral orofacial sensory inputs influence motor-neural control of muscle strength in other parts of body as there may be associations between orofacial motor control mechanisms[33,34] and associations between changes in dental occlusion and postural stability[35,36].

In these experimental studies, modification of dental occlusion may influence physical performance in a short time[33–36]. In a clinical trial, elderly persons with dementia underwent denture treatment, and then they experienced decreased frequency of falls during the 1-year investigative period[13].

The present study had a limitation that it was not designed as a randomised controlled trial. Nevertheless, to the best of our knowledge, the present study is the first to elucidate the influence of changes in chewing ability on parameters of physical performance among community-dwelling elderly persons. Further sophisticated study designs such as a randomised controlled trial are required to confirm the findings reported.

Conclusions

Our hypothesis that dental treatment might improve physical performance among the elderly was not confirmed in the present study. Nevertheless, in the subjects where masticatory ability was improved by dental treatment, one-leg standing time with eyes open significantly improved, suggesting that chewing ability may positively contribute to enhancing balance function among the elderly.

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