Alterations in the Masticatory System in Patients with Amyotrophic Lateral Sclerosis

Nina Riera-Punet, DDS
Assistant Professor
Department of Prosthodontics
School of Dentistry
Faculty of Medicine and Health Sciences
University of Barcelona
Barcelona, Catalonia, Spain

Jordi Martinez-Gomis, DDS, PhD
Associate Professor
Department of Prosthodontics
School of Dentistry
Faculty of Medicine and Health Sciences
University of Barcelona
Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL
Barcelona, Catalonia, Spain

Andrés Paipa, MD
ALS Unit
Department of Neurology
Bellvitge University Hospital
Barcelona, Catalonia, Spain

Monica Povedano, MD
ALS Unit
Department of Neurology
Bellvitge University Hospital
Barcelona, Catalonia, Spain

Maria Peraire, MD, DDS, PhD
Professor
Department of Prosthodontics
School of Dentistry
Faculty of Medicine and Health Sciences
University of Barcelona
Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL
Barcelona, Catalonia, Spain

Correspondence to:
Dr Jordi Martinez-Gomis
Campus de Bellvitge
Universitat de Barcelona
C/ Feixa Llarga s/n, 08907 L'Hospitalet de Llobregat
Catalonia, Spain
Fax: (+34) 934035558
Email: jmartinezgomis@ub.edu

Aims: To determine the effect of amyotrophic lateral sclerosis (ALS) on aspects of masticatory function and to assess the relationship between ALS and the prevalence of traumatic mucosal lesions caused by oral self-injury. **Methods:** A total of 153 ALS patients and 23 control subjects participated in this cross-sectional study. Clinical characteristics including site of onset, medication, type of feeding, and use of noninvasive mechanical ventilation were recorded. The Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) protocol and a specific questionnaire to assess aspects of masticatory dysfunction and frequency of self-injury of the oral mucosa were applied to all participants. Maximum mandibular range of motion, maximum bite force, and maximum finger-thumb grip force were determined and tested with Mann Whitney, Kruskal-Wallis, or chi-square tests. $P < .05$ was considered significant. **Results:** Maximum unassisted and assisted mouth opening, protrusion, left laterotrusion, and finger-thumb grip force were significantly reduced in both spinal- (n = 102) and bulbar-onset (n = 40) patients compared to the control group; however, bite force was reduced only in bulbar-onset patients. ALS patients with tube feeding (n = 16) had the greatest reduction in maximum bite force and mandibular opening. There was no relationship between TMD and ALS. Oral self-injury due to biting was more frequent in the ALS group (29.9%) than in the control group (8.7%) and in the bulbar-onset group (55.0%) compared to the spinal- (20.8%) and respiratory-onset (18.2%) groups. Of the ALS patients in the study, 10% sought dental treatment related to the condition. **Conclusion:** The ALS patients in this study had a reduction in finger-thumb grip force that was twice as great as the reduction in bite force. The maximum range of mandibular movement was also reduced, especially in bulbar-onset patients. ALS patients did not have a higher prevalence of TMD but did have more traumatic mucosal injury than controls. The dentist should be an integral part of the multidisciplinary team to manage ALS patients.
J Oral Facial Pain Headache 2018;32:84–90. doi: 10.11607/ofph.1882

Keywords: *amyotrophic lateral sclerosis, craniomandibular disorders, mandibular range of motion, occlusal force, self-biting*

Amyotrophic lateral sclerosis (ALS) is a heterogenous, multisystem, progressive neurodegenerative disease that affects the lower and upper motor neurons in the spinal cord, brainstem, and brain, causing muscle atrophy, muscle weakness, and spasticity.[1] Risk factors associated with ALS are older age, male sex, and family history.[2] Its incidence rates in Catalonia and Europe are approximately 1.4 and 2.1 per 100,000 people a year, respectively,[3,4] and survival rates vary from months to several years, with median survival time from onset ranging from 24 months in northern Europe to 48 months in central Asia.[5]

The typical clinical characteristics of ALS are variable and depend on whether the site of onset is spinal, bulbar, or respiratory. Most patients with ALS have a spinal onset, causing referred weakness and muscle atrophy, fasciculations (reflecting involvement of lower motor neurons), and hyperreflexia and hypertonia (reflecting involvement of upper motor neurons). Weakness starts in bulbar muscles in about 20% of patients, with dysarthria, dysphagia, and tongue fasciculations. Bulbar-onset ALS has a poorer prognosis due to swallowing difficulties, weight loss, aspiration, and respiratory involvement, with poorer

Table 1 Characteristics of Patients with Amyotrophic Lateral Sclerosis (ALS)

Characteristics	Total (n = 153)	ALS onset			*P* value between each onset subgroup*
		Bulbar (n = 40)	Spinal (n = 102)	Respiratory (n = 11)	
Sex (% male)	53.6	42.5	54.9	81.8	.06
Median age (y)	64.2	66.1	61.8	70.7	.001
Familiar (%)	5.2	10	3.9	0	.247
Median time elapsed since symptom onset (mo)	30.8	21.6	35.4	32.3	.001
Median time elapsed since ALS diagnosis (mo)	16.1	9.1	20.9	11.6	.003
Riluzol (%)	77.8	77.5	77.5	81.8	.946
Baclofen (%)	25.5	17.5	31.4	0	.031
Amitriptyline (%)	28.1	57.5	18.6	9.1	< .001
Botulinum toxin (%)	9.8	25	4.9	0	.001
Noninvasive ventilation (%)	32	25	27.5	100	< .001
Oral feeding (%)	89.5	72.5	95.1	100	< .001
Tube feeding (%)	22.9	45	14.7	18.2	.001

*Chi-square test or Kruskal-Wallis test were used for statistical analyses.

adaptation to noninvasive ventilation. About 3% to 5% of ALS patients have a respiratory onset, reporting orthopnea or dyspnea and mild or even no spinal or bulbar signs. Up to 10% of patients with ALS have an affected relative and are thus considered to have familial ALS.[6]

The role of the dentist in ALS disease is not yet well defined. For example, one patient with ALS was misdiagnosed as having a temporomandibular disorder (TMD) because she reported a decreased mouth-opening range and pain on palpation of the temporalis muscles.[7] In another clinical case, masseter muscle spasticity was also described as a first symptom of ALS.[8] Recurrent jaw dislocation following botulinum toxin treatment for sialorrhea has also been reported.[9] Several treatments have been described to improve dysarthria in ALS patients, including palatal lift and palatal augmentation prostheses,[10,11] and a special oral appliance has been devised to decrease drooling in a patient with a Class II malocclusion.[12] In another study, dental treatment with total intravenous (IV) anesthesia in an ALS patient was successful, although the patient had a severe gag reflex and an impaired airway protection reflex.[13] Although oral health status was not affected by ALS in a cohort of 37 Australian patients,[14] the study concluded that the dental profession should be a part of the multidisciplinary team for the management of ALS patients. These patients' oral health could be maintained during the disease period with minimal clinical intervention.[15]

Masticatory function includes a number of features, such as bite force, mandibular mobility, and masticatory performance.[16,17] To the best of the authors' knowledge, no clinical study with a large sample has been performed to assess alterations in the masticatory system in patients with ALS. Information on this topic would help in the preparation of guidelines for dentists regarding the management of ALS patients and may contribute to improving patients' comfort.

The main aim of the present cross-sectional controlled study was to determine the effect of ALS on aspects of masticatory function, including mandibular range of motion, bite force, and prevalence of TMD. The study also aimed to assess the relationship between ALS and the prevalence of traumatic mucosal lesions caused by oral self-injury. Additionally, potential differences between bulbar- and spinal-onset patients were explored. The working hypothesis was that patients affected by ALS would have lower bite force, a reduced mandibular range of motion, a higher prevalence of TMD, and a higher incidence of traumatic mucosal ulcers due to self-injury than healthy subjects.

Materials and Methods

Participants

Between April 2015 and September 2016, patients diagnosed with ALS according to the revised El Escorial diagnostic criteria[18] and attending the Motor Neuron Disease Unit of the Bellvitge University Hospital were invited to participate in this cross-sectional study. Patients who could not be evaluated because of their clinical condition were excluded. The control group included 23 participants recruited from families or caregivers of ALS patients and other age- and gender-matched subjects. The nature of the study was explained in full to all the participants, and all signed an informed consent form approved by Bellvitge University Hospital Ethics Committee (Code PR260/15). All experiments were carried out in accordance with the principles of the Helsinki Declaration.

ALS-Related Characteristics

Patients were routinely evaluated by the ALS unit neurology team. Chronologic variables registered were date of onset, time to diagnosis, and time to evaluation. Demographics on sex, age, and family

history were also registered, and a phenotypic classification was performed according to the site of onset (bulbar, spinal, or respiratory). Medication, use of mechanical ventilation, and gastrostomy were also registered (Table 1).

Assessment of TMD

All participants were examined and interviewed by the same trained dental clinician and answered the symptoms questionnaire of the Diagnostic Criteria for TMD (DC/TMD) protocol.[19] The clinical examination included the measurement of maximum opening, protrusion, and laterotrusion; palpation and auscultation of the temporomandibular joints (TMJs); and palpation of the masticatory muscles.[19–21] Following the DC/TMD algorithms, all subjects were defined as non-TMD or assigned to one of the four subgroups (myalgia, arthralgia, TMD-related headache, or disc displacement). Multiple diagnoses were possible.

Questionnaire

Participants were also assessed by means of a questionnaire about awareness of clenching/grinding, jaw blocking, and presence of cramps in the masticatory muscles (with dichotomous no/yes answers for all three questions). Self-injury to the tongue, lips, or cheeks was also assessed and rated on a 5-point Likert scale (never, yearly, monthly, weekly, or daily) and was considered clinically relevant if the participant answered either weekly or daily. Finally, the information from this questionnaire was used to determine whether participants might be candidates for receiving oral treatment to manage these oral-related problems (no/yes).

Clinical Examination

Overbite was measured according to the DC/TMD protocol.[19] Briefly, a horizontal pencil mark was placed on the buccal surface of the right mandibular central incisor in relation to the maxillary antagonist incisor while the posterior teeth were in the maximum intercuspal position.[22] To measure both maximum unassisted and maximum active mouth opening, the interincisal distance between the maxillary and mandibular reference teeth (the same as the ones used to measure the overbite) was measured after asking the participants to open as wide as they could, even if it was painful. To measure the maximum assisted or maximum passive mouth opening, participants were asked to open as wide as they could, and the operator pushed the mouth open further using moderate pressure. Afterwards, the interincisal distance between the maxillary and mandibular reference teeth (the same as the ones used to measure the overbite) was measured. Right and left laterotrusion were measured by taking into account the midline discrepancy, and protrusion was assessed by adding the overjet to correct the amount of movement.[21]

Bite and Grip Force Measurements

A bite-force transducer (gnathodynamometer) calibrated with loads from 0 to 1,200 N was used to measure unilateral maximum bite force between the second premolars or the first molars on both sides.[23,24] Bite force was measured three times with the order changed for each side, and the highest value was selected for analysis. The finger-thumb grip force of each hand was measured in a similar manner using the bite-force transducer.[25]

Statistical Analyses

The normal distribution fit of the data was tested by means of the Kolmogorov-Smirnov test. Comparisons between patient and control groups were performed using Mann-Whitney *U* test or chi-square test, as appropriate. Comparisons between bulbar-, spinal-, and respiratory-onset groups and the control group were performed using Kruskal-Wallis H test and chi-square test, as appropriate. Spearman rank correlation coefficients were calculated in order to evaluate the bivariate correlations between quantitative parameters. Statistical analysis was performed using the SPSS program (IBM SPSS Statistics, version 23.0.0.2), and $P < .05$ was considered significant.

Results

This study included 153 patients (median age 64 years; 46% women) and 23 controls (median age 52 years; 56% women). Among the patients with ALS, onset was bulbar in 26%, spinal in 67%, and respiratory in 7% (Table 1). Only 5.2% of these patients had a hereditary component. The median time from symptom onset to exploration was 30.8 months, and the median time since diagnosis was 16.1 months. The medications prescribed were riluzol (77.8%), baclofen (25.5%), amitriptyline (28.1%), and botulinum toxin (9.8%). Almost a third (32%) of the ALS patients received noninvasive ventilation, while 11% needed supplemental tube feeding, 77% had normal eating habits, and 12% had either probe or oral feeding.

Participants' perceptions of alterations in the masticatory system are shown in Table 2. Although ALS patients did not report clenching or grinding their teeth or suffering cramps more frequently than controls, they reported more limitations in mouth movement and more sialorrhea, especially those with bulbar onset ($P < .001$; chi-square). Oral self-injury due to biting was reported more frequently in the ALS group than in the control group ($P < .001$; chi-square) and by those with bulbar onset more than those with spinal

Table 2 Comparison Between ALS Patients and Control Group of Participants' Perceptions of Alterations in the Masticatory System

		ALS onset					
	Total (n = 153)	Bulbar (n = 40)	Spinal (n = 102)	Respiratory (n = 11)	Control group (n = 23)	*P* value: Patient vs control group*	*P* value: Control vs each onset subgroup*
Grinding or clenching (%)	51.0	60.0	51.0	18.2	65.2	.2	.053
Cramps (%)	2.7	2.7	3.0	0	0	.44	.8
Limitations in mouth movement (%)	37.3	70.0	28.4	0	0	< .001	< .001
Sialorrhea (%)	44.4	85.0	31.0	18.2	4.3	< .001	< .001
Total self-injury/oral lesions (%)	29.9	55.0	20.8	18.2	8.7	.03	< .001
Self-injury tongue (%)	13.6	27.5	7.3	18.2	0	.06	.002
Self-injury lip (%)	12.2	15.0	11.5	9.1	4.3	.26	.63
Self-injury cheek (%)	17.0	35.0	11.5	0	4.3	.12	.001
Seeking oral treatment (%)	9.8	20.0	6.9	0	0	.12	.016

*Chi-square test used for statistical analyses.

Table 3 Comparison Between ALS Patients and Control Group of Temporomandibular Disorder (TMD) Diagnoses, Mandibular Movements, and Muscular Force

		ALS onset					
	Total (n = 153)	Bulbar (n = 40)	Spinal (n = 102)	Respiratory (n = 11)	Control group (n = 23)	*P* value: Patient vs control group	*P* value: Control vs each onset subgroup*
TMD							
Myalgia (%)	9.2	10.0	8.8	9.1	17.4	.22	.68
Arthralgia (%)	5.9	7.5	5.9	0	0	.23	.49
TMD-related headache (%)	0.7	0	1.0	0	4.3	.12	.44
Disc displacement (%)	25.5	17.5	30.4	9.1	39.1	.17	.12
Mandibular movement							
Median maximum unassisted opening (mm)	44.0	42.5	46.0	43.0	50.0	.001	< .001
Median maximum assisted opening (mm)	46.5	44.5	48.0	46.0	53.0	< .001	< .001
Median difference between assisted and unassisted maximum opening (mm)	2.0	2.5	2.0	2.0	2.0	.59	.23
Limited mouth opening (%)	20.3	40	14.7	0	4.3	.07	< .001
Median maximum right laterotrusion (mm)	6.0	5.0	6.0	8.0	8.0	.02	.005
Median maximum left laterotrusion (mm)	6.0	5.5	6.0	6.0	8.0	< .001	< .001
Median maximum protrusion (mm)	6.0	4.0	7.0	6.0	8.0	.001	< .001
Muscular force							
Median maximum bite force (N)	237	198	256	274	346	< .001	< .001
Median finger-thumb grip force (N)	22.6	41.2	16.7	22.6	75.5	< .001	< .001

*Chi-square test or Kruskal-Wallis test used for statistical analyses.

or respiratory onset ($P < .05$; chi-square). The most frequently injured sites were the tongue and cheeks, and 35% of bulbar-onset patients reported self-injury due to biting the cheek daily or weekly. Ten percent of ALS patients were candidates for oral treatment related to their ALS. Among the patients with bulbar onset, 20% sought oral treatment, compared with only 6.9% of spinal-onset patients ($P = .02$, chi-square).

The proportions of participants with TMD according to DC/TMD subgroup are shown in Table 3. There was no relationship between the diagnosis of any TMD group and ALS ($P > .05$, chi-square), nor between arthralgia and feeding via gastric tube ($P > .05$, chi-square). Maximum unassisted and assisted mouth opening, protrusion, and left laterotrusion were significantly reduced in the spinal-onset group compared to the control group ($P < .05$, Mann-Whitney) and also in the bulbar-onset group compared to the spinal-onset group ($P < .05$, Mann Whitney). In the bulbar-onset group, 40% had limited unassisted mouth opening (ie, < 40 mm), and both finger-thumb grip and bite force were significantly reduced in bulbar-onset patients compared to the control group ($P < .001$, Mann Whitney). In spinal-onset patients, only finger-thumb grip force was significantly reduced compared to the bulbar-onset group ($P < .05$, Mann Whitney); however, whereas the scores of bulbar-onset patients for finger-thumb grip and bite forces were nearly 50% of those recorded by control subjects, the scores of spinal-onset patients were 22% (finger force) and 74% (bite force) with respect to normal control scores.

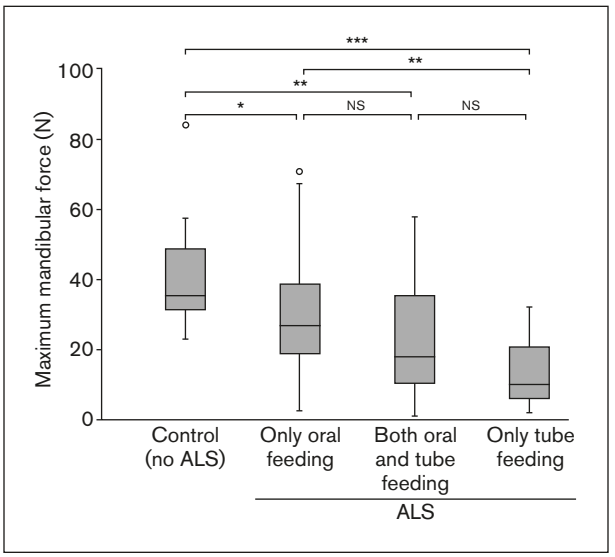

Fig 1 Box plot of maximum bite force comparison between feeding groups. NS = not significant. *$P \leq .05$. **$P \leq .01$. ***$P \leq .001$. Kruskal-Wallis test and pairwise comparisons were used for statistical analyses.

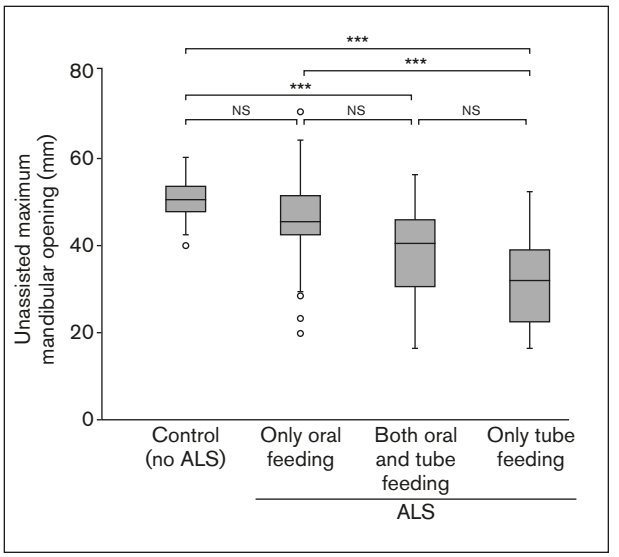

Fig 2 Box plot of maximum unassisted mouth opening comparison between feeding groups. NS = not significant. ***$P \leq .001$. Kruskal-Wallis test and pairwise comparisons were used for statistical analyses.

Table 4 Spearman Correlation Coefficients Between Variables Related to Maximum Range of Mandibular Movement or Maximum Muscular Force

	unAMO	AMO	RL	LL	Protrusion	Bite force	Finger force
Unassisted mouth opening	1						
Assisted mouth opening	.966**	1					
Right laterotrusion	.278**	.293**	1				
Left laterotrusion	.400**	.431**	.544**	1			
Protrusion	.462**	.466**	.443**	.488**	1		
Bite force	.217**	.218**	.309**	.244**	.362**	1	
Finger-thumb grip force	.260**	.273**	.066	.074	.086	.079	1

**Correlation significant at $P < .01$ level (2-tailed test). unAMO = unassisted mouth opening; AMO = assisted mouth opening; RL = right laterotrusion; LL = left laterotrusion.

Comparisons between type of feeding for ALS patients and control subjects for mandibular force and mouth opening, respectively, are shown in Figs 1 and 2. ALS patients with gastrostomy had a significant reduction in maximum bite force and in mandibular opening compared to control subjects. ALS patients with tube feeding only (n = 16) had the greatest reduction in maximum bite force and mandibular opening.

The Spearman correlation coefficients between variables related to mandibular movement or muscular force are shown in Table 4. All variables related to mandibular movement and bite force were significantly correlated with each other ($P < .01$, Spearman correlation). Although maximum finger-thumb grip force was correlated with maximum mouth opening, it was not correlated with bite force.

Discussion

The results of the present study suggest that approximately 10% of ALS patients are candidates for oral treatment specifically because of their disease. The chief complaint of the majority of these patients was traumatic lesions in the lips, cheeks, or tongue due to self-biting. To the authors' knowledge, this is the first large study demonstrating such a high rate of oral self-biting injuries, especially in bulbar-onset patients. Customized oral appliances or acrylic splints and mouthguards have been used in other cases of oral self-injury[26]; however, prospective studies are needed to assess the efficacy, side effects, and technical complications of an oral appliance for managing alterations in the masticatory system in ALS patients. This study supports a multidisciplinary approach to

the management of ALS patients, and the dentist should be an integral part of the management team to help treat the negative effects of ALS on the stomatognathic system.[14,15]

Maximum mandibular movement and bite force were both significantly reduced in ALS patients regardless of type of onset, and both aspects of masticatory function were significantly correlated. Moreover, the greatest reduction was observed in bulbar-onset ALS patients, especially those with tube feeding only. Whereas the relative amount of muscular force reduction in bulbar-onset patients was similar for finger-thumb grip and bite force, in spinal-onset patients, the relative reduction was three times higher for finger force than for bite force. This result is expected due to the limb muscle weakness that characterizes this type of patient. A reduction in mouth opening may hinder oral hygiene and also perhaps the efficacy of noninvasive ventilation. Therefore, in order to minimize these complications and before indicating gastric tube feeding, especially in bulbar-onset patients, a physiotherapy program comprising active exercises could be applied to slow down the reduction in mouth opening. The relationship between mouth opening and efficacy of noninvasive ventilation could be the focus of new research in a prospective study.

No differences in TMD prevalence were detected in ALS patients compared to the control group or compared to general or geriatric populations.[27,28] As ALS patients report arthralgia in joints with weak musculature,[29] they might also be expected to suffer TMJ arthralgia. Some ALS patients did not use the jaw to eat because they were feeding via a gastric tube; however, these patients did not report arthralgia in the TMJ probably because they still used masticatory muscles for functions besides chewing, such as clenching.

The 153 ALS patients who participated in the present study represent approximately 30% of all ALS patients diagnosed in Catalonia, which has a population of some 7,500,000 inhabitants.[3] The clinical characteristics of this patient group were consistent with the results of other studies, such as the distribution of ALS site of onset,[30] the percentage of the hereditary component,[31] the male/female ratio (regardless of the site of onset), the differentiation between bulbar and spinal onset,[5,32] and the time elapsed since the first symptom or the time since diagnosis.[33] Therefore, this sample was highly representative of the population, which is one of the strengths of the present study. The small sample size of the control group and the method of recruitment are considered study limitations; however, although most of the control group came from the families of the patients and were slightly younger, the range of mandibular motion and the prevalence of TMD in the control group were consistent with data from the general population and from elderly subjects reported in other studies.[27,28] Another limitation was the lack of attempt to correlate masticatory system measures with ALS functional rating scale scores.

Conclusions

The ALS patients in the present study showed reductions in both bite force and finger-thumb grip force. The reduction was twice as large for the finger force than for the bite force. The maximum range of mandibular movement (mouth opening, protrusion, and laterotrusion) was also reduced in the ALS patients, especially in bulbar-onset phenotypes. The prevalence of TMD in the ALS patients was similar to that in the control subjects and consistent with that in general population studies. The ALS patients had more traumatic mucosal injury than controls, especially in the tongue and cheek. The dentist should be an integral part of the multidisciplinary team in order to improve the comfort of ALS patients.

Acknowledgments

Partial funding from the Bellvitge Campus Research Committee, University of Barcelona (ACESB2014/04), and from the Faculty of Dentistry, University of Barcelona. The authors report no conflicts of interest.

References

1. Robberecht W, Philips T. The changing scene of amyotrophic lateral sclerosis. Nat Rev Neurosci 2013;14:248–264.
2. Ingre C, Roos PM, Piehl F, Kamel F, Fang F. Risk factors for amyotrophic lateral sclerosis. Clin Epidemiol 2015;7:181–193.
3. Pradas J, Puig T, Rojas-García R, et al. Amyotrophic lateral sclerosis in Catalonia: A population based study. Amyotroph Lateral Scler Frontotemporal Degener 2013;14:278–283.
4. Chiò A, Logroscino G, Traynor BJ, et al. Global epidemiology of amyotrophic lateral sclerosis: A systematic review of the published literature. Neuroepidemiology 2013;41:118–130.
5. Marin B, Logroscino G, Boumédiene F, et al. Clinical and demographic factors and outcome of amyotrophic lateral sclerosis in relation to population ancestral origin. Eur J Epidemiol 2016;31:229–245.
6. Swinnen B, Robberecht W. The phenotypic variability of amyotrophic lateral sclerosis. Nat Rev Neurol 2014;10:661–670.
7. Pang KM, Park JW. Masticatory muscle pain and progressive mouth opening limitation caused by amyotrophic lateral sclerosis: A case report. J Oral Facial Pain Headache 2015;29:91–96.
8. Cisse FA, Dubois-Boissier MD, Jousserand G, Antoine JC, Camdessanche JP. Trismus as the first symptom of amyotrophic lateral sclerosis. Amyotroph Lateral Scler 2012;13:475–476.

9. Tan EK, Lo YL, Seah A, Auchus AP. Recurrent jaw dislocation after botulinum toxin treatment for sialorrhoea in amyotrophic lateral sclerosis. J Neurol Sci 2001;190:95–97.
10. Esposito SJ, Mitsumoto H, Shanks M. Use of palatal lift and palatal augmentation prostheses to improve dysarthria in patients with amyotrophic lateral sclerosis: A case series. J Prosthet Dent 2000;83:90–98.
11. Decker M, Prell T, Schelhorn-Neise P, Küpper H, Witte OW, Grosskreutz J. Specially designed palate prosthesis reconstitutes speech in amyotrophic lateral sclerosis. Amyotroph Lateral Scler 2012;13:560–561.
12. Asher RS, Winquist H. Appliance therapy for chronic drooling in a patient with mental retardation. Spec Care Dentist 1994;14:30–32.
13. Austin S, Kumar S, Russell D, da Silva EJ, Boote M. Dental treatment for a patient with motor neurone disease completed under total intravenous anaesthesia: A case report. J Disabil Oral Health 2011;12:124–127.
14. Tay CM, Howe J, Borromeo GI. Oral health and dental treatment needs of people with motor neurone disease. Aust Dent J 2014;59:309–313.
15. Bergendal B, McAllister A. Orofacial function and monitoring of oral care in amyotrophic lateral sclerosis. Acta Odontol Scand 2017;75:179–185.
16. Rovira-Lastra B, Flores-Orozco EI, Salsench J, Peraire M, Martinez-Gomis J. Is the side with the best masticatory performance selected for chewing? Arch Oral Biol 2014;59:1316–1320.
17. Flores-Orozco EI, Tiznado-Orozco GE, Osuna-González OD, Amaro-Navarrete CL, Rovira-Lastra B, Martinez-Gomis J. Lack of relationship between masticatory performance and nutritional status in adults with natural dentition. Arch Oral Biol 2016;71:117–121.
18. Brooks BR, Miller RG, Swash M, Munsat TL, World Federation of Neurology Research Group on Motor Neuron Diseases. El Escorial revisited: Revised criteria for the diagnosis of amyotrophic lateral sclerosis. Amyotroph Lateral Scler Other Motor Neuron Disord 2000;1:293–299.
19. Schiffman E, Ohrbach R, Truelove E, et al. Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) for Clinical and Research Applications: Recommendations of the International RDC/TMD Consortium Network and Orofacial Pain Special Interest Group. J Oral Facial Pain Headache 2014;28:6–27.
20. Martinez-Gomis J, Lujan-Climent M, Palau S, Bizar J, Salsench J, Peraire M. Relationship between chewing side preference and handedness and lateral asymmetry of peripheral factors. Arch Oral Biol 2009;54:101–107.
21. Martínez-Gomis J, Willaert E, Nogues L, Pascual M, Somoza M, Monasterio C. Five years of sleep apnea treatment with a mandibular advancement device. Side effects and technical complications. Angle Orthod 2010;80:30–36.
22. Salsench J, Martínez-Gomis J, Torrent J, Bizar J, Samsó J, Peraire M. Relationship between duration of unilateral masticatory cycles and the type of lateral dental guidance: A preliminary study. Int J Prosthodont 2005;18:339–346.
23. Flores-Orozco EI, Rovira-Lastra B, Willaert E, Peraire M, Martinez-Gomis J. Relationship between jaw movement and masticatory performance in adults with natural dentition. Acta Odontol Scand 2016;74:103–107.
24. Rovira-Lastra B, Flores-Orozco EI, Ayuso-Montero R, Peraire M, Martinez-Gomis J. Peripheral, functional and postural asymmetries related to the preferred chewing side in adults with natural dentition. J Oral Rehabil 2016;43:279–285.
25. Lujan-Climent M, Martinez-Gomis J, Palau S, Ayuso-Montero R, Salsench J, Peraire M. Influence of static and dynamic occlusal characteristics and muscle force on masticatory performance in dentate adults. Eur J Oral Sci 2008;116:229–236.
26. Limeres J, Feijoo JF, Baluja F, Seoane JM, Diniz M, Diz P. Oral self-injury: An update. Dent Traumatol 2013;29:8–14.
27. Manfredini D, Guarda-Nardini L, Winocur E, Piccotti F, Ahlberg J, Lobbezoo F. Research Diagnostic Criteria for Temporomandibular Disorders: A systematic review of Axis I epidemiologic findings. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:453–462.
28. Schmitter M, Rammelsberg P, Hassel A. The prevalence of signs and symptoms of temporomandibular disorders in very old subjects. J Oral Rehabil 2005;32:467–473.
29. Ho DT, Ruthazer R, Russell JA. Shoulder pain in amyotrophic lateral sclerosis. J Clin Neuromuscul Dis 2011;13:53–55.
30. Kiernan MC, Vucic S, Cheah BC, et al. Amyotrophic lateral sclerosis. Lancet 2011;377:942–955.
31. Turner MR, Hardiman O, Benatar M, et al. Controversies and priorities in amyotrophic lateral sclerosis. Lancet Neurol 2013;12:310–322.
32. McCombe PA, Henderson RD. Effects of gender in amyotrophic lateral sclerosis. Gend Med 2010;7:557–570.
33. Gordon PH. Amyotrophic lateral sclerosis: An update for 2013 clinical features, pathophysiology, management and therapeutic trials. Aging Dis 2013;4:295–310.