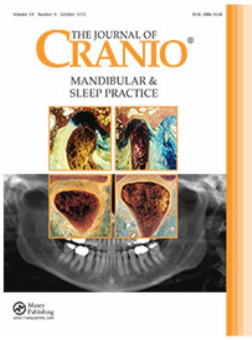

Taylor & Francis
Taylor & Francis Group

CRANIO®
The Journal of Craniomandibular & Sleep Practice

ISSN: 0886-9634 (Print) 2151-0903 (Online) Journal homepage: https://www.tandfonline.com/loi/ycra20

Effect of laterotrusive occlusal scheme on chewing duration, external intercostal muscular activity, heart rate, and oxygen saturation

Rodolfo Miralles, Saúl Valenzuela, Camila Marambio, Natalia Andrea Gamboa, Aler Daniel Fuentes, Hugo Santander, Mario Felipe Gutiérrez, Claudia Zúñiga & Ricardo Bull

To cite this article: Rodolfo Miralles, Saúl Valenzuela, Camila Marambio, Natalia Andrea Gamboa, Aler Daniel Fuentes, Hugo Santander, Mario Felipe Gutiérrez, Claudia Zúñiga & Ricardo Bull (2020): Effect of laterotrusive occlusal scheme on chewing duration, external intercostal muscular activity, heart rate, and oxygen saturation, CRANIO®, DOI: 10.1080/08869634.2020.1757893

To link to this article: https://doi.org/10.1080/08869634.2020.1757893

Published online: 03 May 2020.

CRANIO®: THE JOURNAL OF CRANIOMANDIBULAR & SLEEP PRACTICE
https://doi.org/10.1080/08869634.2020.1757893

OCCLUSION

Effect of laterotrusive occlusal scheme on chewing duration, external intercostal muscular activity, heart rate, and oxygen saturation

Rodolfo Miralles DDS [a], Saúl Valenzuela DDS [a,b], Camila Marambio BDent[b], Natalia Andrea Gamboa DDS [a,b], Aler Daniel Fuentes DDS, MSc, PhD [a,b], Hugo Santander DDS [a], Mario Felipe Gutiérrez DDS, MSc, PhD [a,b], Claudia Zúñiga DDS, MSc [a,c] and Ricardo Bull MD [a]

[a]Faculty of Medicine, Oral Physiology Laboratory, Biomedical Sciences Institute, University of Chile, Santiago, Chile; [b]Faculty of Dentistry, Institute for Research in Dental Sciences, University of Chile, Santiago, Chile; [c]Faculty of Dentistry, Universidad Finis Terrae, Santiago, Chile

ABSTRACT

Objective: To evaluate the effect of the laterotrusive occlusal scheme on chewing duration, external intercostal (EIC) electromyographic (EMG) activity, heart rate (HR), and oxygen saturation (OS) during different tasks in the upright seated position.
Methods: Fifty young participants, 25 with canine guidance and 25 with group function, were included. Chewing duration, bilateral EIC EMG activity, HR, and OS were recorded during the following tasks: 1) chewing until swallowing threshold; 2) laterotrusive teeth grinding.
Results: Chewing duration, bilateral EIC EMG activity, HR, and OS showed no significant differences between the two laterotrusive occlusal schemes during the tasks studied.
Conclusion: These results suggest that chewing duration, EIC muscle activity, HR, and OS were not significantly influenced by the laterotrusive occlusal scheme. Therefore, when a modification of the laterotrusive occlusal scheme is needed during oral rehabilitation or orthodontic treatment, canine guidance or group function should not significantly change EMG activity of EIC muscles.

KEYWORDS
Canine guidance; group function; chewing; teeth grinding; heart rate; oxygen; saturation; electromyography

Introduction

Teeth grinding is an activity of major concern to dentists because of its consequences: tooth destruction, breakage of dental restoration or rehabilitation, exacerbation of temporomandibular disorders, induction of headache, and grinding sounds that may interfere with the sleep of family or life partners [1]. It is an unconscious oral parafunctional activity, contrary to normal functions, such as speech, breathing, chewing, and swallowing. Teeth grinding is characterized by different intensity and periodic repetition [2] and is prevalent in all age groups, social classes, and cultures [3–10].

EMG recordings during teeth grinding from intercuspal position (IP) to lateral edge-to-edge contact position (eccentric grinding) and vice versa (concentric grinding) have been reported for anterior temporalis [11], masseter [12], sternocleidomastoid [13], supra- and infrahyoid [14,15], and diaphragm muscles [16], between subjects with different laterotrusive occlusal schemes such as canine guidance (CG) and group function (GF). To the authors' knowledge, external intercostal (EIC) EMG activity during teeth grinding has not been previously reported in subjects with CG or GF. In addition, none of the aforementioned studies recorded EMG activity during chewing, which is an essential biologic function that aims to prepare a food bolus to be acceptable for swallowing and the subsequent digestive and metabolic activities [17].

EMG recording is a non-invasive method that can be used to evaluate the work of EIC muscles during chewing and teeth grinding in subjects with CG or GF, since it is well known that there is a linear relationship between the electrical activity and the force developed by a muscle, and therefore, the muscular work [18–20]. In addition, surface EMG provides objective, valid, and reproducible data on muscle contractions [21–23].

It is important to know about the activity of EIC muscles during chewing since it is a frequent function in humans, as well as during teeth grinding because of their prevalence [7,8,24–27], and the fact that dentists may modify the laterotrusive occlusal scheme during oral rehabilitation procedures or orthodontic treatment.

On the other hand, heart rate (HR) and oxygen saturation (OS) have been measured in episodes of teeth grinding during sleep [1,28–34] and, recently, during teeth grinding [16], but not chewing in wakefulness.

CONTACT Rodolfo Miralles rmiralle@med.uchile.cl Oral Physiology Laboratory, Biomedical Sciences Institute, Faculty of Medicine, University of Chile, Independencia 1027, Independencia, Santiago 838-0453, Chile

Recently, the comparison of the mean HR in 35 patients with symptoms of bruxism (study group) and 25 asymptomatic patients (control group) showed a statistically significant difference. The study group showed an average HR lower than the control group [28], in contrast with a previous study that characterized sleep bruxism as short tachycardic outbursts [35]. On the other hand, it was suggested that the mild transient hypoxia observed before rhythmic masticatory muscle activity onset was not associated with a change in end-tidal CO_2. Moreover, the mild and brief fluctuations in OS (hypoxia) before rhythmic masticatory muscle activity onset may reflect a physiological response during sleep with little influence on sleep bruxism genesis [36].

A higher EIC activity with a type of laterotrusive occlusal scheme during chewing and teeth grinding could be a risk factor for exceeding the adaptive capability of these muscles in healthy subjects, driving, in the long-term, to an imbalance of their respiratory system homeostasis.

Based on the aforementioned studies, there is a need to know the effect of canine guidance and group function on chewing duration, EIC EMG activity, HR, and OS. Therefore, this study compares the effect of the laterotrusive occlusal scheme on chewing duration, EIC EMG activity, HR, and OS in the context of activities of the cranio-cervical-mandibular unit.

Materials and methods

Ethics approval

Protocols were based on ethical principles originating in the Declaration of Helsinki. This study was approved by the ethical-scientific committee of the Faculty of Dentistry of the University of Chile (18/006). Participants gave informed written consent before participating in the study after a detailed explanation of the experimental protocol and the possible risks involved. They could withdraw from the study at any point in time.

Participants

This cross-sectional study included 50 young male participants, who were recruited from the Dental and Medical School of the University of Chile. Participants were male to avoid difficulties with breast size, asymmetry of breasts, and the use of a bra in the female students during the EMG recordings. To be included, all participants had to have complete natural dentition (excluding the third molars), bilateral canine guidance or group function, Class I or II canine relationship, no presence of unilateral or bilateral crossbite, no current or history of orthodontic treatment within the last 12 months, no history or presence of orofacial or craniomandibular pain, no fractured teeth, no large restorations that included an incisal edge on one or more cusps, no cardiovascular, hematological or respiratory diseases, and no ingestion of medication that could affect their muscle activity.

To determine the laterotrusive occlusal scheme, the participants were asked to bite in their IP and then to slide the mandible from IP position to an edge-to-edge contact position for both right and left sides. Two clinicians performed all clinical examinations. An agreement of both examiners was needed for a participant's selection. Consistency in the clinical diagnosis across the examiners was high, and when there was no agreement, the subject was excluded.

Participants were asked about their most frequently used side during chewing (working side). The opposite side was referred to as the non-working side. If they had no clear preference, they had to chew a fruit chew candy to determine it visually. The period during which the examiners selected the sample was 12 weeks.

The body mass index (BMI) was obtained for each participant, dividing the weight (kg) by the square of the height (m^2). Age and BMI were used to confirm the homogeneity of both groups.

The selected sample included the following two groups of 25 participants each, according to their type of laterotrusive occlusal scheme (Table 1):

(1) Canine guidance, with only upper and lower canines in contact on the working side and no occlusal contact on the non-working side for both right and left lateral excursion (mean age 20.64 ± 2.34 years; range 17 to 28 years);
(2) Group function, with premolars and first molars other than canines in contact on the working side and no contact on the non-working side for both left and right lateral excursions (mean age 21.56 years ± 2.20; range 18 to 26 years).

The sample size was calculated according to a pilot study, considering the EMG activity of the EIC muscle during chewing on the working side of three participants of each group (canine guidance, mean = 3.92 ± 0.94; group function, mean = 4.64 ± 0.66). Size effect was calculated according to Cohen's d test (0.89) and based on a significance level of 0.05 and a power of 80%; finally, the sample size calculated was 21 participants for each group. The G*Power program, version 3.1.9.3 was used (University of Düsseldorf, Germany, 2017, available at: http://www.gpower.hhu.de).

Table 1. Characteristics of study participants.

Canine Guidance			Group Function		
Participant	Age	BMI	Participant	Age	BMI
1	19	24.69	1	18	26.09
2	20	21.19	2	21	19.86
3	23	21.87	3	21	23.05
4	19	21.32	4	23	23.99
5	22	20.21	5	21	22.50
6	18	22.58	6	21	20.46
7	17	24.43	7	24	23.41
8	19	20.21	8	22	23.20
9	21	26.23	9	26	22.52
10	23	24.07	10	23	23.14
11	20	26.69	11	20	28.75
12	23	21.91	12	22	22.68
13	21	27.12	13	20	21.07
14	23	28.32	14	18	20.26
15	20	20.79	15	20	23.63
16	21	22.07	16	21	21.33
17	20	22.11	17	23	22.07
18	28	25.95	18	22	28.43
19	20	21.68	19	20	21.90
20	23	25.93	20	26	24.91
21	20	20.37	21	20	22.58
22	18	20.30	22	20	24.22
23	19	22.84	23	21	26.26
24	18	22.53	24	26	20.80
25	21	20.07	25	20	20.72

BMI: Body mass index.

All participants were asked to perform the following tasks three times in one single session:

- Long chewing: each participant had to chew a fruit chew candy (Frugelé, Ambrosoli®, Carozzi®; Santiago, Chile) on the working side until their swallowing threshold.
- Teeth grinding: each participant had to grind strongly and continuously from IP to edge-to-edge position on the working side and vice versa for 10 s, while they performed the movement following a metronome at 50 pulses/m.

Before the participants performed the tasks, an examiner explained to each one the conditions so they could perform them correctly.

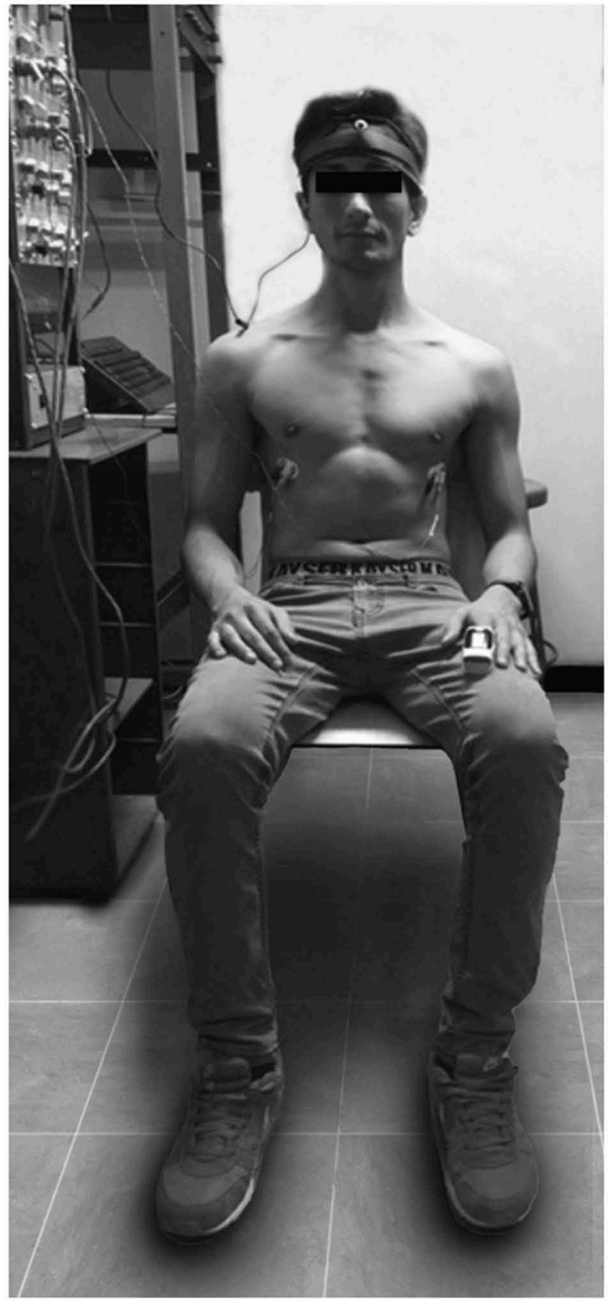

Figure 1. Participant seated in upright position with electrodes positioned.

Chewing duration

For chewing duration, the entire duration of long chewing was measured in seconds. The average value of three records was used for comparison between the two groups.

Electromyography

Bipolar surface electrodes (BioFLEX, BioRESEARCH Associates, Inc., Brown Deer, WI, USA) were placed bilaterally on the EIC muscles (Figure 1). Careful skin abrasion with alcohol was performed to decrease impedance on the right and left sides. Both electrodes were located bilaterally in the fifth intercostal space in relation to a vertical line that passes through the clavicular midline and the center of the nipple, positioning the medial edge of the electrode in relation to this vertical line [37]. A large surface ground electrode (approximately 9 cm^2) was attached to the forehead. The electrode impedance between both electrodes was measured (Kaise Electric Works, LTD., Model SK-200, Japan); maximal acceptable impedance was 10 KΩ. EMG activity was recorded using a 2-channel computerized instrument with amplified (Model 7P5B preamplifier, Grass Instrument Co., Quincy, MA, USA) and filtered signals (110 Hz high pass and 2 kHz low pass), with a common mode rejection ratio higher than 100 dB. The output was filtered again (notch frequency of 50 Hz), full-wave rectified and then integrated (time constant of 0.1 s) and recorded online on a computer exclusively dedicated to the acquisition and processing of EMG signals. The EMG signal was acquired at a sample rate of 200 Hz (50 Hz each channel) with a 12 bits A/D converter (MAX191) connected to the computer through an RS-232 port. The system was calibrated before each recording. EMG activity was recorded while the participant was in the seated upright position, eyes open and looking straight ahead, with the head unsupported, his back supported on the chair, hands on the lap, and feet resting on the floor.

In order to standardize the duration of EIC EMG activity, the first 10 s of the three long chewing recording were measured, which was called "short chewing." After that, three recordings of bilateral EIC EMG activity during teeth grinding were performed, with a duration of 10 s each. EMG activity during short chewing as well as teeth grinding was measured. To obtain the average value of each recording, measurements were performed every 0.1 s using a computer program. The average value of three EMG recordings for each task was used for comparison between canine guidance and group function.

The sequence of long chewing or teeth grinding task was assigned by a random function program (Excel, Microsoft Corporation, Redmond, WA, USA). A 20 s resting period was allowed between each task.

Heart rate and oxygen saturation

HR and OS were measured by means of a fingertip pulse oximeter (Choicemmed® model 300-C2, Beijing, China) placed on the index finger of the left hand of the participant. A baseline measurement was performed before the first task. Posteriorly, at the end of each recording of long chewing and teeth grinding, HR and OS were measured. For each participant, baseline and the mean value of the three measurements of HR and OS were used for comparison between canine guidance and group function.

Statistical analysis

Age, BMI, HR, and OS presented a non-normal distribution ($p < 0.05$; Shapiro-Wilk test). Therefore, a Mann-Whitney U-test was used to compare these variables between the two groups.

Ladder transformation through different statistical functions was used to allow the normalization of EMG during short chewing and grinding; therefore, *t*-test was used to compare these variables between the two groups. The level of significance was set at $p < 0.05$. The data were analyzed using SPSS software (IBM SPSS Statistic ® v 21).

Results

The explanatory variables age and BMI (Table 1) did not show significant differences between the groups ($p > 0.05$).

Chewing duration

In participants with canine guidance, task-to-task variability was ≤ 5.60%; whereas, in the participants with group function, it was ≤ 7.26%. The chewing duration until swallowing threshold (long chewing) was similar between participants with canine guidance and group function ($p > 0.05$) (Table 2).

Electromyography

In participants with canine guidance, task-to-task variability on the working side was ≤ 25.1% and ≤ 28.2% for teeth grinding and short chewing, respectively. On the non-working side, it was ≤ 32.3% and ≤ 35.5%, respectively. In participants with group function, task-to-task variability on the working side was ≤ 18.8% and ≤ 17.4% for teeth grinding and short chewing, respectively. On the non-working side, it was ≤ 23.1% and ≤ 20.9%, respectively. EMG activity of EIC muscles during short chewing and teeth grinding EMG did not show significant differences between participants with canine guidance and group function on the working side or on the non-working side ($p > 0.05$; Table 3).

Heart rate and oxygen saturation

In participants with canine guidance, task-to-task variability of HR was ≤ 3.74% and ≤ 3.59% for long chewing and teeth grinding, respectively. In participants with group function, it was ≤ 3.74% and ≤ 2.93%, respectively.

Table 2. Comparison of chewing duration (s) until swallowing threshold, between participants with canine guidance and group function.

	Canine Guidance	Group Function	
	Median (IQR)	Median (IQR)	*p*-value
Long Chewing	50.00 (40.33 to 59.85)	48.73 (41.02 to 65.02)	0.92 NS

NS: Not Significant (Mann-Whitney *U*-test); s: second. IQR: Interquartile range.

Table 3. Comparison of external intercostal electromyographic activity (μV·s) between participants with canine guidance and group function.

Task	Side	Canine Guidance Mean ± SD	Group Function Mean ± SD	p-value
Short chewing	Working side	2.61 1.16	2.93 1.04	0.175 NS
	Non-working side	2.77 1.74	2.88 1.23	0.479 NS
Teeth grinding	Working side	2.39 0.96	2.76 1.01	0.166 NS
	Non-working side	2.57 1.39	2.63 1.15	0.768 NS

SD: Standard deviation; NS: Not Significant (t-test).

In participants with group function, task-to-task variability of OS was ≤ 0.05% and ≤ 0.07% for long chewing and teeth grinding, respectively. In participants with group function, it was ≤ 0.09% and ≤ 0.13%, respectively. The HR and OS showed no significant differences between the groups ($p > 0.05$; Table 4).

Discussion

Chewing duration

The similar chewing duration (long chewing) observed in both groups in the present study is in disagreement with Salsench et al. [38], who found that subjects with canine protection showed a higher chewing cycle duration than subjects with group function. Therefore, the current finding suggests that chewing duration until swallowing threshold is not modified by the type of laterotrusive occlusal scheme. Because the participants were chewing voluntarily, it suggests that the influences from the brain stem and cortical areas related to chewing are more powerful than the influences from the peripheral receptors of the stomatognathic system on the motor neuron pool controlling the activity of EIC muscles. Therefore, the finding of the present study seems to be in agreement with Hellsing [39], who concluded that during voluntary activity (as during long chewing), the motor activity might function without significant involvement of the peripheral mechanisms.

Electromyography

Since EIC EMG activity between participants with canine guidance and group function had not been compared until this work, the lack of significant differences between both laterotrusive occlusal schemes could not be compared with other studies. The finding of the present study implies new knowledge regarding bilateral EMG activity of the EIC muscles, which is different from their known primary function as “obligatory” muscles of respiration [40]. Therefore, the primary function of EIC muscles is performed during breathing and is not modified by the laterotrusive occlusal scheme during chewing and teeth grinding.

The similar EMG activity observed in the EIC muscles between participants with canine guidance and group function is in agreement with EMG activity recorded in the diaphragm muscle during teeth grinding between them [16]. It is important to note that, in this last study, diaphragm EMG activity was not recorded during chewing. Taking into consideration the results observed in the EIC muscles in the present study as well as in the diaphragm muscle [16], it seems that the influences from the brain stem and cortical areas related to respiration are more powerful than those from the peripheral receptors of the stomatognathic system on the motor neuron pool that controls the activity of diaphragm and EIC muscles.

The effect of both laterotrusive occlusal schemes on chewing duration, activity of EIC muscles, HR, and OS was similar. However, it is important to take into account findings showing that the significant decrease of EMG activity in the anterior temporalis [11,41–44], masseter [41–43], and sternocleidomastoid [13] muscles in patients with canine guidance, when compared with group function patients, is more relevant to the health of the masticatory system during oral rehabilitation procedures or orthodontic treatment.

It is important to consider that EMG activity of the EIC muscles recorded during teeth grinding in awake participants does not correspond to an activity during a bruxism episode, since neither of the participants was

Table 4. Comparison of heart rate (bmp) and oxygen saturation (%) during natural rate chewing until swallowing threshold and tooth grinding between participants with canine guidance and group function.

Variable	Task	Canine Guidance Median (IQR)	Group Function Median (IQR)	p-value
Heart rate	Baseline	69.00 (60.00 to 82.50)	72.89 (65.50 to 79.50)	0.50 NS
	Long chewing	76.33 (72.34 to 94.17)	80.00 (75.00 to 87.00)	0.55 NS
	Teeth grinding	66.67 (60.00 to 80.33)	71.67 (65.17 to 76.17)	0.42 NS
Oxygen saturation	Baseline	99.00 (99.00 to 99.00)	99.00 (99.00 to 99.00)	0.54 NS
	Long chewing	99.00 (99.00 to 99.00)	99.00 (98.67 to 99.00)	0.40 NS
	Teeth grinding	99.00 (99.00 to 99.00)	99.00 (98.84 to 99.00)	0.58 NS

NS: Not Significant (Mann-Whitney *U*-test); bmp: beats per minute; IQR: Interquartile range.

diagnosed with possible, probable, or definitive bruxism [45]; but people frequently grind their teeth [7,8,24–27], whether they are bruxers or not.

It must be kept in mind that the results of the present study were obtained in asymptomatic young participants. This is crucial because Chen et al. [46] observed that the frequency of non-functional tooth contact was approximately four times higher in patients with myogenous facial pain than in healthy subjects. Moreover, Funato et al. [47] found that patients with temporomandibular dysfunction have 3.6 times more non-functional tooth contacts than healthy subjects. Therefore, it could be important to replicate this study in patients with temporomandibular disorders, since upon increase of the frequency of teeth grinding episodes, the EMG activity of the EIC muscles may be different in participants with canine guidance vs. group function.

Heart rate and oxygen saturation

In the present study, HR and OS during chewing and teeth grinding were found to be similar in both groups. This is in agreement with the result observed in a recent study during teeth grinding [16], suggesting that sympathetic-vagal balance is not modified by the laterotrusive occlusal scheme. However, some studies have observed that rhythmic masticatory muscle activity/sleep bruxism episodes are related to autonomic cardiac variation such as tachycardia, due to a rise in the activity of the sympathetic nervous system [35,48–56]. Dumay et al. [31] found that a subgroup of subjects with sleep bruxism had minor transient hypoxia, potentially associated with the onset of rhythmic masticatory muscle activity/sleep bruxism episodes. A decrease in oxygen saturation may trigger a cascade of physiological events that activate the whole body by stimulating the sympathetic system and the respiratory muscles. It has been suggested that a hypoxia event can trigger a whole-body response to address any change in blood oxygen levels to preserve brain and whole-body integrity [32,34]. On the contrary, it is interesting to point out that, in a recent study [28], patients with symptoms of bruxism showed an average heart rate lower than those in asymptomatic patients.

Limitations of the study

This study has at least three limitations. First, the subjects examined were only male, which limits the ability to extrapolate these findings to the general population; second, surface electrodes on the chest could capture electrocardiogram (ECG) and/or activity from neighboring muscles; and third, the instruction given to participants to perform teeth grinding is not necessarily equivalent to a teeth grinding episode of bruxism performed by a symptomatic subject.

Conclusion

Chewing duration, external intercostal electromyographic activity, heart rate, and oxygen saturation were not significantly influenced by the type of laterotrusive occlusal scheme. These findings add new knowledge about the effect of the laterotrusive occlusal scheme on EMG activity of obligatory muscles of respiration. Therefore, when the laterotrusive occlusal scheme must be modified during oral rehabilitation or orthodontic treatment, this procedure should not significantly change EMG activity of EIC muscles.

Acknowledgments

Thanks to Mr. Juan Fernández, from the Language and Translation services of the Faculty of Dentistry, for kindly proofreading and checking the spelling and grammar of this paper.

Contributors

R.M., S.V., C.M., N.A.G., A.D.F., and H.S., contributed to conception, design, data acquisition, analysis and interpretation, drafted and critically revised the manuscript; M.F.G., C. Z., and R.B., contributed to design and data interpretation, drafted and critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of the work.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

No funding was received.

Ethics approval

Protocols based on ethical principles that have their origin in the Declaration of Helsinki were used (18/006).

ORCID

Rodolfo Miralles DDS http://orcid.org/0000-0001-8220-9788
Saúl Valenzuela DDS http://orcid.org/0000-0002-6881-3388
Natalia Andrea Gamboa DDS http://orcid.org/0000-0003-2604-2842

Aler Daniel Fuentes DDS, MSc, PhD http://orcid.org/0000-0003-2040-2376
Hugo Santander DDS http://orcid.org/0000-0001-8533-2773
Mario Felipe Gutiérrez DDS, MSc, PhD http://orcid.org/0000-0002-1827-5956
Claudia Zúñiga DDS, MSc http://orcid.org/0000-0001-8699-025X
Ricardo Bull MD http://orcid.org/0000-0003-0576-1311

References

[1] Lavigne GJ, Khoury S, Abe S, et al. Bruxism physiology and pathology: an overview for clinicians. J Oral Rehabil. 2008;35(7):476–494.
[2] Demjaha G, Kapusevska B, Pejkovska-Shahpaska B. Bruxism unconscious oral habit in everyday life. Open Access Maced J Med Sci. 2019;7(5):876–881.
[3] Baad-Hansen L, Thymi M, Lobbezoo F, et al. To what extent is bruxism associated with musculoskeletal signs and symptoms? A systematic review. J Oral Rehabil. 2019;46(9):845–861.
[4] Kardes S, Kardes E. Seasonality of bruxism: evidence from Google trends. Sleep Breath. 2019;23(2):695–701.
[5] Zani A, Lobbezoo F, Bracci A, et al. Ecological momentary assessment and intervention principles for the study of awake bruxism behaviors, Part 1: general principles and preliminary data on healthy young Italian adults. Front Neurol. 2019;10:169.
[6] Lobbezoo F, Ahlberg J, Raphael KG, et al. International consensus on the assessment of bruxism: report of a work in progress. J Oral Rehabil. 2018;45(11):837–844.
[7] Progiante PS, Pattussi MP, Lawrence HP, et al. Prevalence of temporomandibular disorders in an adult Brazilian community population using the research diagnostic criteria (Axes I and II) for temporomandibular disorders (The Maringá Study). Int J Prosthodont. 2015;28(6):600–609.
[8] Manfredini D, Restrepo C, Diaz-Serrano K, et al. Prevalence of sleep bruxism in children: a systematic review of the literature. J Oral Rehabil. 2013;40(8):631–642.
[9] Baba K, Haketa T, Sasaki Y, et al. Association between masseter muscle activity levels recorded during sleep and signs and symptoms of temporomandibular disorders in healthy young adults. J Orofac Pain. 2005;19(3):226–231.
[10] Glaros AG, Williams K, Lausten L. The role of parafunctions, emotions and stress in predicting facial pain. J Am Dent Assoc. 2005;136(4):451–458.
[11] Gutierrez MF, Miralles R, Fuentes A, et al. The effect of tooth clenching and grinding on anterior temporalis electromyographic activity in healthy subjects. CRANIO®. 2010;28(1):43–49.
[12] Campillo MJ, Miralles RSantander H, et al. Influence of laterotrusive occlusal scheme on bilateral masseter emg activity during clenching and grinding. Cranio®. 2008;26(4):263–73.
[13] Rodríguez K, Miralles R, Gutiérrez MF, et al. Influence of jaw clenching and tooth grinding on bilateral sternocleidomastoid EMG activity. CRANIO®. 2011;29(1):14–22.
[14] Valenzuela S, Portus C, Miralles R, et al. Bilateral supra- and infrahyoid EMG activity during eccentric jaw clenching and tooth grinding tasks in subjects with canine guidance or group function. CRANIO®. 2012;30(3):209–217.
[15] Valenzuela S, Baeza M, Miralles R, et al. Laterotrusive occlusal schemes and their effect on supra- and infrahyoid electromyographic activity. Angle Orthod. 2006;76(4):585–590.
[16] Valenzuela S, Miralles RMuñoz MI, et al. Awake teeth grinding in participants with canine guidance or group function: effect on diaphragm emg activity, heart rate, and oxygen saturation. CRANIO®. 2019.
[17] Peyron MA, Woda A, Bourdiol P, et al. Age-related changes in mastication. J Oral Rehabil. 2017;44(4):299–312.
[18] Lippold OCJ. The relation between integrated action potentials in a human muscle and its isometric tension. J Physiol. 1952;117(4):492–499.
[19] Kawazoe Y, Kotani H, Hamada T. Relation between integrated electromyographic activity and biting force during voluntary isometric contraction in human masticatory muscles. J Dent Res. 1979;58(5):1440–1449.
[20] Bakke M, Michler L, Han K, et al. Clinical significance of isometric bite force versus electrical activity in temporal and masseter muscles. Scand J Dent Res. 1989;97(6):539–551.
[21] Hugger S, Schindler HJ, Kordass B, et al. Clinical relevance of surface EMG of the masticatory muscles. (Part 1): resting activity, maximal and submaximal voluntary contraction, symmetry of EMG activity. Int J Comput Dent. 2012;15(4):297–314.
[22] Lund JP, Widmer CG. Evaluation of the use of surface electromyography in the diagnosis, documentation, and treatment of dental patients. J Craniomandib Disord. 1989;3(3):125–137.
[23] Giannakopoulos NN, Schindler HJ, Hellmann D. Co-contraction behaviour of masticatory and neck muscles during tooth grinding. J Oral Rehabil. 2018;45(7):504–511.
[24] Cavallo P, Savarese G, Carpinelli L. Bruxism and health related quality of life in southern Italy's prison inmates. Community Dent Health. 2014;31(2):117–122. [cited 2020 Mar 16]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25055610
[25] Machado E, Dal-Fabbro C, Cunali PA, et al. Prevalence of sleep bruxism in children: a systematic review. Dental Press J Orthod. 2014;19(6):54–61.
[26] Vieira-Andrade RG, Drumond CL, Martins PA, et al. Prevalence of sleep bruxism and associated factors in preschool children. Pediatr Dent. 2014;36(1):46–50.
[27] Lobbezoo F, Ahlberg J, Manfredini D, et al. Are bruxism and the bite causally related? J Oral Rehabil. 2012;39(7):489–501.
[28] Saczuk K, Lapinska B, Wilmont P, et al. The Bruxoff device as a screening method for sleep bruxism in dental practice. J Clin Med. 2019;8(7):930.
[29] Martynowicz H, Dymczyk P, Dominiak M, et al. Evaluation of intensity of sleep bruxism in arterial hypertension. J Clin Med. 2018;7(10):327.

[30] Mayer P, Heinzer R, Lavigne G. Sleep bruxism in respiratory medicine practice. Chest. 2016;149(1):262–271.

[31] Dumais IE, Lavigne GJ, Carra MC, et al. Could transient hypoxia be associated with rhythmic masticatory muscle activity in sleep bruxism in the absence of sleep-disordered breathing? A preliminary report. J Oral Rehabil. 2015;42(11):810–818.

[32] Freet CS, Stoner JF, Tang X. Baroreflex and chemoreflex controls of sympathetic activity following intermittent hypoxia. Auton Neurosci. 2013;174(1–2):8–14.

[33] Carra MC, Huynh N, Lavigne G. Sleep bruxism: a comprehensive overview for the dental clinician interested in sleep medicine. Dent Clin North Am. 2012;56 (2):387–413.

[34] Ziegler MG, Milic M, Elayan H. Cardiovascular regulation in obstructive sleep apnea. Drug Discov Today Dis Model. 2011;8(4):155–160.

[35] Okeson JP, Phillips BA, Berry DTR, et al. Nocturnal bruxing events: a report of normative data and cardiovascular response. J Oral Rehabil. 1994;21(6):623–630.

[36] Suzuki Y, Rompré P, Mayer P, et al. Changes in oxygen and carbon dioxide in the genesis of sleep bruxism: a mechanism study. J Prosthodont Res. 2020;64(1):43–47.

[37] Hawkes EZ, Nowicky AV, McConnell AK. Diaphragm and intercostal surface EMG and muscle performance after acute inspiratory muscle loading. Respir Physiol Neurobiol. 2007;155(3):213–219.

[38] Salsench J, Martínez-Gomis J, Torrent J, et al. Relationship between duration of unilateral masticatory cycles and the type of lateral dental guidance: a preliminary study. Int J Prosthodont. 2005;18 (4):339–346. [cited 2020 Mar 16]. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16052790

[39] Hellsing G. On the regulation of interincisor bite force in man. J Oral Rehabil. 1980;7(5):403–411.

[40] Hudson AL, Gandevia SC, Butler JE. Control of human inspiratory motoneurones during voluntary and involuntary contractions. Respir Physiol Neurobiol. 2011;179(1):23–33.

[41] Williamson EH, Lundquist DO. Anterior guidance: its effect on electromyographic activity of the temporal and masseter muscles. J Prosthet Dent. 1983;49(6):816–823.

[42] Shupe RJ, Mohamed SE, Christensen LV, et al. Effects of occlusal guidance on jaw muscle activity. J Prosthet Dent. 1984;51(6):811–818.

[43] Manns A, Chan C, Miralles R. Influence of group function and canine guidance on electromyographic activity of elevator muscles. J Prosthet Dent. 1987;57(4):494–501.

[44] Akoren AC, Karaagaclioglu L. Comparison of the electromyographic activity of individuals with canine guidance and group function occlusion. J Oral Rehabil. 1995;22(1):73–77.

[45] Lobbezoo F, Ahlberg J, Glaros AG, et al. Bruxism defined and graded: an international consensus. J Oral Rehabil. 2013;40(1):2–4.

[46] Chen GY, Palla S, Erni S, et al. Nonfunctional tooth contact in healthy controls and patients with myogenous facial pain. J Orofac Pain. 2007;21(3):185–193.

[47] Funato M, Ono Y, Baba K, et al. Evaluation of the non-functional tooth contact in patients with temporomandibular disorders by using newly developed electronic system. J Oral Rehabil. 2014;41 (3):170–176.

[48] Kato T, Rompré P, Montplaisir JY, et al. Sleep bruxism: an oromotor activity secondary to micro-arousal. J Dent Res. 2001;80(10):1940–1944.

[49] Macaluso GM, Guerra P, Di Giovanni G, et al. Sleep bruxism is a disorder related to periodic arousals during sleep. J Dent Res. 1998;77(4):565–573.

[50] Huynh N, Kato T, Rompré PH, et al. Sleep bruxism is associated to micro-arousals and an increase in cardiac sympathetic activity. J Sleep Res. 2006;15(3):339–346.

[51] Nashed A, Lanfranchi P, Rompré P, et al. Sleep bruxism is associated with a rise in arterial blood pressure. Sleep. 2012;35(4):529–536.

[52] Bader GG, Kampe T, Tagdae T, et al. Descriptive physiological data on a sleep bruxism population. Sleep. 1997;20(11):982–990.

[53] Bader G, Lavigne G. Sleep bruxism; an overview of an oromandibular sleep movement disorder. Review Article Sleep Med Rev. 2000;4(1):27–43.

[54] Sjöholm TT, Piha SJ, Lehtinen I. Cardiovascular autonomic control is disturbed in nocturnal teethgrinders. Clin Physiol. 1995;15(4):349–354.

[55] Marthol H, Reich S, Jacke J, et al. Enhanced sympathetic cardiac modulation in bruxism patients. Clin Auton Res. 2006;16(4):276–280.

[56] Satoh T, Harada Y. Electrophysiological study on tooth-grinding during sleep. Electroencephalogr Clin Neurophysiol. 1973;35(3):267–275.