INDIVIDUAL FEATURES OF THE MASTICATORY MUSCLE BIOELECTRICAL ACTIVITY IN ORGANIZATION OF CHEWING FUNCTION

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The chewing experience acquired during ontogeny may lead to developing functional asymmetry of the masticatory apparatus, adversely affecting the maxillofacial region functions. The study aimed to assess asymmetry of the masticatory muscle activity in healthy individuals showing no dentofacial system dysfunction. In 17 volunteers (6 males, 11 females aged 18–23 years), motor functional asymmetry of the brain was assessed using standard motor tests, and surface electromyogram (EMG) of the masseter (MM) and temporalis muscle (TMs) was recorded on the right and left sides: in the resting state, with the maximum voluntary bite force, during deliberate unilateral mastication (alternately on the left and right sides), and bilateral voluntary chewing. Three groups with various asymmetry manifestations were distinguished and characterized based on the asymmetry indices of standard EMG parameters (integrated EMG (AIint), average amplitude (AIav), and chewing bursts duration (AId)) of the right and left muscles: 1) showing stable unilateral asymmetry of the MM and TM activity; 2) showing the “dynamic asymmetry” that was different for the MMs and TMs; 3) showing the “adaptive control”, when the muscle activity asymmetry was manifested adequately to the chewing test, and AIint of the MMs and TMs reached 40 ± 18% and 97 ± 20% during chewing on the left side, 242 ± 39% and 127 ± 32% during chewing on the right side, 115 ± 12% and 115 ± 24% during bilateral chewing. The major significant between-group differences in AIint, AIav, and AId were reported for the MMs (the impact of the “group” factor on these indices was as follows: $F = 11.0$, $p < 0.01$; $F = 5.72$ and $F = 3.73$, $p < 0.05$; repeated measures ANOVA). Thus, in young adulthood, some people develop functional asymmetry of the masticatory muscles in the form of excessive predominance of electrical activity on one side of the face with changes in both amplitude and duration of the “chewing” EMG bursts.

Keywords: chewing, electromyography, functional chewing asymmetry, masticatory muscles, neutral bite

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ИНДИВИДУАЛЬНЫЕ ОСОБЕННОСТИ АСИММЕТРИИ БИОЭЛЕКТРИЧЕСКОЙ АКТИВНОСТИ ЖЕВАТЕЛЬНЫХ МЫШЦ В ОРГАНИЗАЦИИ ЖЕВАТЕЛЬНОЙ ФУНКЦИИ

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Приобретаемый в онтогенезе опыт жевания может приводить к формированию функциональной асимметрии аппарата жевания с неблагоприятным влиянием на функции челюстно-лицевой области. Целью работы было оценить асимметрию активности жевательных мышц у здоровых людей без дисфункций зубочелюстной системы. У 17 добровольцев (6 мужчин, 11 женщин, 18–23 лет) проводили оценку моторной функциональной асимметрии мозга с помощью стандартных тестов и регистрацию поверхностной электромиограммы (ЭМГ) собственно-жевательных (СЖМ) и височных мышц (ВМ): в покое, при максимальном сжатии челюстей, при жевании — изолированном (поочередно на левой и правой сторонах) и произвольном. На основе индексов асимметрии показателей ЭМГ (общей площади (ИАинт), средней амплитуды (ИАср) и продолжительности жевания (ИАвр)) мышц справа и слева были выделены и описаны три группы с разными проявлениями асимметрии: 1) со стабильной односторонней асимметрией активности СЖМ и ВМ; 2) с «динамичной асимметрией», различной для СЖМ и ВМ; 3) с «адаптивным контролем», когда асимметрия активности мышц была адекватна жевательной пробе. В третьей группе ИАинт для СЖМ и ВМ был равен 40 ± 18% и 97 ± 20% при жевании на левой стороне, 242 ± 39% и 127 ± 32% — на правой, 115 ± 12% и 115 ± 24% при свободном жевании. Основные статистически значимые различия ИАинт, ИАср и ИАвр между группами выявлены для СЖМ (влияние фактора «группа» на данные индексы $F = 11{,}0$, $p < 0{,}01$; $F = 5{,}72$ и $F = 3{,}73$, $p < 0{,}05$; ANOVA repeated measures). Таким образом, в молодом возрасте у ряда людей формируется функциональная асимметрия жевательных мышц в виде избыточного преобладания электрической активности на одной стороне лица, с изменением как амплитудного, так и временного компонентов «жевательных» вспышек ЭМГ.

Ключевые слова: жевание, электромиография, функциональная асимметрия жевания, жевательные мышцы, нейтральный прикус

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Chewing represents a behavioral act culminating in the formation of the food bolus adequate for swallowing [1]. The program of action implemented by the hierarchically organized motor control system of the brain represents one of the key components of the functional system of any behavioral act [2]. The basic rhythmic activity of the masticatory muscles is provided by the brainstem motor program generator coordinating neuronal activity in the trigeminal motor nucleus innervating the masticatory muscles [2]. Excitation of these neurons during chewing is continuously adjusted by sensory signals from the dentofacial system, primarily from the periodontal mechanoreceptors and masticatory muscle proprioceptors [3], as well as from maxillofacial receptors of other types [4], which represents a key link of the innate, and therefore, involuntary mastication component. The cerebral cortex ensures supreme control of the brainstem chewing center via the corticobulbar tract [5–7], thereby also ensuring the conditioned and voluntary chewing component.

Shaping individual characteristics of masticatory activity is determined by the features of the maxillofacial region ontogeny, dentofacial system condition [8], as well as neurophysiology of the brain and chewing experience [9]. Adaptation to the development of the maxillofacial region functions during ontogeny, as well as interhemispheric features of the individual's motor control can result in individual functional asymmetry of chewing. Such asymmetry must manifest itself as predominant activity of the masticatory muscles on one side of the face, regardless of the current dominant side for chewing. Our objective was to assess the possibility of having the masticatory activity functional asymmetry in healthy young adults without any dentofacial system dysfunction. The study aimed to determine the dynamics and asymmetry of the masticatory muscle activity in healthy young volunteers in cases of forced and free chewing side change.

METHODS

Seventeen volunteers (6 males and 11 females, aged 18–23 years) participated in this study. The inclusion criteria: complete, intact dental arches with neutral occlusion (Angle class I on the left and right); no clinical symptoms of the temporomandibular joint (TMJ) abnormality. The exclusion criteria: age under 18 years, pregnancy, almond allergy, patient's refusal to take part in the study. At the beginning of the experiment procedure, motor functional asymmetry of the brain was assessed using standard motor tests (arm crossing test, "applause", leg crossing test) [10]. Then, surface electromyography (EMG) of both left and right masseter muscles (MMs) and temporalis muscles (TMs) was recorded using the 4-channel Synapsis EMG system for dental research (Neurotech, Taganrog, Russia). Pseudo-monopolar EMG electrodes were used. The resting-state EMG was recorded (10 s) with the maximum voluntary bite force (10 s) and during alternate chewing tests, in each of which the subject was chewing one almond nut: 1) deliberate unilateral mastication on the left side; 2) deliberate unilateral mastication on the right side; 3) bilateral voluntary chewing with changing the dominant side in a free manner convenient for the subject. EMG was recorded for 30 s in each chewing test, then the record's fragments from the beginning of mastication to initiation of the swallowing reflex were analyzed. An area

of the integrated EMG (μV*ms), mean voltage (Aav, μV) and duration (s) of the identified bursts were computed for each chewing stroke. The following parameters were measured: total integrated EMG, including the EMG amplitude and temporal characteristics; average amplitude of EMG bursts for the test — indicator showing high correlation with the force of muscle contraction [11]; total duration of the chewing strokes during the chewing test (chewing duration, s). To assess the asymmetry of the paired masticatory muscles' electrical activity, asymmetry indices were calculated for the right and left symmetrical muscles for each test using the formula (X right/X left) — 100%, where X represented an appropriate EMG indicator.

Statistical analysis of the study results was performed using the Statistica 12 software package (StatSoft Inc., USA). To analyze the differences in asymmetry indices based on the set of chewing tests, we used the repeated measures ANOVA (Fisher's *post-hoc* test), while one-way nonparametric Kruskall–Wallis ANOVA was used for the test with maximum bite force. Statistical significance of the differences (p) is shown in the figures.

RESULTS

Primary bilateral asymmetry of muscle's activity was assessed with the integrated EMG asymmetry index (AInt). The dynamic changes in Aint during chewing, test by test, were similar in 88% of subjects (Fig. 1). After switching from unilateral chewing on the left side to unilateral chewing on the right side, Aint rises, what indicates increased muscle activity on the right side compared to the left side. Then, Aint decreased again during bilateral voluntary chewing, remaining higher compared to the first chewing test (in 93% measurements) or similar (and 7%). We divided the subjects into three groups based on the shift of the Aint in accordance with changing the dominant side for chewing. Individuals of group I (with "stable asymmetry", $n = 6$) showed predominance of the MM's and TM's EMG activity on one side of the face in most tests, which was clearly visible in the bilateral chewing test. In two individuals of this group, the muscle's activity was greater on the right side (subgroup Ia; Aint > 100%), while in four individuals it was larger on the left side (subgroup Ib; Aint < 100%) (Fig.1). Individuals of group II (with "dynamic asymmetry", $n = 5$) demonstrated the oppositely directed manifestations of the MM's and TM's activity in some chewing tests. We included the subjects with the lack of the MM and TM adaptation to one or both isolated chewing tests that manifested itself in considerable (> 20%) predominance of appropriate activity on the side opposite to the dominant one in this group of subjects. Furthermore, the Aint reported for one paired muscle group was above 100%, while that for the other group was below 100% (Fig. 1). We assigned individuals, in whom activity of both muscles was larger on the dominant side compared to another side during the unilateral chewing tests, to group III (showing "adaptive control", $n = 6$) (Fig. 1). In three individuals, the dynamic changes in the Aint enabled inclusion in groups II and III. In two of them, TM activity was slightly greater on the right (≤ 20%), when chewing on the left side, in other cases adequate adaptation to chewing on one dominant side was observed. Although the right-sided TM asymmetry persisted in these individuals during bilateral chewing, the differences between the TMs and MMs in the degree of asymmetry decreased. That is why we assigned these subjects to group III. In the third subject, the TM activity was 12% larger on the left side compared to the other, when chewing on the right side, and this feature persisted during bilateral chewing with increasing degree of asymmetry that was oppositely directed in the TMs and MMs. This allowed us to include this subject in group II.

Unilateral masticatory muscle activity predominance revealed in groups Ia and Ib did not match predominance of the

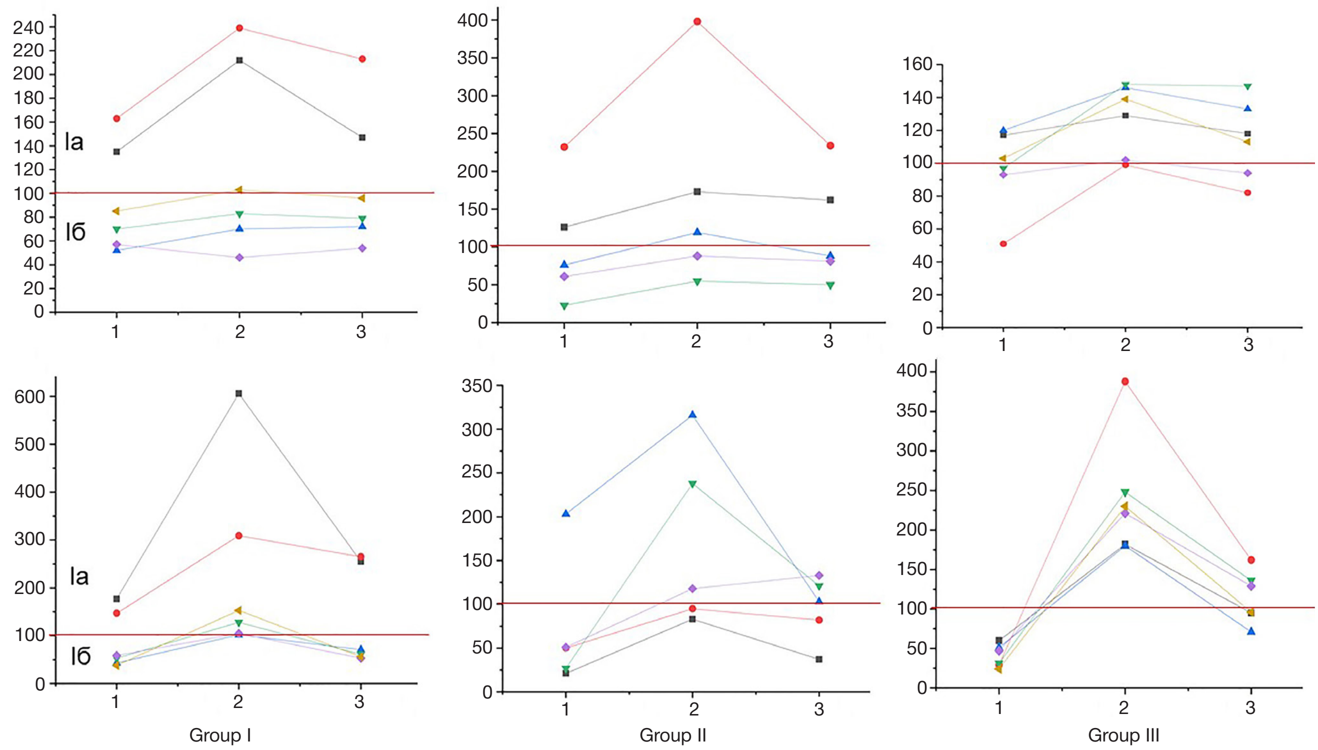

Fig. 1. Individual dynamics of the integrated AMG asymmetry index (Alint) in the identified groups. The x-axis represents the ordinal numbers of the chewing test (see Methods), and the *y*-axis represents Alint values (%). The upper row represents Alint of the temporal muscles, the lower row represents Alint of the masseter muscles. Each line shows individual Alint dynamics in a volunteer

right or left extremity movements during standard motor tests, reflecting the interhemispheric asymmetry in motor control (see Table).

As for the temporalis muscles, the ANOVA analysis revealed a significant impact of the "test" factor on the Alint ($F = 19.9$; $p < 0.0001$), as well as the trend towards interaction between the "group" and "test" ($p = 0.07$). The significant impact of the "test" ($F = 36.6$; $p < 0.0001$) and "group" ($F = 11.0$; $p < 0.01$) on the Alint was reported for the MMs, along with the significant interaction between the "group" and "test" factors ($F = 2.76$; $p < 0.05$).

In the identified groups, significant differences in the Alint values between the tests were reported for all groups, except for the Ib subgroup (Fig. 2). During unilateral chewing on the right side, the Alint significantly increased relative to the test involving chewing on the left side in subgroup Ia and group II for the TMs, in subgroup Ia, groups II, III for the MMs (post-hoc analysis). Later, during the bilateral chewing test the Alint values decreased in all groups. When comparing Alint during the chewing on the left side and bilateral chewing, the Alint values were significantly lower in the first test compared to bilateral chewing in group II for the TMs and in group III for the MMs.

Significant between-group differences in the Alint values were reported mainly for the MMs (Fig. 2B). The largest number of significant differences was reported for subgroup Ia in comparison with other groups. In the subjects of subgroup Ia, the Alint values were significantly higher compared to other groups in every test (except for the test involving chewing on the left side in the subjects of group II), which indicates marked predominance of the MM activity on the right side. In the subjects of subgroup Ib, the Alint values, in contrast, were significantly lower, than in the subjects of subgroup Ia, in all tests, and lower, than in individuals of group III in the test involving chewing on the right side. We found no significant between-groups differences in the Alint values during chewing tests in the subjects of groups II and III. In the voluntary bilateral chewing test, subjects of group I showed considerable deviation of the Alint values from 100% (> 100% in subgroup Ia and <100% in subgroup Ib), while in other groups the values of this index were close to 100%.

As for the temporalis muscles, significant between-group differences in the Alint values were reported only for the subjects of group I, during chewing on the right side (Fig. 2A). There was lower Alint in the subjects of subgroup Ib compared to the subjects of subgroup Ia and group II.

Then we compared manifestations of the mastication muscle activity asymmetry observed during chewing in the identified groups with the EMG integrated area asymmetry index in the test with maximum bite force (Almbf). In the subjects of subgroup Ia, the TM and MM activity was larger on the right side, while in the majority of subjects of subgroup Ib (75%), it was higher on the left side. In other groups, the majority of subjects showed the TM and MM activity predominance on the right relative to the left side (60 % in group II for both groups of muscles; 83% and 67% in group III for the TMs and MMs, respectively). The Almbf values of the groups are shown in Fig. 3. The differences between groups were non-significant.

Then we analyzed between-group differences in the asymmetry index of the average EMG amplitude (Alav) in the chewing tests. No significant impact of the "group" and "test"

Table. Percentage of subjects (%) with dominant movement of the right limbs in the identified groups

Ia	Iб	II	III
50%	75%	60%	67%

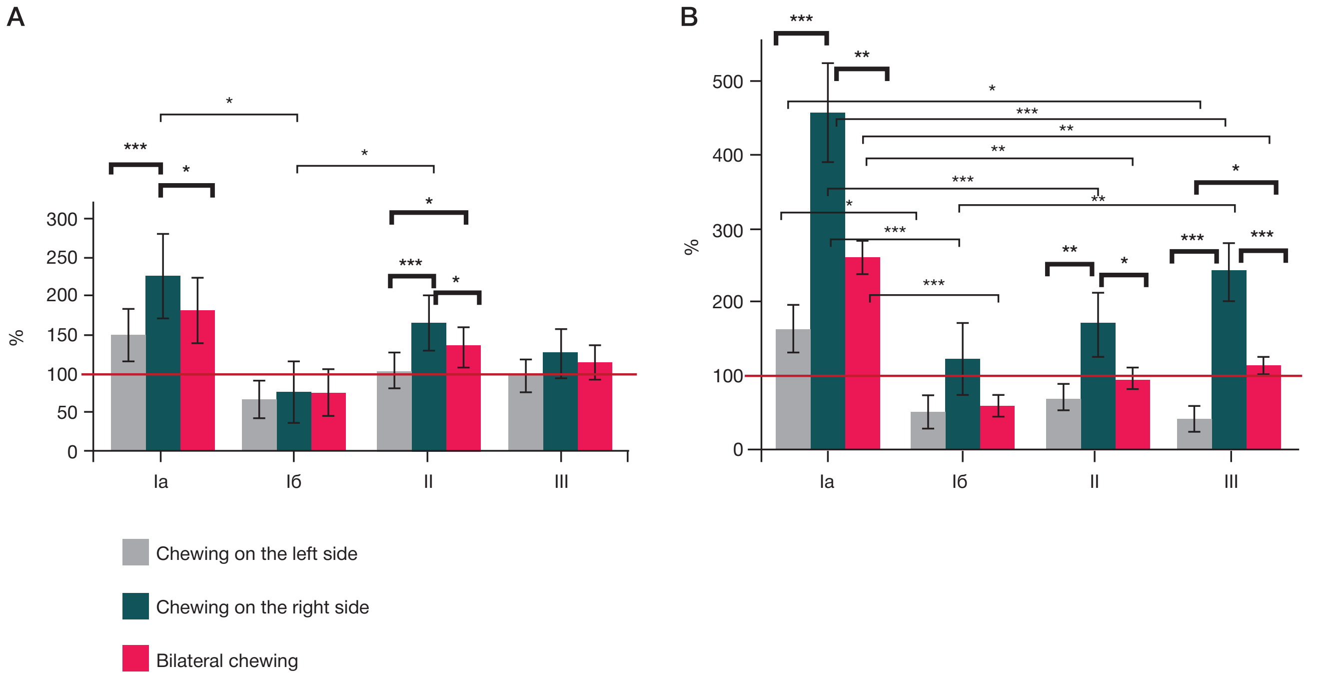

Fig. 2. The integrated EMG asymmetry index (Alint, %) in the chewing tests in the identified groups of volunteers. For each muscle, the bars represent intra-group mean Alint, the whiskers represent the SEM. The *red line* indicates the equal EMG activity of symmetrical muscles (Alint = 100%). **A**. Temporal muscles. **B**. Masseter muscles. Group designations: see text. Significant differences are indicated by *square brackets* above the bars (repeated measures ANOVA, Fisher's *post-hoc* test): within-group differences between the chewing tests are highlighted in *bold*, between-group differences reported during a similar chewing test are highlighted in the *light font* as follows: * — $p < 0.05$; ** — $p < 0.01$; *** — $p < 0.001$

factors on the Alav values was reported for the temporalis muscles. Here, the post-hoc analysis revealed only one between-group difference in Alav during chewing on the left side between subgroup Ib and group II (Fig. 4A).

Significant impact of the "group" ($F = 5.72$; $p = 0.01$) and "test" ($F = 34.17$; $p < 0.0001$) on the Alav values in the chewing tests was reported for the MMs. The dynamics of the Alav shifts test by test in MM was statistically significant in almost all groups. The Alav values increased during chewing on the right side relative to chewing on the left side (post-hoc analysis) in all subjects (Fig. 4B). In the bilateral chewing test, the Alav values significantly decreased in subgroup Ia, groups II, III, and showed a downward trend in subgroup Ib ($p = 0.07$).

The between-group differences in the Alav for the MMs were similar to the differences in the Alint (Fig. 4B). In the subjects of subgroup Ia, the Alav largely exceed 100% in all the tests, which reflected the larger strength of MM contraction on the right side. In the subgroup Ia, the Alav was significantly higher relative to subgroup Ib and group III during chewing on the left side, and higher than all other groups during chewing on the right side. In the bilateral chewing test, the Alav values of the subjects of subgroup Ia were significantly higher compared to the subjects of subgroup Ib, and showed an upward trend relative to the subjects of groups II and III ($p < 0.07$). In the subjects of subgroup Ib, the Alav values were far below 100% in the tests with chewing on the left side and bilateral chewing, which suggests significant predominance of masticatory muscles activity on the left side. The Alav values of the subjects of subgroup Ib were significantly lower compared to the subjects of subgroup Ia in all tests, and the subjects of group III during chewing on the right side. Furthermore, a downward trend of the Alav values relative to group II during chewing on the right side could be noted in the subjects of subgroup Ib ($p < 0.1$). There were no significant differences in the Alav values between group II and other groups. As it was for Alint, the average Alav values during bilateral chewing were much over 100% in the subjects of subgroup Ia, below 100% in subgroup Ib, close to 100% in groups II and III.

Then we assessed the asymmetry index of the total chewing EMG bursts duration ("chewing duration") in the chewing tests (Ald). Significant impact of the "test" factor on the Ald values was reported for the temporalis muscles ($F = 5.09$; $p < 0.05$). No between-group differences in the Ald values were reported for the TMs. The post-hoc analysis revealed significant within-group differences in the Ald values for the TMs between the tests of unilateral chewing on the left and right side in

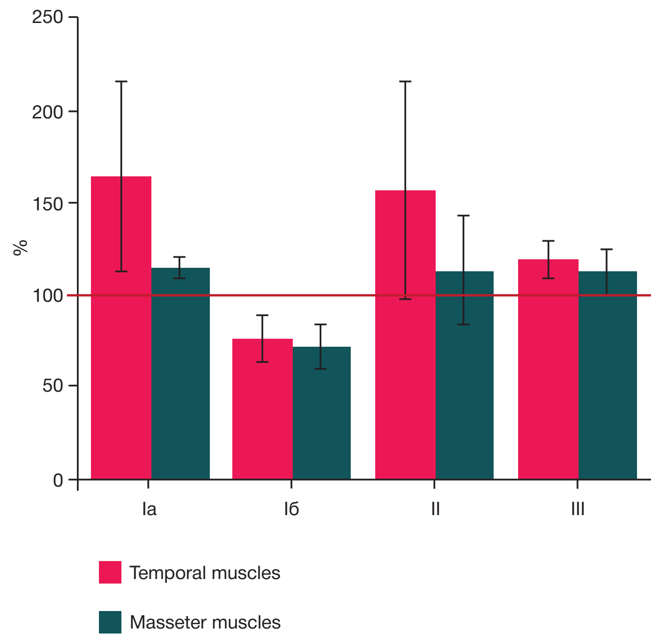

Fig. 3. The integrated EMG asymmetry index in the chewing test with maximum bite force (Almbf, %) in the identified groups of volunteers. For each muscle, the bars represent intra-group mean Almbf, the whiskers represent the SEM. The *red line* indicates the equal EMG activity of symmetrical muscles (Almbf = 100%). Group designations: see text

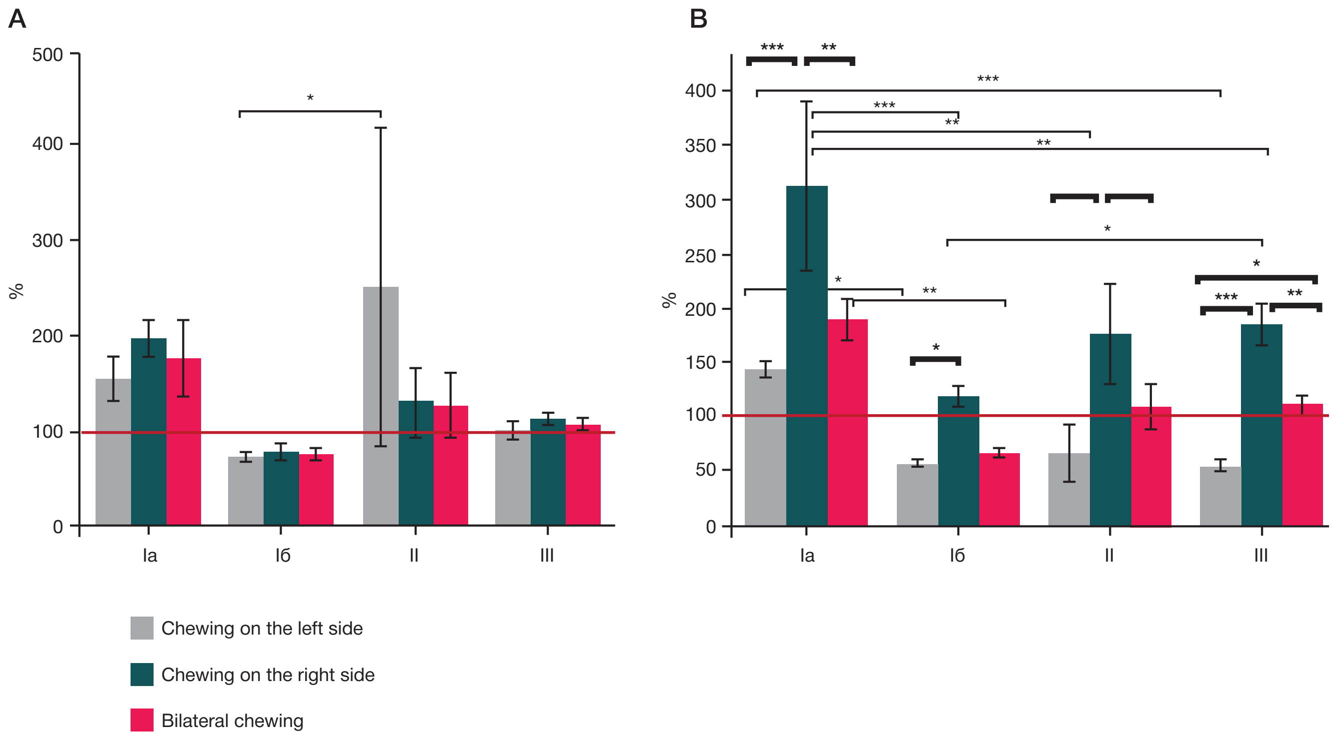

Fig. 4. The asymmetry index of the average EMG amplitude (AIav, %) in the chewing tests in the identified groups of volunteers. For each muscle, the bars represent intra-group mean AIav, the whiskers represent the SEM. The *red line* indicates the equal EMG activity of symmetrical muscles (AIav = 100%). **A**. Temporal muscles. **B**. Masseter muscles. Group designations: see text. Significant differences are indicated by *square brackets* above the bars (repeated measures ANOVA, Fisher's *post-hoc* test): within-group differences between the chewing tests are highlighted in *bold*, between-group differences reported during a similar chewing test are highlighted in the *light font* as follows: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

groups II and III (Fig. 5A). The average AId values of these groups corresponded to the test type: below 100% during chewing on the left side and over 100% during chewing on the right side.

Significant impact of the "group" factor on the AId values was reported for the MMs ($F = 3.73$; $p < 0.05$), along with the interaction between the "group" and "test" factors ($F = 2.97$; $p < 0.05$). Significant within-group differences in the AId

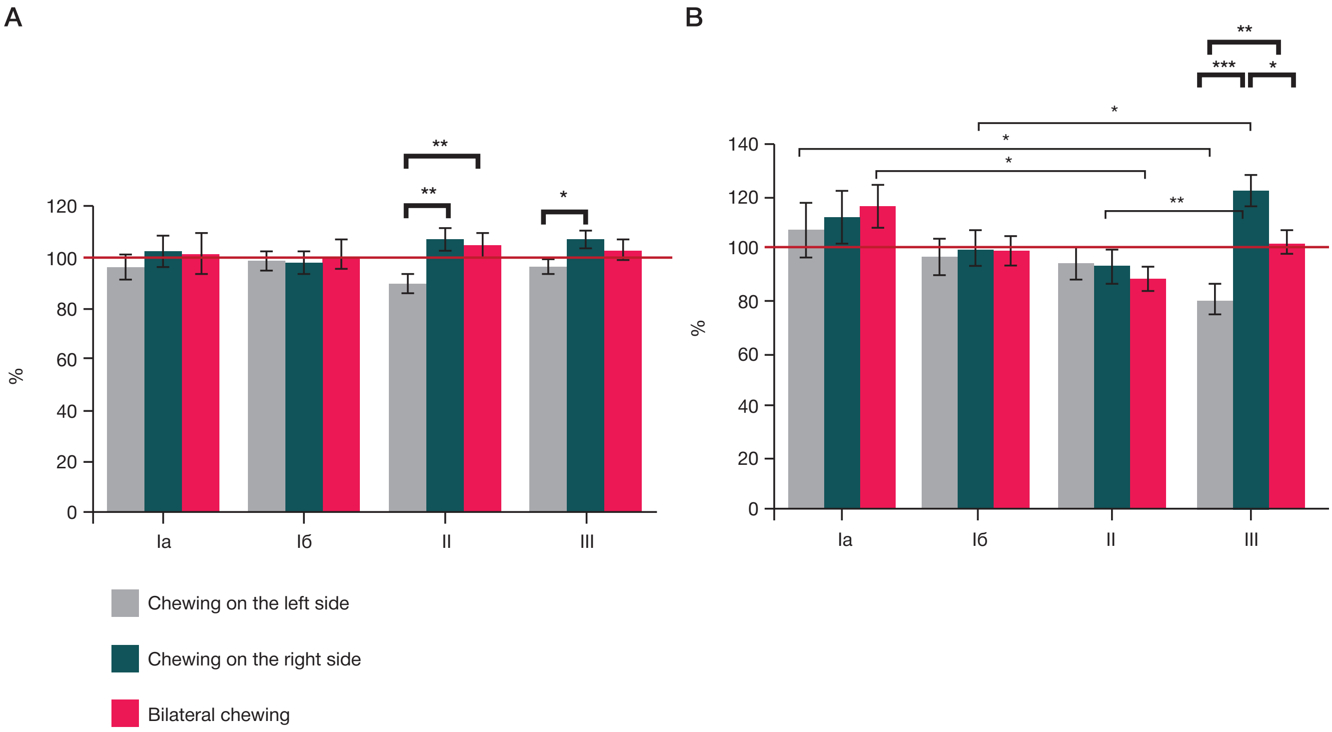

Fig. 5. The asymmetry index of the total chewing bursts duration in EMG (Aid, %) in the chewing tests in the identified groups of volunteers. For each muscle, the bars represent intra-group mean AId, the whiskers represent the SEM. The *red line* indicates the equal EMG activity of symmetrical muscles (AId = 100%). **A**. Temporal muscles. **B**. Masseter muscles. Group designations: see text. Significant differences are indicated by *square brackets* above the bars (repeated measures ANOVA, Fisher's *post-hoc* test): within-group differences between the chewing tests are highlighted in *bold*, between-group differences reported during a similar chewing test are highlighted in the *light font* as follows: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

between the tests were reported only for group III (*post-hoc* analysis; Fig. 5B), where the AId value was lowest during the test with unilateral chewing on the left side (below 100%), which suggests more prolonged MM activity on the left side. In the next test with chewing on the right side, the AId values increased well over 100% in the subjects of group III, which corresponded to more prolonged MM contraction on the right side (Fig. 5B). Then, in the bilateral chewing test, the AId values decreased significantly, getting close to 100%.

The greatest between-group differences in the MM AId values were reported in subgroup Ia, as it was with the other abovementioned asymmetry indices (Fig. 5B). Thus, in the subjects of subgroup Ia, the AId values were significantly higher, than in the subjects of group III in the test with chewing on the left side, compared to the subjects of group II in the bilateral chewing test. In the subjects of subgroup Ib and group II, the AId values were significantly lower, than in the subjects of group III in the test with chewing on the right side.

DISCUSSION

We have distinguished and described several asymmetry types for the activity of paired masticatory muscles based on the EMG data of the masticatory and temporalis muscles of the volunteers having complete intact dental arches with neutral occlusion (Angle I class on the left and on the right), without any clinical symptoms of the TMJ abnormality.

It has been shown that in 35% of subjects asymmetry of the overall electrical activity of paired muscles on the right and left corresponds to the masticatory goal during the chewing. When performing the unilateral chewing tests, activity of muscles of both types in these individuals was significantly larger on the dominant side, while no evident activity asymmetry was observed during bilateral chewing. Thus, the motor control associated with such mastication organization ensures adequate masticatory muscle involvement in the mastication program. That is why these study participants were referred to as the group showing “adaptive control”. The rest of participants showed maladaptive asymmetry of activity of the main masticatory muscles during unilateral and bilateral mastication. Furthermore, 35% of the study participants showed significant predominance of the masticatory muscle bioelectrical activity on one side of the face in all tests. The subjects with such mastication features were referred to as the group with “stable asymmetry”. Other 30% of participants demonstrated the oppositely directed MM and TM activity asymmetry manifestations during chewing, while they showed no predominance of activity on the dominant side for at least one of the studied pairs of muscles during unilateral chewing. This group was referred to as the group with “dynamic asymmetry”. The analysis of the EMG amplitude and temporal components during mastication in the subjects of these groups also revealed significant between-group differences in asymmetry of these indicators. Furthermore, the major differences were reported for the MMs: both between-group and between the tests within each group.

The available literature data on asymmetry of the electrical activity of the leading masticatory muscles in healthy individuals are rather controversial. This is likely to be due to different experimental design. Thus, in a number of studies asymmetry of the masticatory muscle EMG indicators was assessed using the test with maximum bite force only [12, 13]. However, as shown in our study, no full match of the sign of asymmetry of the paired masticatory muscles is observed with maximum bite force and during chewing of the natural substrate. Despite the fact that the trend towards predominance of the MM and TM electrical activity on one side of the face in the test with maximum bite force is preserved in the group with “stable asymmetry”, we have found no significant differences in the integrated EMG asymmetry index values between groups. Since voluntary jaw clenching and chewing food represent behavioral responses of different types aimed at achieving different results, it is reasonable to assume the differences in motor program organization during execution of these tests. In other studies, the masticatory muscle electrical activity was assessed only during unilateral chewing [14, 15], which did not provide a comprehensive view of the mastication motor control organization. Furthermore, the masticatory muscle activity asymmetry is usually assessed without allocating subgroups in accordance with the asymmetry patterns in different tests [13, 15, 16]. This makes comparison of our results with the literature data on assessing the masticatory muscle asymmetry difficult. However, the facts reported in the papers on the topic allow us to suggest what mechanisms underly the identified differences in the masticatory muscle activity asymmetry in the groups we have identified.

The masticatory muscle activity ratio reported during chewing reflects primarily the features of motor control. The lack of TMJ abnormalities, bite abnormalities, and dental lesions in the study participants suggest the key effect of behavioral features on developing the masticatory muscle function asymmetry. The functional interhemispheric asymmetry manifested by dominance of certain arm or leg during movement might be one such factor. The motor tests we have performed [10] have revealed predominance of right-handed individuals in each of the identified groups. This suggests that there is no direct relationship between the presence of interhemispheric asymmetry in organization of motor control of the limbs and masticatory muscles, which seems logical due to various types of behavior involving these groups of muscles.

In our opinion, the lack of the exact match between manifestations of bilateral masticatory muscle activity asymmetry with maximum bite force and during chewing demonstrates different cortical organization of the fast and slow motor unit recruiting in the masticatory muscle contraction during execution of the habitual behavioral action (chewing of food) and in the unfamiliar nonspecific jaw clench test.

It is interesting that the majority of between-group differences in masticatory asymmetry were reported for the MMs. According to the available literature data, the MM and TM control on the right and left side is performed in concert, which, for example, is reflected in the existence of significant correlations between the EMG activity of muscles on the left and right side, as well as between the activity of the right MM and both TMs in the test with maximum bite force [8]. This ensures coordination of muscle contraction during chewing. However, motor control of each muscle is specific, which is, in particular, manifested by low coefficient of the above correlations (not exceeding 0.6), no correlation between the activity of the left MM and both TMs, as well as by different extent of activation of each muscle during execution of various functional tasks (chewing of various substrates, jaw clench, rhythmic jaw movement, etc.) [17]. Thus, individual chewing pattern can be expressed in the varying degree of the MM and TM activity asymmetry.

In a number of studies, it has been found that the contribution of the MMs to the overall electrical activity of these masticatory muscles during chewing of solid food when performing such EMG recording during the chewing tests is larger, than that of the TMs: during both free chewing [16] and on the dominant side during unilateral chewing [18]. In the latter case, the integrated EMG asymmetry between the dominant and contralateral side is greater for the MMs, than for the TMs [14, 16, 19]. Furthermore, the MM motor control program is more variable, which is indicated, for example, by the increase in the frequency of the MM electrical potential oscillation with the jaws clenched after the short-term normalization of occlusion with a splint in dental patients, along with the lack of significant differences in the frequency of the TM potential oscillation [20]. These facts confirm greater importance of controlling the MM activity compared to the TM activity during organization of chewing, which can result in higher variability of the MM bilateral asymmetry manifestations in individuals having no maxillofacial abnormalities. In this regard, our data reflect mostly manifestations of individual behavioral adaptation of the chewing function. Such behavioral components can affect dental processes. For example, the presence of the TMJ dysfunction can be accompanied by various MM and TM electrical activity shifts and its asymmetry in various studies [21]. The types of the masticatory muscle activity ratio we have reported in healthy individuals will enable more reliable and accurate diagnosis and adjustment of their functional asymmetry.

CONCLUSIONS

Some dentally healthy young adults show unilateral asymmetry of the electrical activity of the temporalis and masseter muscles during chewing that is not correlated to the activity asymmetry with maximum bite force and limb dominance in motor tests. Three groups were distinguished based on the extent of the integrated EMG asymmetry associated with chewing: 1) showing stable predominance of the masticatory muscle activity on one side of the face; 2) showing the oppositely directed asymmetry reported for the temporalis and masseter muscles; 3) showing predominance of muscle activity on the dominant side during unilateral chewing and negligible asymmetry during bilateral chewing. The identified groups also show differences in asymmetry of the EMG indicators characterizing the intensity and duration of masseter muscle excitation during chewing.

References

1. Alyavija O, Nishanova A, Gulyamova S. Funkcional'naja sistema, obespechivajushhaja processy pishhevarenija v rotovoj polosti. Stomatologija. 2018; 1 (70): 54–57. Russian.
2. Gerstner G, Madhavan S and Crane E. Mammalian Oral Rhythms and Motor Control. Biomechanics in Applications. InTech. 2011. Available from: http://dx.doi.org/10.5772/19501.
3. Piancino MG, Isola G, Cannavale R, Cutroneo G, Vermiglio G, Bracco P, Anastasi GP. From periodontal mechanoreceptors to chewing motor control: A systematic review. Arch Oral Biol. 2017; 78: 109–121. DOI: 10.1016/j.archoralbio.2017.02.010.
4. van der Glas HW, van der Bilt A, Abbink JH, Mason AG, Cadden SW. Functional roles of oral reflexes in chewing and biting: Phase-, task- and site-dependent reflex sensitivity. Arch Oral Biol. 2007; 52 (4): 365–369. Available from: https://doi.org/10.1016/j.archoralbio.2006.10.022.
5. Nordstrom MA. Insights into the bilateral cortical control of human masticatory muscles revealed by transcranial magnetic stimulation. Arch Oral Biol. 2007; 52 (4): 338–42. DOI: 10.1016/j.archoralbio.2006.09.013.
6. Onozuka M, Fujita M, Watanabe K, Hirano Y, Niwa M, Nishiyama K, et al. Age-related changes in brain regional activity during chewing: a functional magnetic resonance imaging study. J Dent Res. 2003; 82: 657–660.
7. Quintero A, Ichesco E, Myers C, Schutt R, Gerstner GE. Brain activity and human unilateral chewing: an FMRI study. J Dent Res. 2013; 92: 136–42.
8. Pyo CY, Kim TH, Kim DH. Association between masticatory muscle activity and oral conditions in young female college students. Anat Cell Biol. 2021; 54 (4): 479–88. DOI: 10.5115/acb.21.107.
9. Almotairy N, Kumar A, Trulsson M, Grigoriadis A. Development of the jaw sensorimotor control and chewing — a systematic review. Physiol Behav. 2018; 194: 456–65. DOI: 10.1016/j.physbeh.2018.06.037.
10. Gurizheva MI. Svjazi dvigatel'nyh i vizual'nyh prob, otrazhajushhih funkcional'nuju asimmetriju polusharij golovnogo mozga devushek. Bjulleten' medicinskih internet-konferencij. 2017; 7 (6): 1154–8. Russian.
11. Bogdanov V Type of correlation between bite force and EMG activity of the temporalis and masseter muscles during maximal and submaximal clenching. Folia Medica. 2023; 65 (6): 975–85. Available from: https://doi.org/10.3897/folmed.65.e107180.
12. Ferrario VF, Sforza C, Colombo A, Ciusa V. An electromyographic investigation of masticatory muscles symmetry in normo-occlusion subjects. J Oral Rehabil. 2000; 27 (1): 33–40. DOI: 10.1046/j.1365-2842.2000.00490.x.
13. Hotta GH, Oliveira AIS de, Oliveira AS de, Pedroni CR. Electromyography and asymmetry index of masticatory muscles in undergraduate students with temporomandibular disorders. Brazilian Journal of Oral Sciences. 2015; 14 (2): 176–81. DOI: 10.1590/1677-3225v14n2a15.
14. Kimoto K, Fushima K, Tamaki K, Toyoda M, Sato S, Uchimura N. Asymmetry of masticatory muscle activity during the closing phase of mastication. Cranio. 2000; 18 (4): 257–63. DOI: 10.1080/08869634.2000.11746139.
15. Na SH, Kang DW. Comparative Electromyographic Analysis Of Masticatory Muscles Between Bilateral And Unilateral Masticators. J Korean Acad Prosthodont. 2002; 40 (6): 577–89.
16. Mioche L, Bourdiol P, Martin JF, Noël Y. Variations in human masseter and temporalis muscle activity related to food texture during free and side-imposed mastication. Arch Oral Biol. 1999; 44 (12): 1005–12. DOI: 10.1016/s0003-9969(99)00103-x. PMID: 10669078.
17. Farella M, Palla S, Erni S, Michelotti A, Gallo L. Masticatory muscle activity during deliberately performed oral tasks. Physiol Meas. 2008; 29 (2008): 1397–410. DOI: 10.1088/0967-3334/29/12/004.
18. Fueki K, Yoshida E, Sugiura T, Igarashi Y. Comparison of electromyographic activity of jaw-closing muscles between mixing ability test and masticatory performance test. J Prosthodont Res. 2009; 53 (2): 72–7. DOI: 10.1016/j.jpor.2008.09.003. Epub 2008 Dec 27. PMID: 19318076.
19. Tomonari H, Seong C, Kwon S, Miyawaki S. Electromyographic activity of superficial masseter and anterior temporal muscles during unilateral mastication of artificial test foods with different textures in healthy subjects. Clin Oral Investig. 2019; 23 (9): 3445–55. DOI: 10.1007/s00784-018-2754-x. Epub 2019 Jan 3. PMID: 30607620.
20. Shatrov IM, Zholudev SE. Jelektromiograficheskaja ocenka reakcii zhevatel'nyh i visochnyh myshc na nagruzku kak pokazatel' funkcional'noj adaptacii zubocheljustnoj sistemy. Problemy stomatologii. 2016; 1: 103–9. Russian.
21. Marcelino V, De Rovere S, Paço M, Gonçalves M, Marcelino S, Guimarães AS, et al. Masticatory Function in Individuals with Temporomandibular Disorders: A Systematic Review and Meta-Analysis. Life (Basel). 2023; 13 (2): 472. DOI: 10.3390/life13020472.

Литература

1. Алявия О., Нишанова А., Гулямова С. Функциональная система, обеспечивающая процессы пищеварения в ротовой полости. Стоматология. 2018; 1 (70): 54–57.
2. Gerstner G, Madhavan S and Crane E. Mammalian Oral Rhythms and Motor Control. Biomechanics in Applications. InTech. 2011. Available from: http://dx.doi.org/10.5772/19501.
3. Piancino MG, Isola G, Cannavale R, Cutroneo G, Vermiglio G, Bracco P, Anastasi GP. From periodontal mechanoreceptors to chewing motor control: A systematic review. Arch Oral Biol. 2017; 78: 109–121. DOI: 10.1016/j.archoralbio.2017.02.010.
4. van der Glas HW, van der Bilt A, Abbink JH, Mason AG, Cadden SW. Functional roles of oral reflexes in chewing and biting: Phase-, task- and site-dependent reflex sensitivity. Arch Oral Biol. 2007; 52 (4): 365–369. Available from: https://doi.org/10.1016/j.archoralbio.2006.10.022.
5. Nordstrom MA. Insights into the bilateral cortical control of human masticatory muscles revealed by transcranial magnetic stimulation. Arch Oral Biol. 2007; 52 (4): 338–42. DOI: 10.1016/j.archoralbio.2006.09.013.
6. Onozuka M, Fujita M, Watanabe K, Hirano Y, Niwa M, Nishiyama K, et al. Age-related changes in brain regional activity during chewing: a functional magnetic resonance imaging study. J Dent Res. 2003; 82: 657–660.
7. Quintero A, Ichesco E, Myers C, Schutt R, Gerstner GE. Brain activity and human unilateral chewing: an FMRI study. J Dent Res. 2013; 92: 136–42.
8. Pyo CY, Kim TH, Kim DH. Association between masticatory muscle activity and oral conditions in young female college students. Anat Cell Biol. 2021; 54 (4): 479–88. DOI: 10.5115/acb.21.107.
9. Almotairy N, Kumar A, Trulsson M, Grigoriadis A. Development of the jaw sensorimotor control and chewing — a systematic review. Physiol Behav. 2018; 194: 456–65. DOI: 10.1016/j.physbeh.2018.06.037.
10. Урижева М. И. Связи двигательных и визуальных проб, отражающих функциональную асимметрию полушарий головного мозга девушек. Бюллетень медицинских интернет-конференций. 2017; 7 (6): 1154–8.
11. Bogdanov V Type of correlation between bite force and EMG activity of the temporalis and masseter muscles during maximal and submaximal clenching. Folia Medica. 2023; 65 (6): 975–85. Available from: https://doi.org/10.3897/folmed.65.e107180.
12. Ferrario VF, Sforza C, Colombo A, Ciusa V. An electromyographic investigation of masticatory muscles symmetry in normo-occlusion subjects. J Oral Rehabil. 2000; 27 (1): 33–40. DOI: 10.1046/j.1365-2842.2000.00490.x.
13. Hotta GH, Oliveira AIS de, Oliveira AS de, Pedroni CR. Electromyography and asymmetry index of masticatory muscles in undergraduate students with temporomandibular disorders. Brazilian Journal of Oral Sciences. 2015; 14 (2): 176–81. DOI: 10.1590/1677-3225v14n2a15.
14. Kimoto K, Fushima K, Tamaki K, Toyoda M, Sato S, Uchimura N. Asymmetry of masticatory muscle activity during the closing phase of mastication. Cranio. 2000; 18 (4): 257–63. DOI: 10.1080/08869634.2000.11746139.
15. Na SH, Kang DW. Comparative Electromyographic Analysis Of Masticatory Muscles Between Bilateral And Unilateral Masticators. J Korean Acad Prosthodont. 2002; 40 (6): 577–89.
16. Mioche L, Bourdiol P, Martin JF, Noël Y. Variations in human masseter and temporalis muscle activity related to food texture during free and side-imposed mastication. Arch Oral Biol. 1999; 44 (12): 1005–12. DOI: 10.1016/s0003-9969(99)00103-x. PMID: 10669078.
17. Farella M, Palla S, Erni S, Michelotti A, Gallo L. Masticatory muscle activity during deliberately performed oral tasks. Physiol Meas. 2008; 29 (2008): 1397–410. DOI: 10.1088/0967-3334/29/12/004.
18. Fueki K, Yoshida E, Sugiura T, Igarashi Y. Comparison of electromyographic activity of jaw-closing muscles between mixing ability test and masticatory performance test. J Prosthodont Res. 2009; 53 (2): 72–7. DOI: 10.1016/j.jpor.2008.09.003. Epub 2008 Dec 27. PMID: 19318076.
19. Tomonari H, Seong C, Kwon S, Miyawaki S. Electromyographic activity of superficial masseter and anterior temporal muscles during unilateral mastication of artificial test foods with different textures in healthy subjects. Clin Oral Investig. 2019; 23 (9): 3445–55. DOI: 10.1007/s00784-018-2754-x. Epub 2019 Jan 3. PMID: 30607620.
20. Шатров И. М., Жолудев С. Е. Электромиографическая оценка реакции жевательных и височных мышц на нагрузку как показатель функциональной адаптации зубочелюстной системы. Проблемы стоматологии. 2016; 1: 103–9.
21. Marcelino V, De Rovere S, Paço M, Gonçalves M, Marcelino S, Guimarães AS, et al. Masticatory Function in Individuals with Temporomandibular Disorders: A Systematic Review and Meta-Analysis. Life (Basel). 2023; 13 (2): 472. DOI: 10.3390/life13020472.