EMG ACTIVITY OF MUSCLES OF THE CRANIOMANDIBULAR SYSTEM IN SUBJECTS WITH NARROWING UPPER JAW AND POSTERIOR CROSSBITE

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Posterior crossbite in children and adolescents has been linked to asymmetrical function and performance of the masticatory muscles. Electromyography (EMG) serves as an objective and widely applicable evidence-based method for diagnosing muscle function. The aim of our study was to analyze electromyographic (EMG) activity of muscles of the craniomandibular system in subjects with a narrowing upper jaw and unilateral posterior crossbite.

Material and methods. The first (study) group consisted of 18 subjects with narrow maxilla and unilateral posterior crossbite. 20 age-matched children with normal occlusion were included in the control group. The average age of subjects in the study group was 8.4±1.4 years, in the control group – 8.8±1.6 years. The exclusion criteria of the study were as follows: previous or active orthodontic treatment, clefts, traumas in the maxillofacial region, and general diseases. EMG activity of the anterior temporal, masseter, sternocleidomastoid (SCM), orbicularis oris, and mentalis muscles on both sides (left and right) was recorded during two 30-second tests: maximum voluntary clenching and swallowing a sip of water. Maximum voluntary clenching was performed in the intercuspal position. EMG data were processed using Neurotech's Synapsis software. EMG activity for each muscle was estimated by the maximum amplitude of the muscle contractions (µV).

Results. EMG activity in children with narrowing upper jaw and unilateral posterior crossbite of anterior temporal, masseter, and sternocleidomastoid muscles was asymmetrical and differed between the left and right sides. Higher bioelectrical muscle activity was found on the crossbite side for the masseter and anterior temporalis muscle, and on the opposite side – for sternocleidomastoid muscles. Values of maximum amplitude of sternocleidomastoid muscles were higher in the study group than in the control group without significant difference. There was a statistically significant difference in EMG activity of mentalis and orbicularis oris muscles between the two groups of children (p<0.05). Values of EMG activity of mentalis and orbicularis oris were higher in the study group.

Key words: EMG activity, craniomandibular system, narrowing upper jaw, crossbite, children, malocclusion, masticatory muscles, sternocleidomastoid muscles.
Introduction
As a vital component of the holistic human body, the craniomandibular system serves several crucial functions, including chewing, swallowing, speaking, and maintaining proper head and neck posture. Due to functional connections with other body segments, the craniomandibular system plays an important role in the entire neuromuscular system [6, 9]. Occlusion, muscle activity, and joint structure components are inextricably linked by nerve-muscle connections and disorders of one of the components have an impact on each other [7, 16, 29]. Posterior crossbite is one of the most prevalent malocclusions in primary and mixed dentition and is reported to occur in 8% to 22% [3, 5, 18, 33]. There is no difference in the prevalence of this malocclusion in gender [3]. Some studies indicate that crossbite reduced its prevalence to 7-14 % during primary and mixed dentitions up to adolescence, because of early orthodontic treatment of children carried out particularly in developed countries [17, 25]. The etiology of posterior crossbite can include any combination of dental, skeletal, and neuromuscular functional components, but the most frequent cause is a reduction in the width of the maxillary dental arch. Such a reduction can be induced by bad habits or obstruction of the upper airways caused by adenoid tissues, allergic rhinitis, or septal deviation [2, 15, 21, 26]. Previous studies have shown that posterior crossbite in children and adolescents has been associated with asymmetrical function and performance of the masticatory muscles [2]. Patients with unilateral posterior crossbite were reported to have asymmetric contraction of the masticatory muscles of the right and left sides of the mandible [12, 14], reduced thickness of the ipsilateral masseter muscle [5], and a different chewing pattern associated with an increase in the reverse chewing cycle [14]. Such muscle pattern violation in mixed dentition can cause asymmetric mandibular growth and as a result facial disharmony [18]. Electromyography (EMG) serves as an objective, widely applicable evidence-based method for diagnosing muscle function. It is utilized to identify various muscle patterns and compare diagnostic data across different individuals. [18, 32].

Therefore, the aim of our study was to analyze electromyographic (EMG) activity of muscles of the craniomandibular system in subjects with a narrowing of the upper jaw and unilateral posterior crossbite.

Materials and methods
38 children of 6-10 years were divided into two groups. The first (study) group consisted of 18 subjects with narrow maxilla and unilateral posterior crossbite, while 20 age-matched children with normal occlusion were included in the control group. The average age of subjects in the study group was 8.4 ± 1.4 years. 10 (55.6%) were girls, 8 (44.4%) were boys. All children were found unilateral crossbite without mandibular shift and a forced bite, 10 (55.6%) of them had right crossbite, and 8 (44.4%) – left crossbite. In the control group, 11 (55.0%) individuals were girls, and 9 (45.5%) were boys. The average age of children was 8.8 ± 1.6 years. Exclusion criteria of the study for subjects of two groups were: previous or active orthodontic treatment, clefts, traumas in the maxillofacial region, and general diseases.

Surface EMG was used to record muscle activity patterns from anterior temporal, massetter, and sternocleidomastoid muscles (SCM) of both sides (left and right), orbicularis oris, and mentalis muscles in all subjects of both groups. The recordings were undertaken two times by two investigators, who had been trained and received a certificate confirming the ability to work with the electromyograph Synapsis. EMG activity was determined as the average of the two measurements. 4-channel electromyograph included in a wide working band (from 0.5 Hz to 15 kHz), sampling frequency for each channel up to 40 kHz, low noise level not exceeding 6 μV, resistance to signal guidance, amplitude range of measured signals 0.1 μV-200μV. Before the EMG recording, the subjects were explained the purpose and features of EMG, to warn about the absence of pain sensations. Children seated with natural head position, their legs rested on feet on a hard floor, hands quietly lying on the hips. Arms and legs were not crossed [10].

To record muscle bioelectrical activity disposable silver chloride surface electrodes (diameter 10 mm) were connected to the electromyograph by 4 separate wires with separate inputs. Electrodes were positioned on the muscular bellies parallel to muscular fibers. These points were identified by palpation in the area with the greatest muscle tension during teeth clenching. To reduce the interelectrode resistance the skin was cleaned and degreased with 70% solution of ethyl alcohol before applying the electrodes [5, 10, 14, 24, 28, 30].

EMG activity was recorded in 2 tests, lasting 30s for each one: maximum voluntary clenching, and swallowing a sip of water. Maximum voluntary clenching was performed in the intercuspal position. EMG data were processed using Neurotech's Synapsis software. EMG activity for each muscle was estimated by the maximum amplitude of the muscle contractions (μV).

The procedures received approval from the Bioethics Committee of Poltava State Medical University (Poltava, Ukraine). All patients signed a statement of informed consent.
EMG activity between sides (right and left/normal and crossbite) was statistically analyzed using Student’s paired t-test (level of significance p<0.05). Indicators of EMG activity of the study and control groups were evaluated using analyses of Fisher’s criterion X². The hypotheses were verified at the level of significance p<0.05.

**Results**

The mean values of EMG activity of temporalis, masseter, sternocleidomastoid, mentalis and orbicularis oris muscles of the subjects of two groups in tests of maximum voluntary clenching test are shown in Table 1.

<table>
<thead>
<tr>
<th>Max. Amplitude, µV</th>
<th>Study</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>m.temporalis dextra</td>
<td>638.49±19.68</td>
<td>563.34±17.22</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.temporalis sinistra</td>
<td>623.09±19.06</td>
<td>581.58±18.01</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.masseter dextra</td>
<td>534.45±17.67*</td>
<td>711.72±20.45</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.masseter sinistra</td>
<td>563.82±17.53</td>
<td>654.41±19.63</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.sternocleidomastoideus dextra</td>
<td>633.28±19.23*</td>
<td>494.35±15.83</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.sternocleidomastoideus sinistra</td>
<td>575.39±18.03</td>
<td>631.38±18.54</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.orbicularis oris</td>
<td>505.49±16.91</td>
<td>645.28±19.14</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.mentalis</td>
<td>320.12±14.27</td>
<td>224.35±11.74</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>m.orbicularis oris</td>
<td>365.89±14.56</td>
<td>252.47±12.08</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>m. mentalis</td>
<td>563.34±17.22</td>
<td>157.44±7.45</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

* p<0.05

EMG activity of the masseter, anterior temporalis, and sternocleidomastoid muscles in children of the control group was characterized by symmetry values on the right and left sides (p>0.05). Masseter muscles’ EMG amplitudes were slightly higher than those of anterior temporalis muscles (p>0.05). EMG values of the sternocleidomastoid muscle were lower and significantly different from the masseter and anterior temporalis muscles (p<0.05). EMG activity of orbicularis oris and mentalis muscles were the lowest among the tested muscles. Children with a narrowing upper jaw and a posterior crossbite had different patterns of EMG activity from children of the control group. To demonstrate asymmetrical muscle work, we analyzed separately the activity of masticatory and sternocleidomastoid muscles in subjects with right and left crossbites in this test.

EMG activity of anterior temporal, masseter, and sternocleidomastoid muscles differed between the left and right sides. Higher bioelectrical muscle activity was found on the crossbite side for the masseter and anterior temporalis muscle, and on the opposite side – for sternocleidomastoid muscles. Values of maximum amplitude of sternocleidomastoid muscles were higher in the study group than in the control group without significant difference. There was a statistically significant difference in EMG activity of mentalis and orbicularis oris muscles between the two groups of children (p<0.05). Values of EMG activity of mentalis and orbicularis oris were higher in the study group. Table 2 shows the mean values and standard deviations of EMG activity of craniomandibular system muscles in swallowing tests for both groups.

<table>
<thead>
<tr>
<th>Max. Amplitude, µV</th>
<th>Study</th>
<th>Control</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>m.temporalis dextra</td>
<td>289.45±11.78</td>
<td>263.34±10.22</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.temporalis sinistra</td>
<td>303.25±12.53</td>
<td>251.36±9.81</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.masseter dextra</td>
<td>376.34±13.56*</td>
<td>294.63±12.09</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>m.masseter sinistra</td>
<td>234.39±10.84</td>
<td>301.22±12.78</td>
<td>&gt;0.05</td>
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<tr>
<td>m.sternocleidomastoideus dextra</td>
<td>329.83±14.7</td>
<td>284.37±13.78</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.sternocleidomastoideus sinistra</td>
<td>375.29±15.62</td>
<td>252.47±12.08</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td>m.orbicularis oris</td>
<td>196.75±11.25</td>
<td>106.02±5.83</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>m. mentalis</td>
<td>234.54±12.08</td>
<td>157.44±7.45</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

* p<0.05

**Table 2.** EMG activity of masticatory, mimic, and sternocleidomastoid muscles in subjects with normal occlusion and narrowing upper jaw and unilateral crossbite in maximum bilateral clenching test
In the test of swallowing a sip of water, there was observed symmetrical activity of the muscles on both sides in children of the control group. Muscle work in subjects with normal occlusion was characterized by greater involvement of mimic and neck muscles in this function, which was confirmed by higher values of EMG activity indicators, compared to the previous test but a significant difference was not found. EMG activity of orbicularis oris, mentalis, and sternocleidomastoid muscles was higher than the values of the masticatory muscles without significant difference. Some differences in muscle work were observed in the study group. The orbicularis oris, mentalis, and sternocleidomastoid muscles demonstrated a higher EMG activity than the masticatory muscles. There was a difference in EMG activity of the muscles of the right and left sides. A significant difference was observed for masseter muscles.

On comparing EMG activity of tested muscles in the two groups there was no significant statistical difference in the EMG activity of tested muscles except for orbicularis oris and mentalis muscles. Indicators of these muscles were higher in children of the study group than in the control group.

Discussion

The masticatory organ is a highly organized multifunctional cybernetic system that works independently and interacts with various internal and external components, adapts permanently to changing environmental factors, and maintains a constant state of unstable homeostasis [28, 29]. One of the main structural components of the cybernetic system is the craniomandibular system, which consists of the muscular apparatus, joints, and ligaments [11, 19, 29]. Muscles of the craniomandibular system are necessary for human life because of functions that are performed (chewing, swallowing, speech, breathing, etc.) [6, 20, 23]. Their activity is interrelated with many factors, in particular occlusion. The prevalence of posterior unilateral crossbite and its accompanying functional issues is increasing. In the literature, there is mainly data devoted to the activity of the masticatory muscles in cases with malocclusion, while mimic, sublingual, and neck muscles are studied particularly in functions or movements of a lower jaw. Therefore, the analysis of the bioelectrical activity of muscles of the craniomandibular system is an important issue. There are conflicting data in the literature about the features of EMG activity of the masticatory muscles. Investigation of activity of the craniomandibular system muscles is very important during the growth of a child, in a period of mixed bite. Functional disorders, particularly breathing, and swallowing functions, are found frequently in childhood and may cause a narrowing upper jaw [4, 15, 21, 25].

As a result, crossbites appear, which can be both bilateral and unilateral. We were interested that the prevalence of crossbite is not significant, but has a tendency to increase, as well as to earlier detection of this malocclusion. This is evidenced by literature data on epidemiological examination of malocclusion [2, 3, 8, 18, 27]. In our research, we paid attention to features of muscle imbalance in children with a narrowing upper jaw and a crossbite. In literature, there are studies devoted to muscle activity in subjects with transversal malocclusion. Most authors emphasized the presence of asymmetric activity [8, 22, 27], although some authors point out the lack of differences compared with subjects with normal occlusion [1]. An insufficient number of studies are devoted to the activity of the neck and mimic muscles in patients with a crossbite. The activity of mimic muscles, in particular the orbicularis oris and chin muscles, was studied in patients with incorrect swallowing function or incompetence of lips. In our study, we examined EMG activity of the masticatory, sternocleidomastoid, orbicularis oris, and mentalis muscles in children with a unilateral posterior crossbite. Children with mixed bite and normal occlusion without missing teeth formed a control group that was selected for comparison. These subjects were examined to study characteristics of normal muscle activity. In the literature, there is data on a large variety of deviations in normal EMG activity of masticatory muscles [5, 8]. Therefore, some authors showed that physiological muscle work is completely symmetrical bioelectrical activity, while others allow a small difference in indicators on the left and right side [4].

We paid attention to the quantitative value of the maximum activity of contractions and symmetry on the left and right sides. Thus, we found the symmetrical bioelectrical activity of the masseter, anterior temporal, and sternocleidomastoid muscles in maximum voluntary clenching test and in function, namely swallowing in children with normal occlusion. Symmetrical activity means that in the control group, EMG activity did not differ by more than 15% on the left and right sides. The average values of the maximum amplitude of muscle constrictive had no statistically significant differences on both sides (p>0.05). The EMG activity of the masseter muscle in tests of maximum voluntary clenching and swallowing was higher than the temporal without a statistically significant difference. Most researchers noted differences in features of muscle activity at rest position in subjects with posterior unilateral crossbite [2]. Studies results showed no significant differences in any of the anterior temporal, masseter muscles in the normocclusive and right posterior crossbite subjects at rest position [2]. Kecik et al. (2007) showed that the anterior temporal and masseter muscle activity at rest position differed significa-
cantly between the crossbite and control groups, and higher muscle activity was found on the crossbite side [13]. Children with a narrowing upper jaw and a unilateral posterior crossbite had a different pattern of EMG activity from children of the control group. During the maximum voluntary clenching test, increased bioelectrical muscle activity was noted on the crossbite side for the masseter and anterior temporalis muscles. In contrast, during the swallowing test, symmetrical muscle activity was observed on both sides, with greater involvement of facial and neck muscles noted in children from the control group. EMG activity of orbicularis oris and mentalis muscles was higher in children of the study group than in the control group.

There is limited data on the characteristics of neck muscle activity in patients with transverse malocclusion. Patients with a crossbite and mandibular shift were found increased EMG activity of sternocleidomastoid muscles on the side of the mandibular displacement [31]. These studies have found associations between crossbite and parameters related to masticatory muscle performance, such as asymmetric electromyographic (EMG) activity. Research results in our study showed asymmetrical EMG activity of neck muscles. In patients with a posterior unilateral crossbite, EMG activity of sternocleidomastoid muscles was higher on the non-cross side than the crossbite side. It means that children with right-side posterior crossbite had higher EMG activity of sternocleidomastoid muscles on the left side, respectively than children with left-side posterior crossbite – on the right side. Values of maximum amplitude of sternocleidomastoid muscles were higher in the study group than in the control group without significant difference, for EMG activity of mentalis and orbicularis oris muscles – with significant difference (p<0.05). We also conducted a study of orbicularis oris and mentalis muscle activity, which indicates a functional insufficiency of these muscles, associated, to our mind, with impaired breathing and swallowing functions. In cases of functional disorders tongue position changes, and myodynamic imbalance appears, which, can lead to a narrowing of the upper jaw, which was observed in the subjects of the study group.

Conclusion
The orofacial region, particularly, its components: craniomandibular (TMJ), neuromuscular systems, and occlusion, perform important functions for human life and are one of the indicators of general somatic human health. Electromyography is a modern, objective, minimally invasive, highly informative method of functional diagnostics of muscles of the craniomandibular system and registration of the motor unit activity. The normal pattern of the masticatory and sternocleidomastoid muscles is characterized by symmetrical EMG activity on the left and right sides. In the tests of maximum voluntary clenching and swallowing of teeth orbicularis oris and mentalis muscles were found the lowest values of EMG activity (p<0.05, p>0.05 to the tests respectively).

Children with narrowing upper jaw and unilateral posterior crossbite are characterized by increased EMG activity of the masticatory muscles on the side of crossbite, increased EMG activity of the sternocleidomastoid muscles of non-crossbite side, increased EMG activity of orbicularis oris and mentalis muscles in swallowing test, asymmetric work of muscles on the right and left sides.

The obtained data proves the importance of dynamic individual screening of the functional state and rebuilding of the muscles of the craniomandibular system.

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The authors declare no conflict of interest

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References


ЕМГ-АКТИВНІСТЬ М'ЯЗІВ КРАНІО-МАНДИБУЛЯРНОЇ СИСТЕМИ В ОСІБ ЗІ ЗВУЖЕНЯМ ВЕРХНЬОЇ ЩЕЛЕПИ ТА ПЕРЕХРЕСНИМ ПРИКУСОМ

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Перехресний прикус у дітей і підлітків пов'язаний з асиметричною роботою жувальних м'язів. Об'єктивним, доказовим методом функціональної діагностики активності м'язів щелепно-лицевої ділянки є електроміографія (ЕМГ). Метою нашого дослідження було проаналізувати електроміографічну (ЕМГ) активність м'язів краніо-мандибулярної системи в осіб зі звуженням верхньої щелепи та одностороннім перехресним прикусом.

Матеріали та методи. Дослідну групу склали 18 осіб зі звуженням верхньої щелепи та одностороннім перехресним прикусом. До контрольної групи увійшли 20 дітей відповідно віку з нормальним прикусом. Середній вік обстежених дослідної групи становив 8,4 ± 1,4 років, контрольної – 8,8 ± 1,6 років. Критеріями виключення з дослідження були: попереднє або активне ортодонтичне лікування, незрощення, травми щелепно-лицевої ділянки, загальні захворювання. За допомогою поверхневої ЕМГ визначали біоелектричну активність переднього скроневого, жувального, грудино-ключично-соскоподібного м'язів з лівої та правої сторони, підборідного, кругового м'яза рота у 2 пробах, тривалістю 30 с кожна: максимальне довільне стискання зубів з обох сторін, ковток води. Дані ЕМГ обробляли за допомогою програмного забезпечення Synapsis компанії Neurotech. ЕМГ-активність для кожного м'яза оцінювали за максимальною амплітудою м'язових скорочень (мкВ).

Результати. ЕМГ-активність у дітей зі звуженням верхньої щелепи та одностороннім перехресним прикусом переднього скроневого, жувального та грудино-ключично-соскоподібного м'язів була асиметричною та відрізнялася між лівою та правою сторонами. Вищу біоелектричну активність виявили на боці перехресного співвідношення зębів, протилежного боку – для грудино-ключично-соскоподібного м'яза. Значення максимальної амплітуди грудино-ключично-соскоподібних м'язів були вищими в контрольній групі, ніж у контрольній без достовірної різниці. Між двома групами дітей виявлено статистично значущу різницю ЕМГ-активності підборідного та колового м'яза рота (p<0,05). Значення їх ЕМГ-активності були вищими в контрольній групі.

Ключові слова: ЕМГ-активність, краніо-мандибулярна система, звуження верхньої щелепи, перехресний прикус, діти, зубо-щелепні аномалії, жувальні м'язи, грудино-ключично-соскоподібні м'язи.