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The neurophysiology aspect of congenital craniofacial deformities in children

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ABSTRACT

Congenital craniofacial deformities in children are conditions with varying degrees of severity between minor and severe, they can be present at birth, but they can also be detected during the child's development.

Material and methods. In the period 2014-2021, 57 children (29 boys and 28 girls), average age 9,1 ± 2,4 months, with craniofacial deformities from different medical centers in the Republic of Moldova were examined polysystemically. In this sense, we evaluated the state of the masseter, temporal and tongue muscles by electromyography with surface electrodes to determine the quality of their muscle activity. Recordings of the bioelectrical activity of muscle activity during exercise were performed using a Nihon Kohden portable electromyograph (Japan).

Results. The balance dysfunction of the neuromuscular system in these children, as a neuro-physiological sign of pathological muscular weakness in the sucking reflex activity, is highlighted in 87.7% of cases by a marked asymmetry ($p<0.001$) of the tongue and masseter muscles activity and, respectively less highlighted ($p<0.05$) of the anterior temporal.

Discussion. Thus, the EMG pattern evaluation highlights a decrease in the average amplitude of the action potentials (μV) mainly for the tongue, mm. masseters and temporalis on the left side, associated with an increase in the potential (ms) average duration from both the affected and the contralateral muscles, thus reflecting the reduction in their contraction capacity and the quality decrease in the act of sucking and mastication, predominantly on the left, in the child with congenital craniofacial deformities and disorders of the sucking reflex in infants.

Conclusions. The neurophysiological examination highlights various forms of muscle function abnormalities in children with craniofacial deformities, which require multifunctional and multidisciplinary recovery.

Keywords: congenital craniofacial deformities, children, electromyography

List of abbreviations

CNS – central nervous system
CDC – the Centers for Disease Control and Prevention
WHO – World Health Organization
EMG – electromyography
CT – computer tomography
MRI – magnetic resonance image
SUMPh – State University of Medicine and Pharmacy
mm – muscles
R – right
L – left

INTRODUCTION

Congenital craniofacial deformities in children are conditions with varying degrees of severity between minor and severe, they can be present at birth, but they can also be detected during the child's development [2,3,9,14,18].

According to the Centers for Disease Control and Prevention (CDC) in the USA, each year in average 1 in 33 children is born with a congenital defect [5,10,12].

According to the data of World Health Organization (WHO), approximately 276,000 children world-

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wide die every year in the first 4 weeks of life due to congenital malformations [17].

From the specialized literature sources, congenital malformations can appear at any stage of pregnancy, although most of them come from the first three months of pregnancy, the period when the cranialfacial region formed [6,15,16].

The reasons of most birth defects are not well known. The vast majority of American authors and experts believe that congenital malformations are based on a complex of harmful factors, among which the most valuable (up to 20% of cases) is heredity and, last but not least, the toxic action of harmful substances in the environment surrounding. Increasingly, in recent years, the probability of increasing incidence due to the combination of both environment harmful as well as heredity factors is being discussed [5,13].

According to the specialized literature sources from recent years, the common pathological link for all congenital malformations is primarily manifested in relation to the damage and involvement degree in the pathological process throughout life of the two unconditional self-survival reflexes with genetically conditioned mechanisms: hunger and thirst [8,11,19].

Having the goal of maintaining the internal environment balance of the child's body at a constant level, these unconditioned inherited reflexes preserve his integrity and reproductive capacity, at the same time they are also the basis for conditioned reflexes formation [1,7,20].

From the mentioned above, it is obvious that at the unconditioned reflexes existence basis in the child are the excitations on the receptors in the perception area through the constant reflex arc with the CNS involvement and the muscular system activity, in order to intensively participate in the body's adaptation to new living conditions.

In this way, unconditioned reflexes are based on the heredo-collateral product of the previous generations' experience, which, in children with congenital malformations, are damaged and constantly inhibited during the adaptive period. This pathological mechanism in children with congenital malformations does not allow the signals acquisition, biologically significant, accepted as conditioned reflexes, damaging the subsequent base formation of the child's higher nervous activity (according to I.P. Pavlov).

In addition to the mentioned, the unconditioned and conditioned response in a healthy child play a primary role in the process of the body's interaction with the environment and are built on the safe reflex responses to these stimuli. The main indicator of its maturity is the unconditioned reflexes of the newborn, evaluated on a scale: satisfactory, increased, low, absent [14,19].

As a result of the mentioned above, it is clearly understandable that after the healthy child's birth, the unconditioned and conditioned reflexes are influenced by the changes in the complex reflex acts with a specific biological orientation and are aimed at the intelligence formation by constantly maintaining the integrity of the body, so that the development degree of the unconditioned reflexes is directly proportional to the nervous system's state.

In congenital craniofacial deformities, we highlight a completely insufficient environment for the child's body adaptation by inhibiting conditioned reflexes, similar to general congenital malformations. According to Sechenov's theory, inhibitions, under these conditions, are subject to conditioned and unconditioned reflexes, in association with the inhibition of neurophysiological processes that occur simultaneously in the muscles, the cerebral cortex and at the level of the subcortex [3,18,20].

Applying the standard neurophysiological method (EMG) to children with congenital craniofacial deformities we can evaluate the formation specifics of conditioned reflexes, appreciating the specifics of changes in existing neural connections and the formation of others in new conditions of persistent pathology. The obtained results need to be appreciated by studying the muscle contraction capacity of the muscles involved in the pathological process, in a state of maximum relaxation, associated with facial expressions, chewing and swallowing, breathing in relation to brain morphology (CT or brain MRI) in these children [4,8,10].

MATERIAL AND METHODS

In the period 2014-2021, 57 children (29 boys and 28 girls), average age 9,1 ± 2,4 months, with craniofacial deformities from different medical centers in the Republic of Moldova were examined polysystemically. The study was conducted within the "Nicolae Testemitanu" State University of Medicine and Pharmacy (SUMPh), at the clinical base in the IMSP Mother and Child Institute (IMC), and within the IMSP "V. Ignatenco" Municipal Clinical Children's Hospital in Chisinau, Republic of Moldova.

Simultaneously with the anamnesis, we considered it opportune in these children, for the viscerocranium's growth and development evaluation to use the cephalometric analysis used in the 3D computer tomography as an indispensable paraclinical investigation for a confirmation of the cranial vault deformation of the children included in the study, which allowed us to obtain values variables of the cranial and facial parameters as well as the ratio between them (Figure 1).

The children were clinically monitored in the context of the clinical manifestation evolution in relation to the possibility of maintaining the balance

FIGURE 1. 3D tomograph (Aquilion Prime SP) and 3D computed tomography image in sagittal section of patient C.R., 9 months old with brachecephaly associated with motor disorders

of the neurophysiological functions through the EMG state of maximum relaxation, but also in the application of muscle effort and ensuring the innervation in plagiocephaly, craniosynostosis and nasolabial clefts. In this sense, we evaluated the state of the masseter, temporal and tongue muscles by electromyography with surface electrodes to determine the quality of their muscle activity. Recordings of the bioelectrical activity of muscle activity during exercise were performed using a Nihon Kohden portable electromyograph (Japan) illustrated in Figure 2.

FIGURE 2. Nihon Kohden portable electromyograph (Japan)

From my own experience, I have accepted the fact that the automaticity of the sucking reflex, mastication and swallowing in children with congenital craniofacial deformities is a neuroreflective process strictly coordinated by the CNS. For these reasons, we targeted our investigations with the application of EMG, using a non-invasive technology to assess the functional state of the nervous system with superficial electrodes at the cutaneous level (on the skin) in the projection of the masseter and temporal muscles, followed by the tongue muscles. To evaluate the quality of the contraction capacity in the conditions of congenital craniofacial deformations, we followed the variable values of the cranial and facial parameters in a state of rest and when applying functional tests with physical effort in 21 children with plagiocephaly, 13 children – with craniosynostosis and 23 children – with clefts.

The procedure did not require special preparations. The patients were examined after eating, under symptomatic medicine treatment, with the exception of patients who required anticoagulant or antiplatelet treatment and who did not require anesthesia or sedation. Likewise, there is no risk that undergoing the investigation will complicate the disease evolution. At the same time, on the examination day we excluded the application of different oils or creams on the skin. The children were examined in a horizontal position in bed for a maximum muscle relaxation, next to an apparatus equipped with a screen connected to a separate computer. We applied the electrodes for the masticatory mm projection (masseter and temporalis) and the tongue, which are connected to the device, with maximum relaxation up to 15 minutes (initial period) – determination of the average amplitude (μV), (a) its symmetry, the average duration of bilateral muscle contraction (s), activity index and asymmetry index which are presented in figure 3 a and b.

The application of physical effort (feeding the child during the examination for 30 seconds), after the results of increasing the amplitude, simultaneously, we calculated the average duration of muscle contraction, bilaterally (s), of activity and asymme-

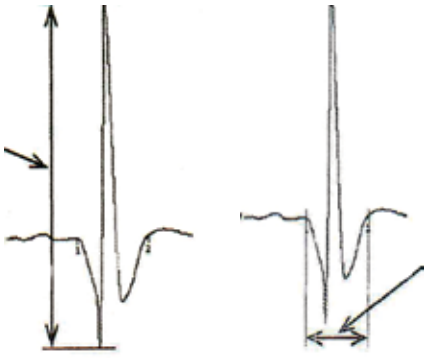


FIGURE 3. Parameters of the muscle motor unit potential: a) shape and amplitude; b) time

try index. We paid special attention to the study of the recovery period duration (amplitude and frequency recovery time) at the initial level after the physical effort test, the activity and asymmetry index of the EMG parameters.

In order to obtain information about the functional state of the neuromuscular systems of the masticatory muscles in congenital craniofacial deformities in children, we applied: a. Installation of superficial electrodes in the region of mm masseter and temporalis, in a horizontal position of the patient in bed, with maximum relaxation up to 15 minutes (initial period), determining the average amplitude (μV), its symmetry, the average duration of bilateral muscle contraction (s), the activity index and the asymmetry index.

The clinical data, imaging and neuro-physiological study (in a state of maximal relaxation and physical exertion) were entered into the electronic table (MS Excel 7.0), completed with additional information, collected from the medical records of the inpatient and outpatient care, forming matrix for statistical processing.

The average variable values were compared with the same parameters in 25 children from the control group to evaluate the quality of the contraction capacity of the nominated muscles, while controlling the therapy effectiveness with special orthodontic headsets and medical recovery of the patient.

Statistical analysis of EMG interference pattern parameters was performed using SPSS Statistics software (version 23.0, IBM, Armonk, NY, USA) and MATLAB R2015b (Mathworks, Natick, Mass). Values of $p < 0.05$ were considered statistically significant.

Results were expressed as average, standard deviations, medians, maximum number and minimum number. Possible associations between measured categorical variables were tested using the Pearson chi-squared test and the Fisher exact test. In order to identify if there were statistically significant differences (p-value) between the patients in the two groups, in terms of the number of occlusal contacts, we used the independent statistical t test. The level of statistical significance was set at 0.05.

RESULTS AND DISCUSSION

It is accepted that the automaticity of the sucking reflex, chewing and swallowing is a neuro-reflective process strictly coordinated by the CNS. This function was exactly targeted in our investigations. For this goal, we used the application of superficial electrodes at the cutaneous level (on the skin) for the masseter and temporalis muscles projection, followed by the tongue muscles, in a state of rest and when applying functional tests with physical effort (a non-invasive technology for evaluating the functional state of the peripheral nerve system) in 21 children with plagiocephaly, 13 children – with craniostenosis and 23 children – with clefts (mean age = 8.9±1.6 months).

Electromyography (EMG), as a complementary neurophysiological investigation of the clinical examination in congenital craniofacial deformities in children, we applied it to evaluate the balance's maintenance of the muscle functions and parafunctions between the forces determined by the innervation ensuring of the viscerocranium's development in totality.

The children were examined in a horizontal position in bed, with maximum relaxation up to 15 minutes (initial period) – determination of the average amplitude (μV), (a) its symmetry, the average duration of bilateral muscle contraction (s), the activity index and the asymmetry index. The application of physical effort (feeding the child during the examination for 30 seconds), after the results of amplitude's increasing, simultaneously, we calculated the average duration of muscle contraction, bilaterally (s), of the activity and the asymmetry index. We paid a special attention to the study of recovery period duration (amplitude and frequency recovery time) at the initial level after the physical effort test, of the activity and the asymmetry index of the EMG parameters.

The selected muscles were necessarily evaluated at rest, then during contraction, both before and after the treatment, whose activity was followed on the computer monitor.

Thus we created the possibility to evaluate all three muscles, depending on the character of the craniofacial deformation. The presence, size and shape of the waves (action potentials) displayed on the monitor provided us with information about the degree of decompensation of the muscle function, but also the quality of the treatment to recover the inhibited functions.

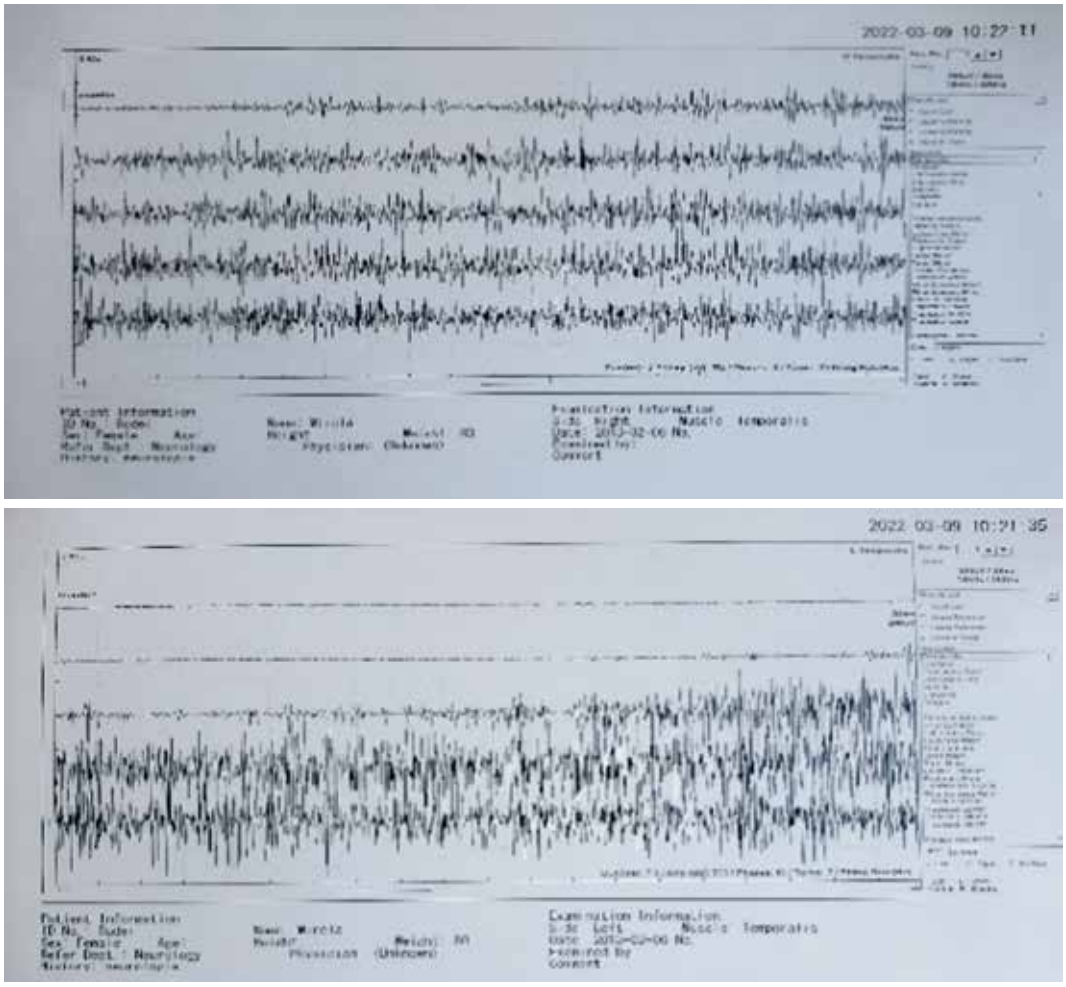
For a maximum muscle relaxation, the patients were installed lying next to a device equipped with a screen connected to a separate computer. We ap-

plied the electrodes in the masticatory mm and the tongue projection, which are connected to the device. The procedure did not require special preparations. The patients were examined after eating, being on a symptomatic treatment, with exception of patients who required anticoagulant or antiplatelet treatment and who did not require anesthesia or sedation. Likewise, there is no risk that the investigation subjection will aggravate the evolution of the disease. At the same time, we excluded the application of different oils or creams to the skin on the examination day.

In the EMG examination we analyzed the clinical manifestations, especially chewing and swallowing disorders (of both solid and liquid foods), in relation to the neurophysiological expressions (amplitude and frequency) of muscle contractions, presented by the muscular system of the oro-maxillo-facial region of these children to highlight unilateral or bilateral muscle weakness or atrophy. These clinical manifestations may be determined by secondary chronic suffering, by a local nervous disease, but may also appear as a secondary clinical manifestation of another pathology.

Thus, the selected children were supervised clinically-neurophysiologically during the study in the anamnesis correlation context with: a) the evaluation of the predominant risk factors; b) clinical manifestations (facial asymmetries and the motor disorders onset of the masticatory apparatus in dynamics and the 14 children without neurological disorders); c) the neurophysiological disturbances specificity of the EMG interference pattern of the masseter and temporalis masticatory muscles, as well as the mm of the tongue, supplemented with the results of the clinical examination and evolutionary imaging (in the periods of 6 months and 12 months of life).

Automaticity of mastication is known to be a neuro-reflective process strictly coordinated by the CNS. This is the function that was targeted in our investigations. Because of mastication, normally, includes the activity of the entire neuromuscular complex of the oro-maxillo-facial region and is not dictated by the diet nature. Congenital craniofacial deformations, especially in plagiocephaly, craniosynostosis or nasolabial clefts to a variable extent can influence automaticity and rhythmicity, simultaneously with their muscle's contraction force due



a

b

FIGURE 4. Neurophysiological examination of the right (a) and left (b) tongue muscles of the patient S.N., 9 months old, with the diagnosis: Sagittal craniostenosis, intracranial hypertension, associated with infantile cerebral palsy

to muscle weakness of the masticatory muscles, especially the masseter muscle, compared to healthy children. The investigation of the neuromuscular component in various congenital craniofacial deformations' forms in children from the research group and from the control group is of particular importance not only for the diagnosis and evolution of the neuro-reflective dysfunction, but also for controlling the therapy effectiveness to restore muscle function.

In the characteristics for highlighting the neuro-muscular imbalance in the craniofacial deformations associated or not with the dysregulation of the sucking reflex, in 57 infants included in the study, we analyzed only two electrophysiological parameters through the EMG pattern: a) the average amplitude variations of the action potentials on the tongue muscles, mm. masseter and temporalis, bilaterally, in different phases of activity and b) the average duration of the potential, bilaterally, in different phases of activity.

The balance dysfunction of the neuromuscular system in these children, as a neuro-physiological sign of pathological muscular weakness in the sucking reflex activity, is highlighted in 87.7% of cases by a marked asymmetry ($p < 0.001$) of the tongue and masseter muscles activity and, respectively less highlighted ($p < 0.05$), of the anterior temporal, illustrated in Figure 4 a, b.

In children with craniosynostosis compared to those without sucking reflex disorders, the amplitude asymmetric decrease and the potential average duration was evidenced by a greater persistence and a longer amplitude reduction of the reflex response.

This abnormal situation can lead to the appearance of pathological peripheral muscle fatigue, manifested by an even more obvious amplitude decrease and potential average duration to lower values, compared to the children from the control group. This neurophysiological criterion in congenital craniofacial deformations can serve as an indicator of the localization and damage degree of the pathological process.

The observation highlights the fact that the treatment period of the congenital craniofacial deformations with the pre-affected muscles restoration activity is more complex and with a longer recovery.

In 25 children from the control group, we did not observe a definite amplitude asymmetry and a potential average duration of the muscle contractions ($p > 0.05$) (Table 1).

Based on the examination results of the EMG interference pattern parameters, in particular of the potential action's average amplitude and the bilateral potential's average duration in different phases of activity, reflected in table 1, we can highlight, first of all, a muscle asymmetry with a greater bioelectrical activity of the tongue and masticatory muscles on the right compared to the bioelectrical activity of the masticatory muscles on the left (R>L) in children with congenital craniofacial deformities ($p < 0.001$).

Applying physical effort (applying the child to the breast) we analyzed the maximum contraction of the muscle contraction's amplitude and frequency for 5 seconds. We calculated the results of increasing the amplitude, its symmetry, the average duration of muscle contraction for 5 seconds, bilaterally (s), the activity and asymmetry index and the recovery period duration – the recovery time of the EMG interference pattern parameters. This allows us to highlight the quality of the sucking reflex and masticatory act in infants with craniofacial deformities in different phases of muscle contractions: absolute rest, maximum voluntary contraction and maximum relaxation phase.

We found that, depending on the average amplitude variations of the potentials action (mV) in the 57 children with congenital craniofacial deformations, compared to the average values of the children from the control group, we highlighted muscu-

TABLE 1. General average amplitude of the tongue muscles, mm. masseter and temporal in 57 children with craniofacial deformities associated with dysregulation of the sucking reflex (mV)

EMG pattern parameters	L_1 The research lot (n^1=57)	L_0 The control lot (n^2=25)	F	p
The average amplitude of tongue muscles, D	325,86	421,76 ± 22,15	24,116	p = 0,000 **p <0,001**
The average amplitude of the tongue muscles, S	266,28	358,59 ± 22,09	22,132	p = 0,000 **p <0,001**
The average amplitude of m. masseter, D	290,20 ± 9,26	419,16±23,75	26,169	p = 0,000 **p <0,001**
The average amplitude of m. masseter, S	199,64 ± 10,64	381,47 ± 21,75	42,486	p = 0,000 **p <0,001**
The average amplitude of the temporal muscle, D	227,51 ± 10,75	325,86 ± 21,2	16,771	p = 0,000 **p <0,001**
The average amplitude of the temporal m, S	155,77 ± 11,69	266,28 ± 18,9	24,173	p = 0,000 **p <0,001**

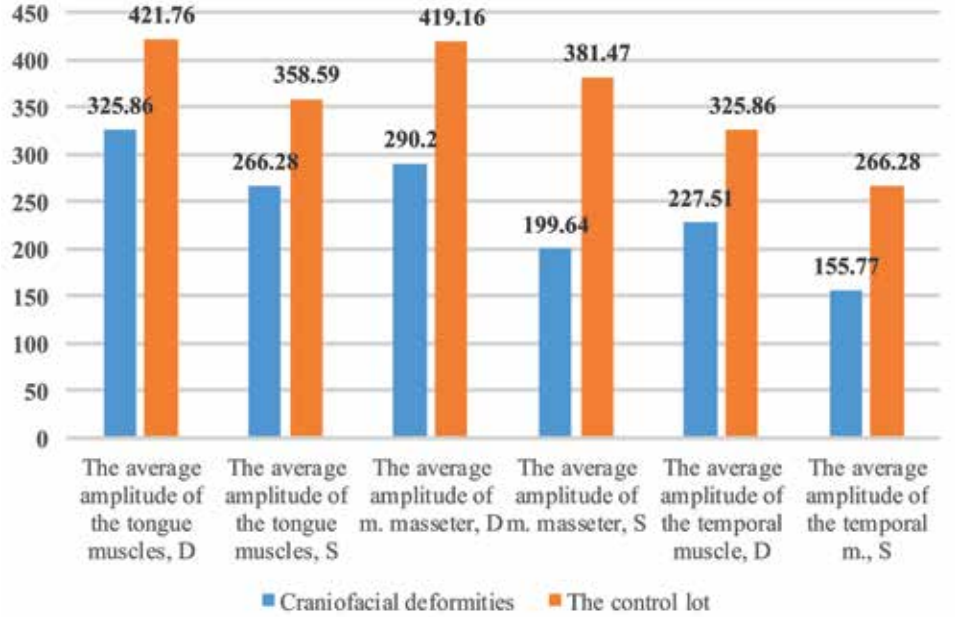


FIGURE 5. Comparative characteristics of average amplitude in patients with craniofacial deformities associated with dysregulation of the sucking reflex (mV) compared to average normal values

lar asymmetries of the neuro-physiological parameters on the tongue, masseter and temporalis muscles, associated with a decrease in the action potentials average amplitude (mV) on the affected side, mainly on the left ($p < 0.001$) that are presented in Figure 5.

Concomitantly with the average amplitude decrease of the action potentials (mV) of the examined muscles, in 57 children with congenital craniofacial deformities, associated with sucking reflex disturbance sin the EMG interference pattern, we also highlight a general increase of the potential action's (ms) average duration, statistically significant in the tongue and masticatory muscles examination, compared to normal average values. This neurophysiological phenomenon reflects the secondary decrease in the contraction capacity of the nominated muscles, obviously causing a bilateral decrease in the act of mastication's quality that is presented in Figure 6.

Thus, the EMG pattern evaluation highlights a decrease in the average amplitude of the action po-

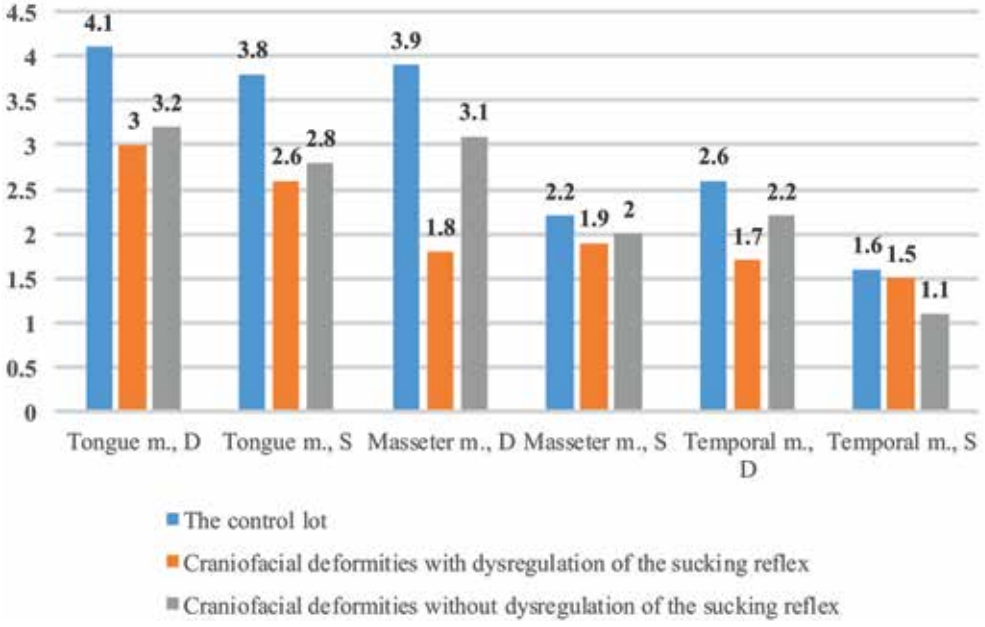


FIGURE 6. Comparative characteristic of the average potential duration (ms) in patients with congenital craniofacial deformities associated or not associated with reflex disorders below normal average values

tentials (mV) mainly for the tongue, mm. masseters and temporalis muscles on the left side, associated with an increase in the potential (ms) average duration from both the affected and the contralateral muscles, thus reflecting the reduction in their contraction capacity and the quality decrease in the act of sucking and mastication, predominantly on the left, in the child with congenital craniofacial deformities and disorders of the sucking reflex in infants.

Multiple structures of the nervous system (peripheral fibers, spinal cord structures, reticular formation, cerebellum, thalamus, hypothalamus, limbic system structures, cerebral cortex, etc.) participate in the automaticity of sucking reflexes and mastication, simultaneously with the structures of the local oro-maxillo-facial region: the system neuromuscular, vascular, ligamentous, articular (temporomandibular joint) etc.

Thus, the analyzed research protocol included the amplitude and frequency parameters of the electromyogram during maximum relaxation of the child, followed by its application to the chest, based on which, after a computerized processing of the neuroimaging results, we obtained a complete image of the chewing act with the involvement of the mm. tongue, masseter and temporalis muscles contractions. Simultaneously with the interpretation of the obtained data, we also took into account the regulatory influences of the nervous structures on the neuromuscular system of mastication.

For this reason, the EMG neuro-physiological parameters from the masticatory muscles and the tongue in relation to the extreme values of the cranial and facial imaging parameters, respecting the cephalometric tracing of the initial and postoperative state, orients the objective of the study on determining the capacity for evolutionary change of hard tissues in relation to the deregulation degree of soft tissue functions relative to the cranial vault midline in conditions of early fusion of the cranial sutures. The interrelationship peculiarities of this report highlight the slowly progressive change in the cranial vault shape in syndrome and non-syndrome craniostenoses vis-à-vis to the stationary form in clefts and reversible in plagiocephaly, followed by the neuro-reflective function disorders of the involved muscles, especially the tongue.

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This phenomenon was also observed by us in the postoperative period, both in infants and early childhood, as well as in late childhood or adolescence.

From what has been reported, we can highlight that the clinical latency period of the sucking reflex dysregulation in children with congenital craniofacial deformities is directly proportional to the influence degree of the CNS on the sucking reflex automaticity. In the clinical manifestations of congenital craniofacial deformations, CNS excitation increases the values of the EMG neuro-physiological parameters, and the inhibition syndrome causes a decrease in the sucking reflexes automaticity, and this phenomenon is also observed in the children from the control group.

Thus, in children with plagiocephaly, increasing CNS excitation will increase the amplitude and frequency of the contraction capacity, but also their capacity to return to the initial stage, in contrast to their decrease in craniosynostosis and nasolabial clefts, highlighting a greater degree of cerebral inactivity. The frequency of muscle contractions is increased in plagiocephaly, stably decreased in nasolabial clefts, and slowly progressively decreased in craniosynostosis. When the child is applied to the breast, CNS excitation occurs, which manifests itself in plagiocephaly by increasing the amplitude and frequency of muscle contractions, but in craniosynostosis, the muscle contractions amplitude and frequency of the respective muscles is highlighted by their pathological inactivity of contraction and return to the initial stage.

CONCLUSION

1. Congenital craniofacial deformities in children damage the functional balance of the bone and muscle system in the neocranium and viscerocranium development.

2. The treatment is complex, in stages and requires the presence of the multidisciplinary team that includes neurophysiological examination with the application of physical effort.

3. The neurophysiological examination highlights various forms of muscle function abnormalities in children with craniofacial deformities, which require multifunctional and multidisciplinary recovery.

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