Electromygraphic Potential of Mastication Muscles of Patients with Hearing Deprivation and Dental Anomalies

Sokologorska-Nykina Yu.K.[1]*, Kuroiedova V.D.[1], Stasiuk O.A.[1], Korobov P.S.[1]

1. Department of Postgraduate Education of orthodontists, Poltava State Medical University, Poltava, Ukraine.

Abstract

One of the important etiological factors in the occurrence of bite pathology is improper work of the muscles of the maxillofacial area. That is why the study of the muscles of the maxillofacial area in normal conditions and with various pathologies of the bite acquire the greatest relevance among scientists all over the world.

The purpose of the study is to determine the functional state of musculus masseter and musculus temporalis in children and adolescents with hearing deprivation.

Surface electromyography of musculus masseter and musculus temporalis was performed in 25 children and adolescents with hearing deprivation in a state of physiological rest and with maximum jaw clenching. All examined had 100% bite pathology. The obtained results were compared with the results of hearing patients with a physiological bite and patients with orthodontic pathology without hearing pathology.

An electromyographic study of masticatory muscles in teenagers with hearing loss allowed us to assess their range of variability, the symmetry of their work during rest and the functional test of maximum voluntary jaw clenching.

Increased biological activity of the masticatory muscles during physiological rest of deaf persons compared to hearing persons with both physiological occlusion and occlusion pathology was established ($p<0.05$; $p<0.01$).

Clinical article (J Int Dent Med Res 2024; 17(1): 239-246)

Keywords: Children with hearing impairments; malocclusion; electromyography; masticatory muscles; temporal muscles; functional muscle activity.

Received date: 04 December 2023 **Accept date:** 19 January 2024

Introduction

This study is a fragment of the scientific research work "Features of rehabilitation of orthodontic patients of various ages" state registration No. 022U201229.

An orthognathic bite is a morphologically and functionally balanced bite. And any deviations from the norm of the function of the form or orofacial structures lead to formed incorrect ratios, which is characterized by a change in the electromyographic activity of the maxillofacial muscles and is an indicator of complex functional relations of the dento-maxillofacial system[1].

One of the important etiological factors in the occurrence of bite pathology is the improper work of the muscles of the maxillofacial area, which affects not only the growth of the jaws, but also the entire orofacial harmony and stability[2]. Any deviation of the functions of oral cavity is defined as a violation of the functioning of the muscles of orofacial complex and causes deviations in craniofacial growth and development of the maxillofacial area[3].

Malocclusion occurs quite often in children with hearing impairment and is aggravated by speech disorders and other deviations or congenital defects, such as attachment of soft tissues of the oral cavity[4, 5]. Due to the absence or specific articulation of speech, which is caused by the pathology of the auditory analyzer, the maxillofacial apparatus of children with hearing deprivation has a number of characteristic morphological features[6,7]. The use of facilitated diagnostic methods for certain dental and orthodontic diseases is most appropriate in this category of patients[8].

*Corresponding author:
Yuliya K. Sokolohorska-Nykina,
Shevchenko str.23, 36000, Poltava, Ukraine.
E-mail: yu.sokolog@pdmu.edu.ua

The key to success in orthodontic treatment is early diagnosis of morphological and functional disorders [9], which has the potential for long-term occlusal stability[10].

In today's conditions, the study of the muscles of maxillofacial area in normal conditions and with various pathologies of the bite are gaining the greatest relevance among scientists all over the world, and the most common method of functional muscle research is electromyography, which is used to control the reorganization of the coordination ratios of the functions of temporal and masticatory muscles in the treatment of bite anomalies [11,12].

In dentistry, local global (surface) electromyography is most often used to collect and record action potentials and measure muscle activity. The main advantage of surface electromyography for the deaf is the painlessness of the technique [13].

The aim of the study. We set ourselves the goal of determining the functional state of the musculus masseter and musculus temporalis of children with hearing deprivation in a state of physiological rest and during a static test of maximal voluntary jaw clenching.

Materials and methods

We performed surface electromyography (EMG) of the musculus masseter and musculus temporalis in 25 children with hearing deprivation studying in the Poltava special boarding school for deaf children, Ukraine. The study was approved by the ethics committee of the Poltava State Medical University. Before the examination, all parents or representatives of the children gave informed consent for the examination.

The studies were approved by the biomedical ethics commission of the Poltava State Medical University № 221 by 22.11.2023 and were conducted in accordance with the written consent of the participants. The materials of the scientific work comply with the Rules of Humane Treatment of Patients in accordance with the requirements of the Tokyo Declaration of the World Medical Association, the international recommendations of the Helsinki Declaration on Human Rights, the Council of Europe Convention on Human Rights and Biomedicine, the Laws of Ukraine, the orders of the Health Ministry of Ukraine and the requirements of the Ethics Code of the Doctor of Ukraine.

The average age of the examined was 18.7±1.31 years. The following criteria were used in the selection of patients: 1) hearing deprivation (deafness); 2) absence of facial deformities; 3) absence of pathological periodontal diseases; 4) lack of orthodontic treatment.

A clinical examination was mandatory before conducting the electromyography. The morphological state of the maxillofacial area was assessed according to the generally accepted algorithm for examination of an orthodontic patient. The diagnosis of bite pathology was determined according to the Angle classification.

All patients had Class I and Class II occlusal relationships according to Angle. All examined children with hearing deprivation had 100% bite pathology. According to orthodontic pathology, they were divided into 2 groups: group 1 - patients with dentoalveolar I class according to Angle, which made up 60% (n=15) of the total number; group 2 - patients with dentoalveolar II class according to Angle - 40% (n=10).

For the control group, the data of the study of patients without hearing pathology with a permanent physiological occlusion and with occlusion pathology of the I class and II class were used, determined by M.I. Dmytrenko [14].

Examination of the bioelectrical activity of the masticatory muscles was carried out on a four-channel electromyographic complex "Neuro-EMG-Micro", which is intended for the study of the human neuromuscular system by means of registration and analysis of electrical signals of muscles and nerves. The average values of the amplitude of oscillations (mcV) of muscle biopotentials on both sides were evaluated.

During the tests, patients kept their head in a free position, without its support. To avoid fatigue between tests, patients were allowed to rest for at least 2 min.

Bipolar surface silver electrodes with a diameter of 10 mm were placed on the most active zones of the examined muscles parallel to their fibers. Neuromotor active zones were determined by palpation during maximum jaw compression. To reduce the impedance of the electrodes, the skin was thoroughly cleaned and degreased before placing the electrode, and conductive paste was applied to the electrodes. Grounding was attached to the wrist, having previously moistened it with water.

The signals were from the muscle activity of four tested muscles (right masseter (MR), left

masseter (ML), right temporalis anterior (TR), left temporalis anterior (TL)). Then EMG signals were recorded for further analysis. Muscle biopotentials were recorded for five seconds in tests: in a state of physiological rest and with maximum jaw clenching.

Electrodes on the musculus masseter were fixed parallel to the muscle fibers approximately 3 cm above and in front of angle of the lower jaw, and on the musculus temporalis the electrode was fixed vertically along the front edge of the muscle corresponding to the fronto-parietal suture (Ferrario et al., 1991) [15].

The analog EMG signal was amplified, digitized and filtered. During the study, the device was directly connected to a computer that presented the data graphically and recorded them for further quantitative analysis.

Measurement protocol. EMG activity was recorded in: 1) a position of physiological rest, without occlusive contact (Rest); calibration 20 mcV. The patient rested with relaxed jaws and closed eyes for at least 2 minutes; 2) maximum arbitrary compression; calibration 200 mcV.

Quantitative EMG analysis was also performed using the indices proposed by Ferrario, 1993 [16]. The index of asymmetry of the symmetric muscles of the musculus masseter and musculus temporalis (AS_{MM}, %) and musculus temporalis (AS_{MT}, %) and their total index ($AStot_{MT\,MM}$, %).

Asymmetry indices range from -100% to +100%, where a negative number indicates the dominance of the left muscle, and a positive number - of the right. We compared the relative contribution of the masseter and temporalis anterior muscles to the average values of the activity index introduced by Naeije et al. (1989) [17].

When the activity indices range from -100% to +100%, a negative number indicates the predominant activity of the anterior temporal muscle, and a positive number indicates the predominant activity of the masticatory muscle. Physiologically, the pair is balanced by a similar pair on the other side, but if this balance is disturbed in any way, the rotation of the lower jaw in the horizontal plane follows.

Statistical processing of the obtained results was carried out using the Student's criteria.

Results

The results of the study are presented in mcV as the average communicative voltage of muscle action potentials, which were used to analyze the degree of correlation of masticatory muscles in patients with hearing deprivation and hearing patients with occlusal relationships in these patients.

The obtained normalized root mean square values of EMG in a state of physiological rest in children with hearing deprivation are shown in the table. 1. During clinical rest m. masseter in gr. 1 turned out to be more active compared to gr. 2. At the same time, the activity of the muscle on the right was higher in patients with class I, in contrast to patients with class II in which, on the contrary, the activity of m. masseter was higher on the left.

Muscle	Research groups	
	Group 1	Group 2
m. temporalis		
Right	54,66±9,78*	31,03±5,85*
Left	42,52±7,03	48,09±9,91
Average value	48,59±8,41	39,56±7,88
m. masseter		
Right	56,38±22,92	35,54±9,5
Left	52,73±16,55	50,27±20,07
Average value	54,55±19,74	42,91±14,79
Astot	53,27±4,49	56,12±6,48
AS_{MM}	9,16±7,53*	-18,01±9,59*
AS_{TA}	-2,68±6,11	0,93±10,84
ACTIV%	-6,19±8,68	-5,2±-11,9

Table 1. Average indicators (M±m) of the amplitude of biopotential oscillations (mcV) of the masticatory muscles in the research groups (state of rest).
Note: *- significant difference between indicators at the p<0.05 level.

In group 1, a balance was observed between the values of muscle activity m. masseter and m. temporalis.

Average indicators of biopotential m. temporalis were slightly lower than biopotential m. masseter. The difference is statistically unreliable (Table 1).

When comparing the amplitude of oscillations of m. masseter between children with hearing impairment gr. 1 and gr. 2 it is determined that under I class according to Angle

(gr. 1), biopotential is slightly higher than in children with hearing impairments of the 2nd class according to Angle (gr. 2). In m. temporalis also exceeded the indicators of biopotential gr. 1 in comparison with gr. 2 (Table 1).

Assessment of biopotential of the temporal muscle for symmetry showed the following: in gr. 1, the biopotential difference between both sides is insignificant, in group 2 there is also activity of m. temporalis, and on the left it was higher without statistical significance of the difference (Table 1).

Muscle	Research groups		
	Hearing impaired children	Children with normal hearing and a physiological bite	Children with normal hearing and malocclusion
m. temporalis			
Right	45,21±6,55**	26,87±3,24**	23,86 ± 2,55**
Left	44,75±5,06*, **	26,38±3,17*	23,11 ± 4,27**
Average value	44,98±5,81	26,63±2,89*	23,49 ± 2,95**
m. masseter			
Right	48,05±13,6	20,28±3,59**	19,35 ± 2,56*
Left	51,75±12,31	20,03±3,27**	21,04 ± 3,29*
Average value	49,89±12,96	20,15±3,00**	20,20 ± 2,79*
Astot	4,08±5,34	1,01±3,92	3,34±4,31
AS_{MM}	13,28±5,80	-4,47±4,76**	-7,94±4,69*
AS_{TA}	-1,72±8,28	5,39±5,41	9,60±5,30
ACTIV%	3,08±6,98	–14,13 ± 2,06	–32,74 ± 4,52

Table 2. Average indicators (M±m) of biopotential oscillation amplitude (mcV) of masticatory muscles of persons with hearing deprivation and persons with normal hearing (state of rest).

Note: *- significant difference between indicators at the p<0.01 level;

**- significant difference between indicators at the p<0.05 level.

Comparison of EMG amplitude indicators of m. masseter in children with hearing deprivation and children with normal hearing and a physiological bite are presented in Table 2. A balance is observed between the values of muscle activity of m. masseter and m. temporalis both in patients with hearing deprivation and in patients with normal hearing, however, the activity of these muscles in the deaf is 2 times higher than in the hearing, the difference is statistically significant p<0.01; p<0.05 (Table 2).

Average values of biopotential of m. masseter of deaf children with malocclusion is more than 2 times compared to hearing children with a physiological bite with a statistically significant difference (p<0.05). The same regularity can be observed in the estimation of m. temporalis in hearing-impaired children with malocclusion, where the indicators are 1.7 times higher than in hearing children with a physiological bite with a statistically significant difference (p<0.05; p<0.01) (Table 2).

Assessment of symmetry m. masseter showed an excess of biopotential in children with hearing deprivation compared to hearing children with a physiological occlusion. In the work of M. temporalis regularity is confirmed statistically.

When comparing the indicators of the muscle activity index (ACTIV, %) in the group of deaf people, a higher activity of m.masseter was found (positive value of ACTIV, %), while hearing persons have higher activity of m. temporalis.

The action potential of the masticatory muscles in the static test of maximal voluntary jaw clenching in patients with hearing deprivation was analyzed. The obtained results of the amplitude of oscillations of the biopotential of the studied muscles indicate a slight decrease in the indicators of the amplitude of oscillations m. masseter and a slight increase in m. temporalis (Table 3).

Muscle	Research groups	
	Group 1	Group 2
M. temporalis		
Right	264,52±59,51	182,81±48,69
Left	208,51±58,64	338,44±78,66
Average value	236,52±59,08	260,63±63,68
M. masseter		
Right	239,95±55,65	212,02±64,04
Left	334,05±65,15	259,63±58,21
Average value	287±60,4	235,83±61,125
Astot	11,4±7,25	-6,91±6,71
AS_{MM}	11,9±7,66	15,36±9,32
AS_{TA}	11,36±10,68	-21,34±10,93**
ACTIV%	10,13±9,28	-7,50483±10,16

Table 3. Average indicators (M±m) of the amplitude of BP oscillations (mcV) of the masticatory muscles in the study groups (maximum voluntary compression test).

Note: **- significant difference between indicators at the p<0.05 level.

So, when testing the maximum arbitrary compression in gr. 1 (I class according to Angle) indicators of biopotential of m. masseter prevail over indicators of m. temporalis, however, we did not find a statistically significant difference. In the group 2, on the contrary, BP indicators of m. temporalis higher than of m. masseter (Table 3).

If in children with hearing deprivation in group 1, biopotential indicators of m. temporalis prevailed on the right side, then in m. masseter, on the contrary, the indicators in the left muscle

were higher, we did not find statistical reliability (Table 3).

And in group 2 (class II according to Angle) in deaf children, biopotential indicators of the studied muscles on the left were higher than on the right (Table 3).

If you compare the BP of masticatory muscles in deaf children between gr. 1 and gr. 2, then the average values of m. temporalis at II cl. slightly higher indicators (Table 3).

Muscle	Research groups		
	Deaf children, bite pathology	Children with normal hearing and a physiological bite	Children with normal hearing and malocclusion
m. temporalis			
right	231,84±40,77	750±93,13	770,36±55,01
left	260,36±47,95	653,41±67,61	647,29±59,86
average value	256,56±49,04	701,89±71,29*	708,82±43,36*
m. masseter			
right	228,78±41,32	510,01±67,67	334,63±37,38
left	304,28±45,27	557,89±68,27	398,33±43,33
average value	266,53±43,29	533,95±64,26*	366,48±35,82*
Astot	4,08±5,34	1,01±3,92	3,34±4,31
AS_{MM}	13,28±5,80	-4,47±4,76**	-7,94±4,69*
AS_{TA}	-1,72±8,28	5,39±5,41	9,60±5,30
ACTIV%	3,08±6,98	–14,13 ± 2,06	–32,74 ± 4,52

Table 4. Average indicators (M±m) of the amplitude of biopotential oscillations (mcV) of masticatory muscles of hearing-deprived and hearing patients (maximum voluntary jaw clenching).

Note: *- significant difference between indicators at the p<0.01 level;

**- significant difference between indicators at the p<0.05 level.

When comparing the AS_{MM} and AS_{TA} asymmetry index indicators, it was established that in teenagers with hearing deprivation with occlusal pathology of the I class the right side dominates, that is, the masticatory muscles on the right (positive values of AS_{MM} and AS_{TA}), while with II cl. by Angle the right is dominated by m. masseter (positive AS_{MM} values), and on the left m. temporalis (negative AS_{TA} values). The difference in the AS_{TA} index between the I class and II class has a statistically reliable. When comparing the indicators of the muscle activity index (ACTIV, %) in persons with deafness depending on the pathology of the bite during the test of maximum voluntary compression, it was established that in the first class according to Angle, the activity of the masticatory muscle prevails the II cl. according to Angle, the activity of the anterior temporal muscle prevails (p<0.05).

The study of the biopotentials of the masticatory muscles during the maximum voluntary squeeze test revealed a violation of physiological balance in patients with hearing deprivation. Lower indicators of the amplitude of biopotential oscillations of the masticatory muscles were noted (Table 4) than in the group of hearing persons with a physiological bite and hearing persons with bite pathology. Bioelectric activity of m. temporalis in persons with hearing deprivation is lower compared to the indicators of hearing people with a physiological bite and compared to hearing people with bite pathology. Indicators of m. masseter in deaf people is lower compared to hearing people with a physiological bite, and hearing people with bite pathology. The difference is statistically significant p<0.01 (Table 4).

When comparing the asymmetry index (ASIM) indicators in the state of maximum voluntary compression in patients with hearing deprivation, a violation of the balance of the right and left muscles was established: greater activity of m was observed on the right side. masseter (positive values of the ASIM $_{MM}$ index, %), from the left - m. temporalis (negative values of the ASIM $_{MT}$ index, %). A statistically significant difference in the ASIM $_{MM}$ indices was noted in the group of patients with hearing deprivation compared to the group of hearing persons with a physiological occlusion (p<0.05) and in comparison with hearing persons with occlusion pathology (p<0.01). When comparing the indicators of the index of muscle activity (ACTIV, %) in persons with deafness during the test of maximum voluntary jaw clenching, a predominance of masticatory muscle activity was established (positive value of ACTIV, %), in contrast to hearing people, both with a physiological bite and with bite pathology, which have negative values.

Discussion

The prevalence of maxillofacial anomalies in Ukraine ranges from 55.70–83.33% [18]. Our research showed that occlusion pathology in children with hearing deprivation occurs in 100%, which is a confirmation of Đeri Aleksandra (2013), which indicates that occlusion pathology occurs more often in deaf children compared to healthy ones [19].

The conducted electromyographic study of masticatory muscles in teenagers with hearing deprivation allowed us to assess their range of variability, the symmetry of their work during rest and the functional test of maximum voluntary jaw

clenching. For the correct anatomical development of the mandibular apparatus and the correct chewing function, such factors as the development of the maxillofacial area and the development and influence of the muscles of maxillofacial area should be taken into account [20]. It is especially important to remember this during the orthodontic examination and treatment of children and adolescents with hearing loss due to the functional features of their maxillofacial area, which are mainly due to the slight or complete lack of use of the facial muscles during speech or due to their use of sign language [21].

Study of electromyographic activity of masticatory muscles in children with sensorineural hearing loss with bite pathology of the I class and II class according to Angle confirmed that the bioelectric activity of these muscles changes depending on the occlusal intermaxillary relations. However, statistical analysis did not confirm the presence of any significant differences between groups. In persons with hearing impairments and hearing loss at physiological rest, EMG indicators of m. temporalis is somewhat dominated by similar indicators of m. masseter. The trend of a slight increase in the potential in m. masseter on the left. The bioelectric activity of the anterior temporal muscle is lower in Class I occlusion compared to Class II occlusion according to Angle, which we associate with the morphological features of dystoocclusion and, as a result, impaired masticatory muscle function.

The conducted study showed that the functional state of the temporal and masticatory muscles of the deaf depends on the existing hearing pathology, namely hearing deprivation. Hyperactivity of the temporal and masticatory muscles at rest and a decrease in their activity during the maximum voluntary jaw clenching test were noted in patients with hearing pathology in comparison with hearing patients, regardless of the bite pathology present in them, with a statistically significant difference ($p<0.05$; $p< 0.01$). A decrease in the indicators of bioelectric activity of the chewing muscles may indicate their increased constant tension or insufficiently perfect function of muscle relaxation.

It has been suggested that the anterior temporalis muscle is generally more active during natural function than the masseter muscle. The temporalis muscle controls the position of the lower jaw and contracts quite vigorously during chewing [22,23]. At the same time, it is important to distinguish the asymmetry of the masticatory and anterior temporal muscles [16].

During the electromyographic study of masticatory muscles in deaf people with bite pathology, slight deviations in the position of the lower jaw during muscle relaxation were found on one side (right), where this difference exists, but it is not statistically significant.

In this study, we established that the bioelectric activity of the anterior temporal muscle in the test of maximum voluntary compression is statistically significantly lower in persons with sensorineural hearing deprivation compared to hearing persons with occlusal disorders, the differences were significant at the $p<0,01$. These findings are consistent with data from a study that reported lower electromyographic activity in the masticatory muscles of deaf individuals [21].

The original asymmetry index and its modifications are quite widely used in EMG to evaluate both healthy patients and patients with craniomandibular disorders, especially when it is necessary to compare the activity of paired muscles [17, 16].

When evaluating the indicators of the asymmetry index of the masticatory muscles, a violation of the balance of the right and left muscles was established, namely, in deaf patients, greater activity of m. masseter is observed on the right and on the left - m. temporalis. The general index of asymmetry in persons with hearing deprivation indicates greater activity in them of m. masseter.

The detected functional imbalance of masticatory and temporal muscles in patients with sensory deprivation is one of the pathogenetic mechanisms that led to the occurrence of bite pathology.

In the orthodontic treatment of patients with hearing loss, it is necessary to use complex methods. At the same time as mechanical apparatus treatment, it is necessary to recommend functional elements and myogymnastic exercises that will lead to strengthening of the chewing muscles and normalization of their work. Training the chewing muscles will contribute to the correct formation of the biodynamic balance of the maxillofacial area.

Conclusions

Thus, the data obtained with the help of electromyographic research in the state of physiological rest indicate that there are changes in the functional activity of m. masseter and m. temporalis. Increased activity of masticatory muscles in a state of physiological rest in the deaf was noted in comparison with the activity of these muscles in patients with a physiological bite and normal hearing ($p<0.05$); indicators of the amplitude (mcV) of the masticatory muscles slightly prevail over the temporal ones. The lack of speech function, namely the lack of articulatory training of the masticatory muscles, has a significant negative impact on the physiological formation of the human dentition system. Perhaps this fact is the explanation of 100% presence of malocclusion in deaf children.

Depending on the type of bite in children with hearing deprivation, both with I and II class according to Angle, the amplitude indicators in the temporal muscles in a state of physiological rest have lower indicators compared to the masticatory muscles. A slight asymmetry was found in the work of the muscles gr. 2, however, the statistical reliability of the results was obtained only for m. temporalis on the right. In comparison with hearing children (physiological bite), the biopotential of m. masseter in deaf children prevails 2 times, and m. temporalis – 1.7 times.

At the same time, during the load (functional test of maximum voluntary clenching of the teeth) in persons with hearing deprivation, a significant decrease is observed in the activity of m. masseter and m. temporalis in comparison with the activity of these muscles in persons with normal hearing. In bite pathology of the I class and II class by Angle the right m. masseter dominates (positive values of AS_{MM}), while at II class the right is dominated by m. temporalis (negative values). The general index of asymmetry in persons with hearing deprivation indicates greater activity in them of m. masseter.

Detection and influence on the functional state of the masticatory and temporal muscles are important in the planning and orthodontic treatment of malocclusion in patients with sensorineural hearing loss.

Surface EMG makes it easy and quick to detect asymmetry indicators even in patients with various types of malocclusion and allows the orthodontist to assess the effect of treatment, monitor patients and manage therapy, and make adjustments to the treatment plan.

Declaration of Interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. Liu P, Wu G, Liu J, Jiao D, Guo J. Assessment of oral parafunctional behaviors and electromyographic activities of the masticatory muscles in young female patients with orthodontic Invisalign treatment. Int J Clin Exp Med, 2017; 10(11) 15323-8.
2. Achmad H, Anas A, Thamrin AZ, Sesioria A. Evaluation of Electromyography and Muscle Contraction in the Use of Myofunctional Appliances: A Systematic Review. Journal of Pharmaceutical Negative Results. 2022;13(4):915-26. https://doi.org/10.47750/pnr.2022.13.S04.108
3. Achmad H, Areni IS, Ramadany S, Inayah NH, Agustin R, Ardiansya R. Reduction of excessive overjet in pediatric malocclusion using myofunctional therapy accompanied by electromyography activity evaluation in orofacial muscles. J of Int Dent and Med Research. 2022;15(2), 656–68.
4. Shojaei E, Jafari Z, Gholami M. Effect of Early Intervention on Language Development in Hearing-Impaired Children. Iran J Otorhinolaryngol. 2016;28(84):13-21.
5. Kent RD. Nonspeech Oral Movements and Oral Motor Disorders: A Narrative Review. Am J Speech Lang Pathol. 2015;24(4):763-89. doi:10.1044/2015_AJSLP-14-0179
6. Prekopp P, Kondé M, Szigeti F J, Baranyi I, Küstel M, Tamás L, Gáborján A. A funkcionális hallászcsökkenés felismerése és komplex diagnosztikája [Recognition and complex diagnostics of functional hearing loss]. Orv Hetil. 2023;164(8):283-292. doi:10.1556/650.2023.32712
7. Zahnert T. The differential diagnosis of hearing loss. Dtsch Arztebl Int. 2011;108(25):433-444. doi:10.3238/arztebl.2011.0433
8. Kuroedova V, Vyzhenko E, Stasyk A. The rapid test method of identification of the type of growth of the jaw bone on the orthopantomogram. Georgian Med News. 2016; 256-257(7-8):14-7.
9. Marañón-Vásquez GA, da Costa Barreto LS, Pithon MM, Nojima LI, Nojima MDCG, de Souza Araújo MT, de Souza MMG. Reasons influencing the preferences of prospective patients and orthodontists for different orthodontic appliances. Korean Journal of Orthodontics. 2021;51(2):115-25. https://doi.org/10.4041/kjod.2021.51.2.115
10. Kerosuo H, Heikinheimo K, Nyström M, Väkiparta M. Outcome and long-term stability of an early orthodontic treatment strategy in public health care. Eur J Orthod. 2013;35(2):183-9. doi:10.1093/ejo/cjs087
11. Yamada T, Sugiyama G, Mori Y. Masticatory muscle function affects the pathological conditions of dentofacial deformities. Jpn Dent Sci Rev. 2020;56(1):56-61. doi:10.1016/j.jdsr.2019.12.001
12. Antolis M, Noerhadi NAI, Purbiati M. Masseter Muscle Activity in Dolichofacial Patients with Temporomandibular Joint Disorders: An Electromyographic Study. Journal of International Dental and Medical Research. 2021;14(1):253-6.
13. Hugger S, Schindler HJ, Kordass B, Hugger A. Clinical relevance of surface EMG of the masticatory muscles. (Part 1): Resting activity, maximal and submaximal voluntary contraction, symmetry of EMG activity. Int J Comput Dent. 2012;15(4):297-314.
14. Dmytrenko MI, Kuroiedova VD, Dvornyk VM. Functional condition of temporal and masticatory muscles in patients with

malocclusion complicated by crowding of frontal teeth. Lik Sprava. 2012; 8(1117):84-90. Ukrainian. https://doi.org/10.31640/LS-2012-8-15
15. Ferrario VF, Sforza C, D'Addona A, Miani A Jr. Reproducibility of electromyographic measures: a statistical analysis. J Oral Rehabil. 1991;18(6):513-21. doi:10.1111/j.1365-2842.1991.tb00074.x
16. Ferrario VF, Sforza C, Miani A Jr, D'Addona A, Barbini E. Electromyographic activity of human masticatory muscles in normal young people. Statistical evaluation of reference values for clinical applications. J Oral Rehabil. 1993;20(3):271-80. doi:10.1111/j.1365-2842.1993.tb01609.x
17. Naeije M, McCarroll RS, Weijs WA. Electromyographic activity of the human masticatory muscles during submaximal clenching in the inter-cuspal position. J Oral Rehabil. 1989;16(1):63-70. doi:10.1111/j.1365-2842.1989.tb01318.x
18. Smolyar N, Lesitskyi M. Prevalence of dental anomalies in children aged 6–16 years. Clinical dentistry. 2021;2(35):63-70. https://doi.org/10.11603/2311-9624.2021.2.12044
19. Đeri A, Kuzmanović-Radman I, Grabež M, Bajić Z, Prtina A, Novaković B, Živković S. Oral health in children with hearing and speech impairment in Banjaluka. Stomatološki glasnik Srbije. 2013; 60(3):139-146. doi: 10.2298/SGS1303139D
20. Siéssere S, de Albuquerque Lima N, Semprini M, et al. Masticatory process in individuals with maxillary and mandibular osteoporosis: electromyographic analysis. Osteoporos Int. 2009;20(11):1847-51. doi:10.1007/s00198-009-0885-2
21. Regalo SC, Vitti M, Semprini M, et al. Electromyographic analysis of the masseter and temporal muscles in oralized deaf individuals. Electromyogr Clin Neurophysiol. 2006;46(4):217-22.
22. Farella M, Palla S, Erni S, Michelotti A, Gallo LM. (2008). Masticatory muscle activity during deliberately performed oral tasks. Physiological Measurement. 2008;29(12):1397-410.
23. Moller E. Action of the muscles of mastication. Front Oral Physiol. 1974;1(0):121-58. doi: 10.1007/BF00424686.