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Functional Changes in the Auditory Analyser during a Temporary Impact of Low-Frequency Vibration for the Treatment of Sagittal Malocclusion

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Nataliia Rashchenko
0000-0001-5565-6849
Bohdan Melnyk
0000-0003-2232-8181

Bogomolets National Medical University, Kyiv, Ukraine

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Abstract:

This study, considering the diverse views of researchers on the impact of vibration on human sensory systems, investigates its effect on the auditory system. Low-frequency mechanical oscillations increase cell membrane permeability and enhance the circulation of organic compounds in blood vessels, thereby accelerating or normalizing metabolism. Vibration also activates redox processes in muscle tissues. However, analysis of current literature reveals no consensus among domestic and foreign researchers regarding its clinical application.

Aim: To investigate the effect of low-frequency vibration on the auditory system and to evaluate functional changes in the acoustic reflex during a temporary five-minute exposure applied in the treatment of sagittal malocclusion.

Materials and Methods: The study involved 20 patients aged 12–17 years with distal malocclusion and normal hearing, confirmed by pure-tone and speech audiometry. Pure-tone threshold audiometry was performed within the frequency range of 125–8000 Hz, along with speech audiometry.

Results: Recording of the acoustic reflex of the middle ear muscles before and after five minutes of vibration—using ipsilateral and contralateral presentation of a 1.0 kHz sound stimulus (1000 ms)—showed a 15.8% increase relative to baseline. In 52.6% of ipsilateral and 36.8% of contralateral cases, the reflex remained unchanged or decreased. After a ten-minute rest, amplitudes returned to baseline in 61.6% (ipsilateral) and 57.9% (contralateral) cases. By the 20th minute, full recovery was observed in all patients.

Conclusions: A five-minute exposure to an orthodontic vibrating device does not affect auditory sensitivity. Instead, it promotes activation rather than inhibition of the neuromuscular mechanism of the acoustic reflex, likely at the brainstem level. This effect is transient and does not alter the functional state of the auditory system.

Наталія Ращенко
0000-0001-5565-6849
Богдан Мельник
0000-0003-2232-8181

Національний медичний університет імені О.О. Богомольця, м. Київ, Україна

Ключові слова:
вібрація;
ортодонтичне лікування;
сагітальні аномалії прикусу;
слухова чутливість;
акустичний рефлекс;
внутрішньовушні м'язи.

Функціональні зміни слухового аналізатора при тимчасовому впливі низькочастотної вібрації під час лікування сагітальних аномалій прикусу

Анотація

У статті, з урахуванням розбіжностей у поглядах науковців щодо впливу вібрації на сенсорні системи людини, досліджено дію вібрації на орган слуху. Встановлено, що механічні коливання низької частоти підвищують проникність клітинних мембран та покращують циркуляцію органічних сполук у судинах, що є визначальним фактором для прискорення або нормалізації метаболізму. Доведено, що під впливом вібрації активуються окисно-відновні процеси у м'язових тканинах.

Водночас аналіз сучасної наукової літератури свідчить про відсутність єдиного підходу вітчизняних та зарубіжних учених щодо застосування вібраційного впливу.

Мета. Дослідити вплив низькочастотної вібрації на слухову систему та оцінити функціональні зміни слухового аналізатора за умови п'ятихвилинного вібраційного впливу під час лікування сагітальних аномалій прикусу.

Матеріали та методи. У дослідженні взяли участь 20 пацієнтів віком 12–17 років із дистальним прикусом та нормальним станом слуху за даними тональ-

ної та мовної аудіометрії. Було застосовано загальноклінічну порогову тональну аудіометрію в діапазоні частот від 125 до 8000 Гц, а також мовну аудіометрію.

Результати. При реєстрації акустичного рефлексу внутрішньовушних м'язів (АРВМ) до та після 5-хвилинного вібраційного впливу з іпсі- та контралатеральним пред'явленням звукового стимулу частотою 1,0 кГц тривалістю 1000 мс, спостерігалося його зростання на 15,8 % відносно вихідного рівня. У 52,6 % випадків при іпсі- та у 36,8 % при контралатеральній стимуляції показник залишався незмінним або знижувався. Повторне дослідження АРВМ після 10-хвилинного відпочинку продемонструвало повернення значень амплітуди до вихідних величин у 61,6 % випадків при іпсі- та у 57,9 % при контралатеральному пред'явленні стимулу. Проте до кінця 20-ї хвилини відпочинку відновлення амплітудно-часових характеристик АРВМ до початкового стану відбулося у всіх без винятку досліджуваних пацієнтів.

Висновки. Підсумовуючи, проведене дослідження продемонструвало, що 5-хвилинний вплив ортодонтичного вібраційного пристрою на зубний ряд не впливає на слухову чутливість органа слуху. Водночас він сприяє активації, а не пригніченню нервово-м'язового механізму АРВМ, що, очевидно, відбувається на рівні стовбура головного мозку, має короткочасний транзиторний характер і не позначається на функціональному стані слухового аналізатора.

Introduction

The treatment of distal malocclusion depends not only on its clinical form and the anatomical level of manifestation, including growth patterns of the upper and lower jaws, but also on the patient's age ***[1]***. The complexity of treating this anomaly lies in the risk of relapse, which necessitates a prolonged retention period ***[2]***.

Various therapeutic approaches are employed, including biological, appliance-based, surgical, and physiotherapeutic methods. Appliance therapy remains the primary method for managing dentoalveolar anomalies and deformities, including distal malocclusion. However, this approach has age-specific indications and biological limitations ***[3]***. In cases of established dentoalveolar deformities, especially in adult patients, multidisciplinary treatment methods are indicated. One such approach is surgical treatment, which may be either primary or auxiliary. The surgical method is considered primary when malocclusion is corrected directly through surgical intervention. The auxiliary method is designed to facilitate orthodontic treatment; it involves not only weakening the cortical layer of the jaws but also modulating biochemical processes in bone tissue through induced inflammation. As a result, bone tissue decalcification occurs, increasing its plasticity. However, clinical practice shows that surgical methods are traumatic and can lead to various complications. Consequently, modern orthodontic practice favors less invasive stimulation methods, such as low-frequency vibration exposure.

It is known that low-frequency mechanical oscillations increase cell membrane permeability and enhance the circulation of organic compounds in blood vessels, which plays a crucial role in accelerating or normalizing metabolism. Exposure to vibration activates redox processes in muscle tissue. However, an analysis of modern scientific literature reveals a lack of consensus among researchers regarding the clinical application of vibration. In particular, some experts highlight the adverse effects of vibration on the human body, especially on the auditory system.

According to S. A. Levytska ***[4]***, tympanometry is an effective supplementary method for diagnosing otitis media with effusion (OME), as otoscopic and tympanometric features of the condition demonstrated markedly higher sensitivity (92%). Another study ***[5]*** examined the condition of the vocal apparatus and middle ear in children with complaints of hoarseness. Impedance audiometry revealed that 17 out of 24 patients exhibited a type C tympanogram, and 7 of them showed a significant reduction in tympanic compliance, indicating specific disorders in the sound conduction system. In the study by K. V. Liakh ***[6]***, the effect of microdebrider-assisted correction of the torus tubarius on Eustachian tube function in children without middle ear pathology was evaluated. Experimental results showed that torus tubarius hypertrophy was detected in 31.3% of patients undergoing primary adenotomy. The microdebrider technique for torus tubarius correction is considered safe with respect to the pressure-equalizing function of the auditory tube. Research by T. A. Shydlovska ***[7]*** underscores the importance of measuring distortion product otoacoustic emissions (DPOAEs) in patients with acute combat-re-

lated trauma, contributing to the timely and objective detection of lesions of receptor structures within the auditory system.

Aim. To investigate the effect of low-frequency vibration on the auditory system, taking into account divergent scientific perspectives on its impact on human sensory functions, and to evaluate functional changes in the auditory system during a short-term (five-minute) vibration exposure applied in the treatment of sagittal malocclusion.

Materials and Methods

We examined 20 patients aged 12 to 17 years with distal malocclusion and normal hearing, as confirmed by pure-tone and speech audiometry. Clinical assessment included pure-tone threshold audiometry in the frequency range of 125–8000 Hz, as well as speech audiometry. Additionally, an objective method for assessing the auditory system was employed: dynamic impedance audiometry, which enables precise determination of changes occurring in middle ear structures. Amplitude dynamics were calculated using the formula proposed by B. Y. Limar et al. (1977). The acoustic reflex recording curves were processed using statistical variation analysis (L. N. Frantsevych, 1980) to identify underlying patterns. For this purpose, the arithmetic mean (M) and the standard error of the mean ($\pm m$) were calculated. To measure variability and compare mean values with distribution series, the standard deviation (σ) was determined. Statistical significance was assessed using Student's t-test.

Millimeter-wave resonance therapy (MRT) was performed according to our methodology ("Methodology of millimeter-wave resonance therapy (MRT) for stimulation of orthodontic treatment in patients with distal malocclusion"). Rationalization Proposal No. 12/93 (1615), June 17, 1993.

Results

Baseline tympanometry with a probe tone of 226 Hz was performed to exclude subclinical pathology, including tympanic membrane hypermobility, patulous Eustachian tube, or residual dysfunction (salpingo-otitis). Following this, the initial threshold for eliciting the acoustic reflex of the intratympanic muscles (ARIM) was determined in each ear using ipsilateral and contralateral presentation of a 1.0 kHz sound stimulus with a duration of 1000 ms. The stimulus intensity was then increased by 10 dB above threshold, and the acoustic reflex was recorded with a time base of 100 ms/cm.

After recording the initial audiometric and ARIM data, a five-minute vibration exposure was applied to the teeth and alveolar process. Immediately thereafter, the audiological assessment was repeated. Upon completion of the vibration exposure, functional changes in the ARIM were observed; therefore, the study was repeated after ten- and twenty-minute rest periods.

The following temporal characteristics of the ARIM were calculated (in ms):

- T_l **(latency):** time required for contraction of the intratympanic muscles to reach 10% of maximum;
- T_n **(rise time):** time required to reach 90% of maximum;
- T_d **(duration):** interval during which the ARIM curve maintains maximum activity;
- T_s **(decay period):** time when reflex activity decreases to 10%;
- T **(total time):** overall duration of the reflex response;
- A **(reflex amplitude):** value ranging from 10% to 90% of maximum, measured in cm^3.

Given the divergent scientific opinions regarding the effect of vibration on human sensory systems, we investigated its impact on the auditory system. We evaluated functional changes in the auditory analyzer during a short-term (five-minute) low-frequency vibration exposure generated by the proposed orthodontic device. Twenty patients aged 12 to 17 years with distal occlusion and normal hearing, and without clinical evidence of ENT pathology according to pure-tone and speech audiometry, were examined. Our findings demonstrated that auditory sensitivity in the frequency range of 125–8000 Hz remained unchanged in all subjects following the five-minute therapeutic low-frequency vibration exposure.

When recording the acoustic reflex of the intratympanic muscles (ARIM) before and after a five-minute vibration exposure—with ipsilateral and contralateral presentation of a 1.0 kHz sound stimulus (1000 ms duration)—we observed a 15.8% increase compared to baseline. In 52.6% of cases with ipsilateral stimulation and 36.8% with contralateral stimulation, the reflex remained unchanged or decreased. After a ten-minute rest, a follow-up study of the ARIM showed that amplitude values had returned to baseline in 61.6% of ipsilateral and 57.9% of contralateral presentations. However, by the end of the 20th minute of rest, restoration of the initial amplitude–temporal characteristics was observed in all patients without exception.

Conclusions

In summary, our study demonstrates that a five-minute exposure to the orthodontic vibrating device on the dentition does not affect the auditory sensitivity of the hearing organ. At the same time, it promotes activation rather than inhibition of the neuromuscular mechanism of the intratympanic muscle acoustic reflex (ARIM). This effect, which likely occurs at the level of the brainstem, is short-term and transient, with no lasting impact on the functional state of the auditory analyzer.

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