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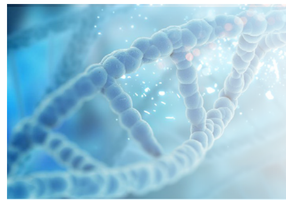

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Cerebral circulation improvement method using boxing and orthodontic mouthguards

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Abstract. Due to the active hostilities in Ukraine, the rates of exacerbations of chronic diseases, trauma to the head and spinal column due to both gunshot wounds and increased force load on the musculoskeletal system have increased significantly. The issue of improving rehabilitation approaches is relevant due to the available statistics on cerebral blood supply pathologies. Given the need for affordable and effective methods of musculoskeletal rehabilitation, the study aims to investigate the effectiveness of orthodontic and boxing mouthguards on the state of cerebral blood vessels. Five patients with a history of contusion and post-traumatic stress disorder were studied at the Kyiv Regional Centre for Mental Health using a physical examination and rheoencephalography. The use of orthodontic and boxing mouthguards showed positive dynamics in the restoration of maxillofacial muscles, compensation of bite height and satisfactory blood supply to brain structures compared to the baseline data. The analysis of the encephalograms showed rheoencephalographic signs of improvement in cerebral circulation: a decrease in spasm of the arterial walls of cerebral vessels, compensation for blood supply deficit, improvement of blood circulation in the carotid basin and venous outflow in the deficit mode were detected. In the examined patients with injuries, pain syndrome and constant mechanical stress on the musculoskeletal system, a decrease in pain and improvement of muscle symmetry in the affected anatomical areas were noted while wearing orthodontic and boxing mouthguards. The obtained results can be implemented in the rehabilitation protocols for patients with concussion, brain concussion, and spinal and skull injuries. The availability and effectiveness of the proposed technique allow it to be used for patients with chronic diseases of the cardiovascular system, especially with complicated blood supply to brain structures

Keywords: medical rehabilitation; orthodontics; skull bones; rheoencephalography; aligner; post-traumatic stress disorder

INTRODUCTION

With the onset of military aggression in Ukraine, the number of stress-related diseases has increased significantly: according to current publications [1-3], there is an active dynamic of exacerbations of chronic pathologies and a sharp increase in psycho-emotional disturbances in patients. Many chronic diseases that were previously in a compensated state, such as diseases of the central nervous system (CNS) or trauma, have begun to acutely disturb patients again. According to a study by I.S. Mironyuk *et al.* [1], in Ukraine, in addition to an increase in morbidity, there are high risks of an increase in overall and premature mortality due to the war. Thus, providing affordable and effective medical correction for the population's health is an urgent issue in Ukraine [2]. In addition, as noted by M.V. Danchenko & Yu.M. Korzh [4], new direct causes of pain syndromes have emerged, such as wearing body armour, military ammunition, and prolonged intense physical activity. Therefore, the question arises of developing reliable methods of treatment, prevention of exacerbations and development of pathologies of the human musculoskeletal system, which directly affects the adequate blood supply to the CNS organs. Given the relevance of this issue for military personnel, the methods should be easy to implement, effective and consider the specifics of traumatic factors.

There are areas of medical rehabilitation not only in Ukraine, where active hostilities are taking place but also

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in many other countries. As V. Steblyuk [5], rehabilitation is focused on a quick, effective, and maximally restorative effect on the patient's musculoskeletal system to improve the quality of life. The importance of this issue is also confirmed by the statistics of the Medical Forces Command: bone defects in the military, especially with gunshot wounds, are noted in almost 12% of patients [3].

However, the question arises as to which medical tool can be used to restore the musculoskeletal system, in particular the CNS blood supply system, when a patient subjectively considers himself or herself healthy but regularly receives an atypical load on the spinal column and spinal cord, such as military personnel whose ammunition weighs up to sixty kilograms [6]. The system of medical, social, and psychological rehabilitation of veterans requires the involvement of intellectual potential and expert approach of specialists in the field of public health, medical rehabilitation and reconstructive surgery [7].

One of the areas of medical rehabilitation is devoted to the recreation of the patient's health by restoring the anatomical position of the dentition. Modern orthodontics almost completely solves the problems associated with functional disorders of the musculoskeletal system that have arisen as a result of malocclusion [8]. The methods used by orthodontists are effective and long-lasting, as changes in orthodontic treatment occur in the whole body, both at the organ and humoral levels [9]. Typically, orthodontic treatment lasts from two to three years, and changes occur not only in the oral cavity but also in the bones of the skull, gait, and posture, as well as in the cervical, thoracic, and lumbar spine. In addition, there are changes in the swallowing mechanism, resulting in changes in the innervation of the oesophagus and mediastinal organs.

Given the relevance of rehabilitation of military and civilian victims of traumatic injuries to the skull bones, cervical spine, and spinal column in general, this study aimed to experiment to investigate the effectiveness of orthodontic aligners in improving cerebral circulation by correcting the symmetry and height of the bite, as well as the anatomical load on the skull bones.

MATERIALS AND METHODS

The study was conducted at the Kyiv Regional Centre for Mental Health under the clinical supervision of neurologist Andrii Tymchenko. Five male patients (A, B, C, D, E) of the treatment centre aged 29 to 58 years were involved in the clinical trial with informed consent. The diagnosis on admission for all patients included shell shock and post-traumatic stress disorder (PTSD). During their cooperation in the research study, the patients underwent anamnestic data collection, physical examination, instruction on wearing orthodontic aligners, and rheoencephalography (REG) before and after the recommended therapy. The study included patients with shell shock and indications for orthodontic treatment of the bite. Patients with a complicated psychiatric or somatic history were excluded.

Individual boxing or orthodontic mouthguards were used for orthodontic treatment. The boxing mouthguard is a two-layer mouthguard made of ethylene vinyl acetate polymer material with a polypropylene frame. It can be adjusted to the patient's bite independently. According to the manufacturer's instructions, the mouthguard is fixed in the oral cavity by the patient at rest, and after hardening and taking on the desired shape, it is ready for daily use. During wear, the patient fixes the mouthguard in a comfortable position in the oral cavity at rest. Its anatomical position corresponded to the patient's bite morphology. The mouthguard was worn for two to three hours. Orthodontic aligners were used both in mass production and in individual production. Patients were enrolled in the study after a physical examination and general clinical examinations (complete blood count and urine test, electrocardiogram, and radiograph of the maxillofacial area). The therapeutic effect was monitored for two weeks, which was assessed by filling the occlusion and posture defect with a mouthguard. The mouthguards were worn for at least 12 hours a day by each patient.

After the patients finished wearing the mouthguard, a REG examination was performed to study cerebral blood flow by diagnosing changes in the electrical resistance of the skull structures, which is caused by volumetric fluctuations in perfusion and partially by the state of the blood filling rate in the cerebral and extracranial vessels during the passage of an alternating current of a certain frequency. Registration was performed on a rheoencephalograph with a high-frequency current of 120 kHz. The therapeutic effect of the caps on cerebral circulation was assessed by the condition of the vessels in the carotid and vertebral-basilar basins at the beginning of the study (baseline data on the condition of the vessels of patients A-E) and at the end of the application of the cap (therapeutic effect on cerebral circulation after two weeks of caps application). During registration, the electrodes were placed on the convex area of the mastoid process of the temporal bone, the upper edge of the brow arch, the occiput and the mastoid process. Hemodynamics was assessed by rheowave propagation time (Qa), fast blood filling time (α1), slow blood filling time (α2), upward wave propagation time (β), maximum fast filling velocity (V), average fast filling velocity (Vb), vascular wall tone as a ratio of anacrotic length to wavelength (α/T), rheographic index (Ri), inter-amplitude incisional index (MKi), inter-amplitude diastolic wave (MKd), brachiocephalic index (BCA).

All data obtained during the study were entered into databases built using Microsoft Excel spreadsheets and Statistica 6.0 software. The study was conducted following the requirements of Good Clinical Practice (GCP) [10] and the Declaration of Helsinki for Clinical Research Involving Human Subjects [11].

RESULTS

The research results are based on the joint efforts in the management and treatment of a sample of five patients undergoing complex rehabilitation therapy. The effectiveness of the complex orthodontic, osteopathic and rehabilitation treatment was confirmed by the indicators of the instrumental study (Table 1, Fig. 1). The rheoencephalography examination must be performed at the beginning of the study in a state of rest, without background load and medication. The next rheoencephalographic examination was performed together with the physical examination only after the use of orthodontic and boxing mouth guards for two weeks.

Table 1. Results of rheoencephalography examination of patient A before treatment (baseline)

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	0.21	0.26	0.19	0.26	Seconds
α1	0.01	0.26	0.04	0.23	Seconds
α2	0.16	0.07	0.14	0.02	Seconds
β	0.23	0.05	0.24	0.1	Seconds
Vb	0.1	0.01	0.1	0.01	
V	0.04	0.02	0.04	0.04	
Ri	0.09 (0.80-2.00)	0.05 (0.80-2.00)	0.1	0.05	
MKi	36.84	45.45	60	18.18	
MKd	31.58	18.18	60	54.55	
α/T	0.425	0.868	0.429	0.714	
BCA	14.29	250	28.57	80	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, *α/T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

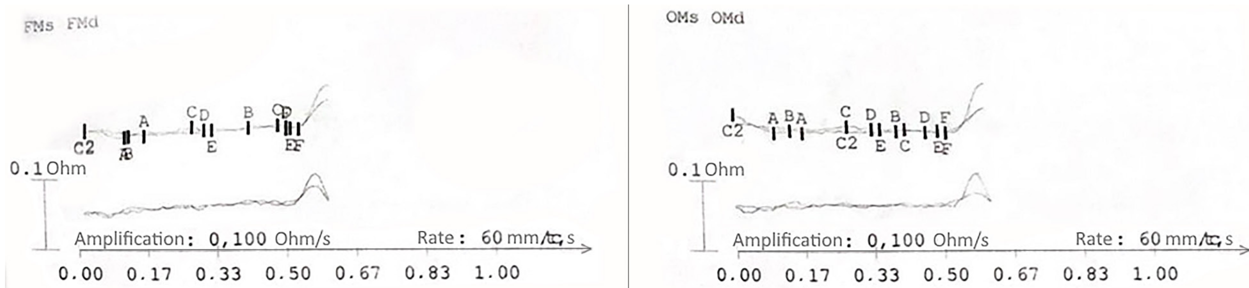

Figure 1. Rheoencephalography examination of patient A before treatment (baseline)
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

REG values were determined by FM, OM leads on the left (s) and right (d). Patient A (33 years old), at the time of the study, according to REG, was diagnosed with signs of reduced blood supply to the brain with severe hypovolaemia and hypertension of blood vessels (Table 1, Fig. 1).

Patient A's REG results after wearing the mouthguard showed moderate hypovolaemia, normal blood filling of the arterial vessels on the right, a moderate increase in cerebral blood vessel tone, and normal resistance artery tone (Table 2, Fig. 2).

Table 2. Results of rheoencephalography examination of patient A after treatment

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	0.15	0.17	0.08	0.07	Seconds
α1	0.07	0.06	0.13	0.16	Seconds
α2	0.08	0.05	0.04	0.04	Seconds
β	0.73	0.8	0.78	0.51	Seconds
Vb	0.4 (1.30-1.80)	0.68 (1.30-1.80)	0.2 (0.90-1.30)	0.38	
V	0.85 (0.70-1.10)	1.11 (0.70-1.10)	0.95 (0.30-0.55)	1.54 (0.30-0.55)	
Ri	0.59 (1.40-1.60)	0.76 (1.40-1.60)	0.43 (0.90-1.05)	0.93 (0.90-1.05)	
MKi	12.71	24.84	39.08	20.86	
MKd	19.49 (45.00-65.00)	28.1 (45.00-65.00)	55.17 (45.00-67.00)	33.69 (45.00-67.00)	
α/T	0.17 (0.13-0.14)	0.121 (0.13-0.14)	0.179 (0.14-0.15)	0.282 (0.14-0.15)	
BCA	24.79	6.45	525	700	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, *α/T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

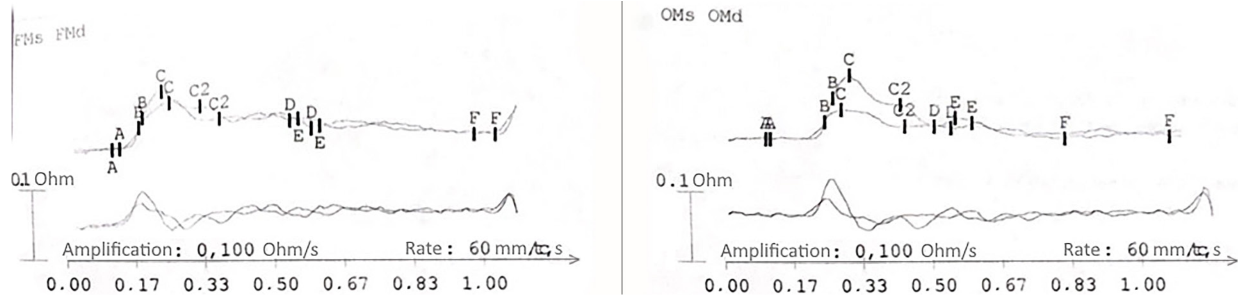

Figure 2. Rheoencephalography examination of patient A after treatment
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

Patient B (58 years old), at the beginning of the REG study, showed signs of severe hypertension of the vessel walls on the right and left, and difficult venous outflow of the deficit type (Table 3, Fig. 3).

Table 3. Results of rheoencephalography examination of patient B before treatment (baseline)

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	-0.01	0.09	-0.05	-0.05	Seconds
α1	0.2	0.1	0.24	0.24	Seconds
α2	0.04	0.04	0.03	0.03	Seconds
β	0.41	0.44	0.41	0.41	Seconds
Vb	0.28	0.55	0.23	0.23	
V	3.37	0.76	1.18	1.18	
Ri	0.88 (0.80-2.00)	0.85 (0.80-2.00)	0.69	0.69	
MKi	15.25	23.39	14.6	14.6	
MKd	15.82 (45.00-65.00)	28.65 (45.00-65.00)	18.98	18.98	
α/T	0.369	0.241	0.397	0.397	
BCA	18.64	21.02	230.77	230.77	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, *α/T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

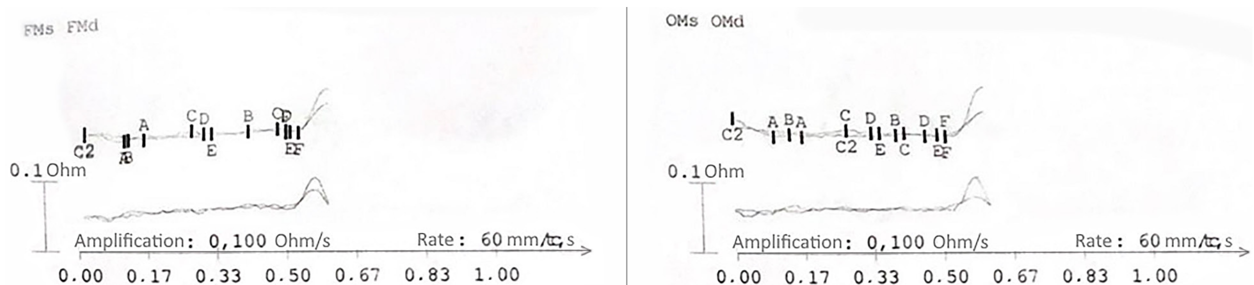

Figure 3. Rheoencephalography examination of patient B before treatment (baseline)
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

After orthodontic treatment, normal blood filling of the cerebral vessels with partial compensation of the venous outflow deficit was found (Table 4, Fig. 4). The tone of the main arteries remained slightly increased but lower than at the beginning of therapy.

Patient C (40 years old) was hospitalised with signs of decreased cerebral blood flow on the left, mild hypovolaemia, increased blood vessel wall tone on the left and significantly decreased arterial resistance tone on the left (Table 5, Fig. 5).

Table 4. Results of rheoencephalography examination of patient B after treatment

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	-0.02	-0.03	-0.03	-0.04	Seconds
α1	0.21	0.22	0.21	0.22	Seconds
α2	0.04	0.04	0.04	0.05	Seconds
β	0.39	0.48	0.49	0.48	Seconds
Vb	0.32	0.28	0.22	0.22	
V	1.45	0.89	1.67	0.67	
Ri	1 (0.80-2.00)	0.97 (0.80-2.00)	0.72	0.73	
MKi	19.4	15.38	10.42	19.05	
MKd	20.9 (45.00-65.00)	24.62	22.92	32.65	
α/T	0.391	0.351	0.338	0.36	
BCA	369.23	123.08	133.33	56.52	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, α/*T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

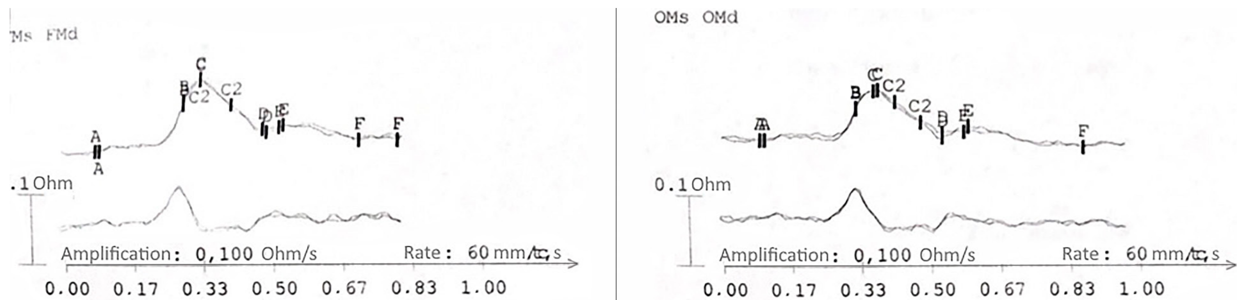

Figure 4. Rheoencephalography examination of patient B after treatment
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

Table 5. Results of rheoencephalography examination of patient C before treatment (baseline)

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	0.03	0.17	0.05	0.16	Seconds
α1	0.16	0.05	0.15	0.05	Seconds
α2	0.06	0.07	0.04	0.03	Seconds
β	0.76	0.68	0.55	0.66	Seconds
Vb	0.32	0.53	0.36	0.47	
V	9.58	0.42	0.6	1.02	
Ri	0.84 (0.80-2.00)	0.54 (0.80-2.00)	0.77	0.42	
MKi	-1.18	57.8	10.32	44.71	
MKd	0	66.06	12.9	60	
α/T	0.224	0.15	0.257	0.108	
BCA	-1.83	18.63	4.67	15	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, α/*T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

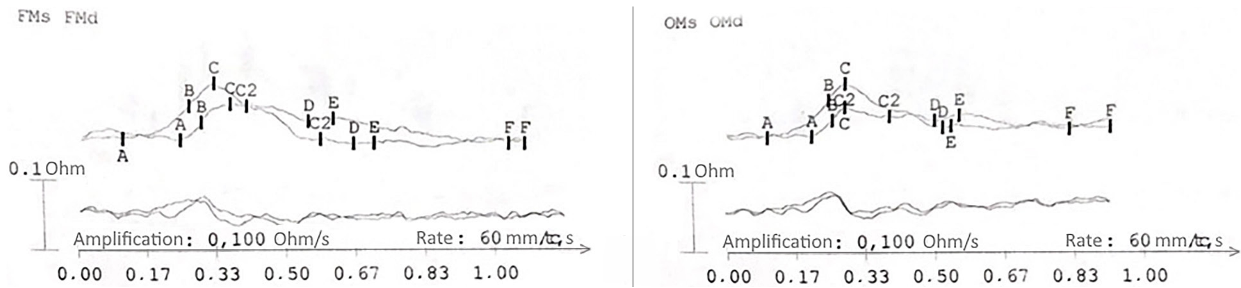

Figure 5. Rheoencephalography examination of patient C before treatment (baseline)
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

After treatment, there were no signs of impaired venous outflow; the tone of the resistance arteries on the left was satisfactory, and on the left it was slightly reduced (Table 6, Fig. 6).

Table 6. Results of rheoencephalography examination of patient C after treatment

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	0.19	0.14	0.01	0.02	Seconds
α1	0.07	0.12	0.24	0.23	Seconds
α2	0.05	0.16	0.04	0.04	Seconds
β	0.79	0.68	0.78	0.81	Seconds
Vb	0.66	0.24	0.22	0.12	
V	0.68	0.44	0.88	0.59	
Ri	0.79 (0.80-2.00)	0.74 (0.80-2.00)	0.77	0.46	
MKi	46.54	24.83	21.43	58.7	
MKd	52.2	25.5	22.08	60.87	
α/T	0.132	0.292	0.264	0.25	
BCA	18.35	330	21.15	371.43	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, α/*T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

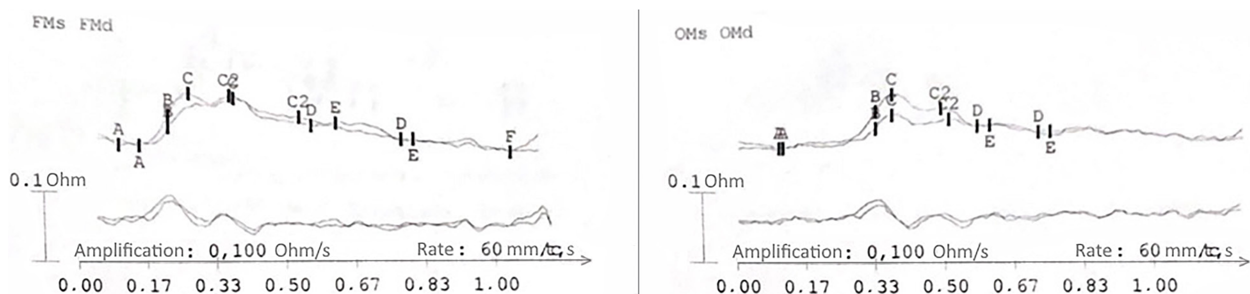

Figure 6. Rheoencephalography examination of patient C after treatment
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

At the beginning of the study, patient D (29 years old) had moderate hypovolaemia, decreased cerebral blood flow, mild hypotension, a moderate decrease in the tone of the resistance arteries on the left and an increased tone of the main arteries on the left (Table 7, Fig. 7).

After orthodontic treatment, Patient D showed signs of significant compensation of venous outflow by the deficit type, mild hypovolaemia, and a decrease in hypertension of the cerebral vessel walls on both sides according to REG (Table 8, Fig. 8).

Table 7. Results of rheoencephalography examination of patient D before treatment (baseline)

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	0.24	0.24	0.24	0.24	Seconds
α1	0.05	0.06	0.04	0.06	Seconds
α2	0.06	0.05	0.03	0.04	Seconds
β	0.67	0.67	0.71	0.68	Seconds
Vb	0.82	0.79	0.41	1	
V	1.74	1.26	0.39	0.56	
Ri	0.83 (0.80-2.00)	0.78 (0.80-2.00)	0.26	0.82	
MKi	31.74	27.39	62.26	32.73	
MKd	34.13	33.12	86.79	38.79	
α/T	0.141	0.141	0.09	0.128	
BCA	5.33	6.54	30	9.76	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, *α/T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

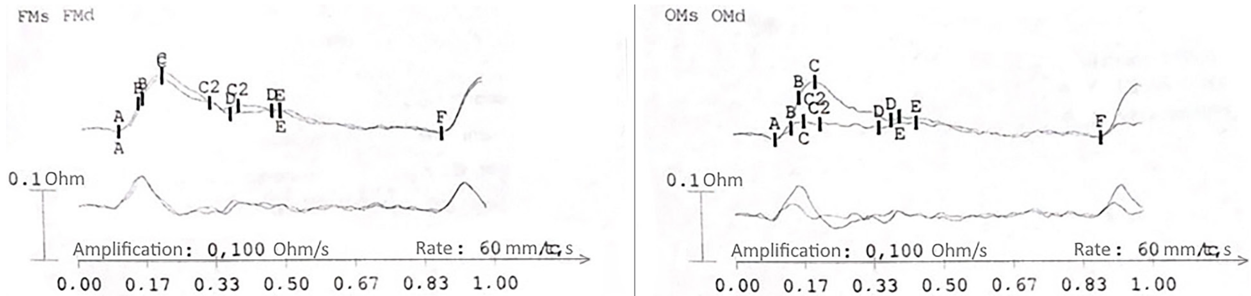

Figure 7. Rheoencephalography examination of patient D before treatment (baseline)
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

Table 8. Results of rheoencephalography examination of patient D after treatment

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	0.22	0.35	0.38	0.39	Seconds
α1	0.23	0.1	0.06	0.06	Seconds
α2	0.04	0.04	0.06	0.04	Seconds
β	0.68	0.49	0.67	0.5	Seconds
Vb	0.26	0.39	0.41	0.87	
V	2.57	0.94	0.75	0.76	
Ri	1.09 (0.80-2.00)	0.76 (0.80-2.00)	0.51	0.82	
MKi	24.31	30.72	20.59	35.15	
MKd	40.37	35.29	74.51	42.42	
α/T	0.284	0.222	0.152	0.167	
BCA	57.14	12.33	23.08	7.27	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, *α/T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

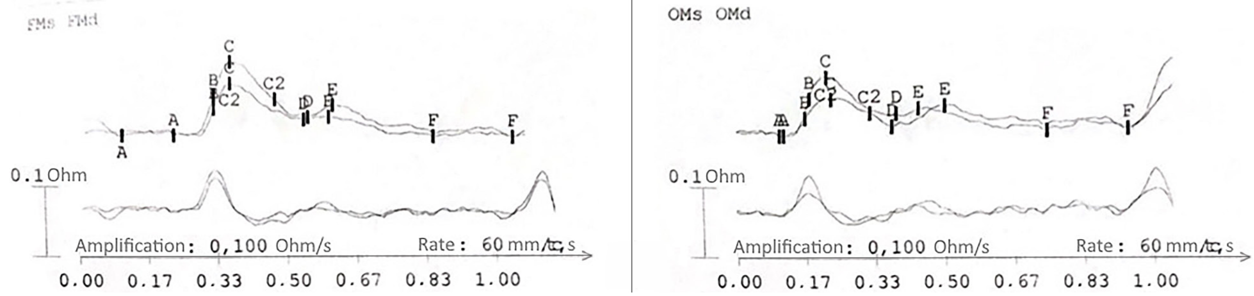

Figure 8. Rheoencephalography examination of patient D after treatment
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

Patient E (30 years old), at the initial REG, had signs of decreased blood filling of cerebral vessels on the left, increased vascular wall tone on the left, mild hypotension, and a significant decrease in the tone of resistance arteries (Table 9, Fig. 9).

Table 9. Results of rheoencephalography examination of patient E before treatment (baseline)

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	0.24	0.21	0.24	0.23	Seconds
α1	0.05	0.09	0.05	0.06	Seconds
α2	0.04	0.02	0.04	0.03	Seconds
β	0.41	0.38	0.58	0.63	Seconds
Vb	0.94	0.57	0.98	0.54	
V	2.48	1.11	1.67	1.52	
Ri	0.85 (0.80-2.00)	0.65 (0.80-2.00)	0.82	0.54	
MKi	9.41	10.77	17.68	19.44	
MKd	15.29	14.62	23.17	22.22	
α/T	0.18	0.224	0.134	0.125	
BCA	13.75	14.81	7.55	14.42	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, α/*T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

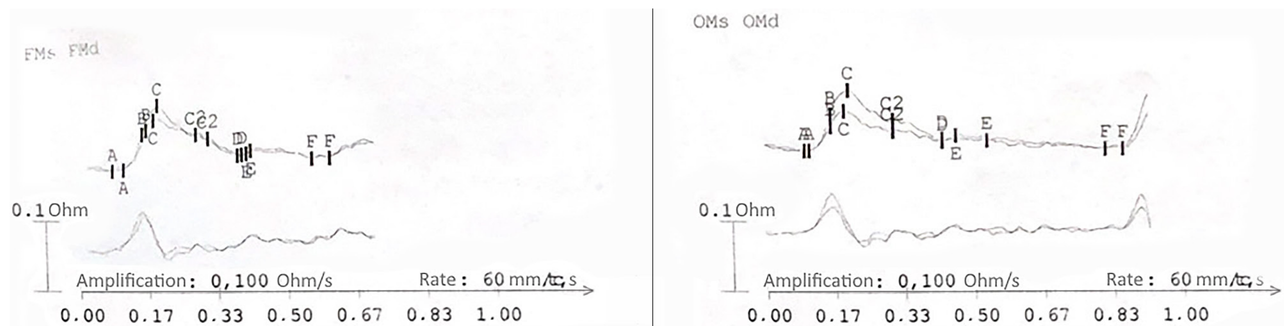

Figure 9. Rheoencephalography examination of patient E before treatment (baseline)
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

Repeated REG of Patient E showed positive dynamics of cerebral blood filling: moderate signs of deficient blood filling, but with satisfactory changes compared to the baseline data before treatment; normal vascular tone on the left and satisfactory on the right; moderate decrease in venous blood flow (Table 10, Fig. 10).

Table 10. Results of rheoencephalography examination of patient E after treatment

Indicator	Frontomastoid (FMs)	Frontomastoid (FMd)	Occipital-mastoid (OMs)	Occipital-mastoid (OMd)	Unit of measurement
Qa	-0.05	-0.05	0.13	0.14	Seconds
α1	0.24	0.24	0.06	0.05	Seconds
α2	0.04	0.04	0.04	0.03	Seconds
β	0.4	0.38	0.57	0.53	Seconds
Vb	0.21	0.21	0.82	0.85	
V	0.45	1.24	1.25	1.79	
Ri	0.69 (0.80-2.00)	0.74 (0.80-2.00)	0.76	0.62	
MKi	35.51	33.56	24.18	16.13	
MKd	36.23	38.93	28.1	23.39	
α/T	0.412	0.424	0.149	0.131	
BCA	172.73	253.85	15.58	11.3	

Notes: *Qa* – rheowave propagation time, α1 – fast blood filling time, α2 – slow blood filling time, β – upward wave propagation time, *Vb* – average fast filling velocity, *V* – maximum fast filling velocity, *Ri* – rheographic index, *MKi* – inter-amplitude incisional index, *MKd* – inter-amplitude diastolic wave, *α/T* – vascular wall tone as a ratio of anacrotic length to wavelength, *BCA* – brachiocephalic index
Source: compiled by the author

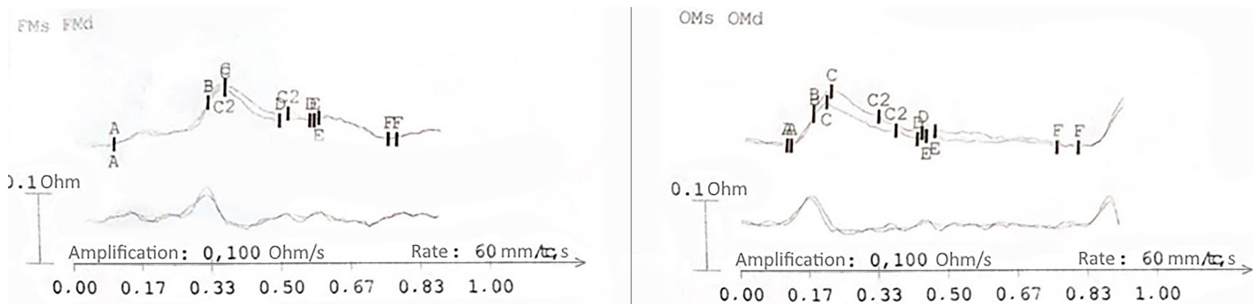

Figure 10. Rheoencephalography examination of patient E after treatment
Notes: FMs – left fronto-mastoid lead, FMd – right fronto-mastoid lead, OMs – left occipital-mastoid lead, OMd – right occipital-mastoid lead
Source: compiled by the author

In general, in the examined patients with limb or back injuries, pain syndrome and constant mechanical stress on the musculoskeletal system, a decrease in pain and improvement of muscle symmetry in the affected anatomical areas were observed with the use of orthodontic or boxing mouthguards. In patients with generalised tremors, contusions and venous stasis of the cranial region, the therapeutic wearing of orthodontic splints showed compensation of blood filling deficit and impaired venous outflow in the vertebrobasilar basin on both sides compared to the baseline data. Arterial blood filling after therapy showed satisfactory results since the restoration of venous outflow required a longer application of the orthodontic method.

DISCUSSION

A scientific and practical study has shown that the use of orthodontic and boxing mouthguards in patients with excessive musculoskeletal stress not only increases the height of the bite and stabilises physical displacements in the skull bone system, but also has a direct impact on the condition of the blood vessel walls, their tone and perfusion. As a result, the blood supply to CNS structures and venous outflow from the sinuses improves. As the results of the current study have shown, if the patient's bite is fixed in a physiological state of comfort, then after excessive or pathological load on the axial skeleton (especially on the cervical spine), it is enough to return the bite to the anatomical state in which it was adequately fixed before the loading effect, and the body's recovery is much faster. A similar emphasis in the protocol for the treatment of deformed occlusion is noted by E. Pasciuti *et al.* [12], where retention brackets were used. The authors evaluated the results of occlusion displacement using radiological examination, which should be used in the further continuation of the current work. According to the metadata of M.R. Muro *et al.* [13], in clinical conditions, orthodontic treatment with aligners should improve the initial deformed bite of patients and guarantee equivalence between the predicted and final results for the effective treatment of bite height deficiency. The authors note that the predicted results at the beginning of treatment are often overestimated and do not always coincide with the objective final positions of the jaw arches, which is due to the insufficiently long use of orthodontic constructions. This fact was partially revealed in the current study, as two patients still had encephalographic signs of

impaired outflow from the venous sinuses, while three patients had vascular spasms.

From the point of view of medical and psychological rehabilitation, restoration of the occlusion and position of the bones of the face and skull is important for the full restoration of function, the control and implementation of which occurs in the cervical spine and brain structures [14, 15]. The anatomical restoration of the occlusion and reduction of bruxism are of particular relevance in the case of maxillofacial injuries. According to K. Khalaf *et al*. [14], prosthetics and medical rehabilitation with implants and mouth guards have a great potential for restoring secondary malocclusion after maxillofacial trauma. According to G. Zanon *et al.* [16], orthodontic treatment has a positive effect on the functioning of the masticatory muscles, as, during treatment, chewing occurs evenly with the involvement of the right and left parts of the jaw structures, which in turn evens out the mechanical effect on the blood vessels. It has also been proven that orthodontic appliances reduce the number of reverse chewing cycles by improving their kinematic parameters (axis and angle of closure, maximum lateral deviation) on both sides and thus becoming symmetrical between the sides and restoring the physiological inclination of the angle of closure in the temporomandibular joint [16-18].

According to anamnestic questionnaires, during the clinical follow-up of patients, a decrease in the symptoms of muscle pain and general fatigue, improvement of posture and coordination of movements during the physical examination after the proposed treatment was noted. In addition, increasing the height of the bite and compensating for the asymmetrical position and movements of the jaw arches and facial muscles with the help of orthodontic and boxing mouthguards also leads to the restoration of the position of the vertebrae of the cervical and thoracic spine [19]. The time required for the initial recovery of muscle fatigue in the upper body is reduced to two hours after the use of orthodontic or boxing mouthguards. No differences between orthodontic and boxing mouthguards were found in the analysis of physical and rheoencephalography indicators of bite and cerebral circulation recovery. According to the results, the main difference was found only in the ease of use by patients and time savings for fitting the mouthguard. The use of boxing mouthguards is a much simpler method than the manufacture of an individual orthodontic mouthguard: it is only necessary to have hot water to soften the polymeric material of the boxing mouthguard, and the total manufacturing time does not exceed five minutes. This observation is confirmed by the results of a randomised clinical trial by A. Kalra *et al.* [20]. Thirty athletes were randomly assigned to one of the groups that were assigned to wear a specific type of mouthguard during two months of a crossover randomised clinical trial with three observation groups as part of orthodontic treatment, playing contact sports for at least two hours a day. As a result, the authors found no significant, statistically significant changes in the performance of different types of mouthguards, while respondents' data on the ease of wearing and use varied.

The clinical observations also showed that almost 70% of respondents clench their teeth when lifting heavy objects, which was revealed at the stage of the initial physical examination of patients at the Kyiv Regional Centre for Mental Health. Clenching of the teeth, i.e., bruxism, also occurs when experiencing stressful conditions, which is especially relevant for respondents in the study cohort with post-traumatic stress disorder. In this way, the body uses its compensatory resources – neuromuscular circuits are activated, which include additional muscle groups that maintain the upright position of the body, promote shock absorption, and prevent spinal injuries [21]. Post-traumatic stress disorder, according to W. Knibbe *et al.* [22], is often associated with painful temporomandibular joint disorders and can often be an etiological factor in bruxism during wakefulness and sleep. The study by S. Passardi *et al.* [23] aimed to study electromyographic changes in the activity of the facial and masticatory muscles in patients with post-traumatic stress disorder and showed that muscle activity was increased in response to negative emotional situations compared to positive ones. The authors also found increased expressive suppression and alexithymia compared to the control group. Thus, the results of the study can be applied not only to patients with objective signs of malocclusion, cerebral circulation, and cervical vertebrae displacement but also to reduce muscle tone in the maxillofacial area in post-traumatic stress disorders.

Studies conducted at the Kyiv Regional Centre for Mental Health show that the use of boxing mouthguards and orthodontic appliances aimed at increasing the height of the bite and reducing hypertension of the muscles of the maxillofacial area improves blood circulation in the brain vessels, namely in the carotid pools. In certain post-treatment rheoencephalograms, it can be seen that the spasm of the vessel walls decreases, which contributes to improved blood supply to the brain structures. In some rheoencephalograms, blood filling indices on both sides were restored to almost normal, sometimes with preserved low-grade hypovolaemia, compared to the one at the beginning of treatment. In addition, rheoencephalographic examination after the use of the caps showed normal indicators of resistance artery tone, compensation of venous outflow from the cerebral sinuses, and sufficient blood filling of the internal carotid artery and vertebrobasilar pools. Compensation for blood supply deficit has a significant therapeutic effect, since along with the normalisation of blood supply, there is a rapid restoration of lost speech, coordination of movements and functioning of organs and body systems by restoring power to the controlling structures in the CSN through endocrine, somatic and parasympathetic regulation. A literature search of open medical databases did not reveal the existence of similar scientific studies that would focus on the effect of mouth guards on cerebral circulation. Therefore, further expanded research on this topic involves the involvement of a larger cohort of subjects with possible concomitant cardiovascular diseases, which would show the feasibility of using mouthguards for patients with various combined nosologies.

CONCLUSIONS

According to the sample study, a decrease in the vertical axial load on the spine was detected, which is especially relevant for military personnel. The load in the current realities of the war in Ukraine occurs when wearing body armour, improper lifting of loads, injuries when disembarking and boarding vehicles with military equipment, and

jumping into a trench with heavy weapons. With the help of orthodontic or boxing mouthguards, effective restoration of the muscles of the upper and lower jaw, bite height, and thus blood supply to adjacent anatomical structures was observed. The acceleration of the body's recovery processes after exertion, trauma, and neuropsychological functions (in the examined patients, these were contusion and post-traumatic stress disorder) was noted. Rheoencephalography signs of cerebral circulation improvement were objectively demonstrated: a decrease in arterial-type spasm of the cerebral vessel walls, improvement of blood circulation in the carotid basin system, compensation for deficit blood filling and venous outflow by deficit type. Restoration of blood supply to the structures of the brain and spinal cord (mainly the cervical spine) has a significant therapeutic effect both immediately after treatment and in the long-term management of patients. Adequate blood supply to the structures of the central nervous system contributes to the rapid and complete restoration of lost functions, such as speech, sensitivity, and coordination of movements.

An important aspect of the proposed therapy is the saving of financial and time resources, as the patient's stay in a rehabilitation facility is reduced, which, accordingly, reduces the cost of patient care. It can also be concluded that, according to the proposed method of improving cerebral circulation and medical rehabilitation, it is more convenient to use boxing mouthguards than orthodontic mouthguards. Boxing mouthguards are more affordable in terms of time and money and are more convenient from a practical point of view compared to orthodontic mouthguards. The results of the study are relevant for implementation in the protocols of patient management in rehabilitation and medical institutions of the country, as well as for the prevention of cerebrovascular complications. Further research on this topic involves the involvement of a larger cohort of patients with concomitant cardiovascular diseases.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

[1] Mironyuk I, Slabkiy G, Shcherbinska O, Bilak-Lukianchuk V. Consequences of the war with the Russian Federation for the public health of Ukraine. Reprod Health Woman. 2022;(8):26–31. DOI: 10.30841/2708-8731.8.2022.273291

[2] Kabantseva AV, Zhogina OO. In: Babov K, editor. Topical issues of organization of neurorehabilitation care in the context of information and psychological warfare; 2021 Sep 30-Oct 1; Odessa: Polygraph. Proceedings of the International Scientific and Practical Conference. Sanatorium Treatment and Rehabilitation: Modern Trends in Development; 2021. P. 75–78. Available from: https://kurort.gov.ua/wp-content/uploads/2021/10/tezy_30.09-01.10.2021.pdf

[3] Kuchyn Y, Horoshko V. Pain syndrome in patients with gunshot wounds of the limbs and post-traumatic stress disorders. Emerg Med. 2021;17(7):24–31. DOI: 10.22141/2224-0586.17.7.2021.244591

[4] Danchenko MV, Korzh YM. Complex program of physical therapy for participants of battle action with osteochondrosis of cervical-oral spine. In: Materials of the V All-Ukrainian remote scientific and practical Internet conference "Problems of human health and physical rehabilitation." 2019. Sumy: Sumy State Pedagogical University named after A.S. Makarenko; 2019. P. 44–53. . Available from: https://repository.sspu.edu.ua/bitstream/123456789/10290/1/Danchenko_Korzh.pdf

[5] Steblyuk V. Problems of medical support and medical and psychological rehabilitation of ATO/JFO veterans. Health Soc. 2022;10(5):151–54. DOI: 10.22141/2306-2436.10.5.2021.275

[6] Slukhenska R, Logush L, Zendyk O, Hulina L. Rehabilitation as an indispensable factor in the recovery of civilians and military personnel. Grail Sci. 2023;(26):430–35. DOI: 10.36074/grail-of-science.14.04.2023.076

[7] Gavlovsky OD. Organization of physical and psychological rehabilitation of participants antiterrorist operations (ATO) in Ukraine. Bull Probl Biol Med. 2019; Issue 2 Part 1 (150):275–79. DOI: 10.29254/2077-4214-2019-2-1-150-275-279

[8] Adel S, Zaher A, El Harouni N, Venugopal A, Premjani P, Vaid N. Robotic applications in orthodontics: Changing the face of contemporary clinical care. BioMed Res Int. 2021; e9954615. DOI: 10.1155/2021/9954615

[9] Virdi GK, Prashar A, Kaur S. Accelerated orthodontics: Getting ahead of ourselves. Int J Health Sci. 2021;5(S1):292–5. DOI: 10.53730/ijhs.v5nS1.5645

[10] Guideline IHT. ICH Harmonised Tripartite Guideline: Guideline for Good Clinical Practice. J Postgrad Med. 2001 Jul-Sep;47(3):199–3. Available from: https://pubmed.ncbi.nlm.nih.gov/11832625/

[11] General Assembly of the World Medical Association. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. J Am Coll Dent. 2014 Summer;81(3):14-8. Available from: https://pubmed.ncbi.nlm.nih.gov/25951678/

[12] Pasciuti E, Coloccia G, Inchingolo AD, Patano A, Ceci S, Bordea IR, et al. Deep bite treatment with aligners: A new protocol. Appl. Sci. 2022;12(13):6709. DOI: 10.3390/app12136709

[13] Muro MP, Caracciolo ACA, Patel MP, Feres MFN, Roscoe MG. Effectiveness and predictability of treatment with clear orthodontic aligners: A scoping review. Int Orthod. 2023 Jun;21(2):e100755. DOI: 10.1016/j.ortho.2023.100755

[14] Khalaf K, Kheder W, El-Kishawi M, AlQahtani HA, Ghiasi FS, Mohammad NN, et al. The role of prosthetic, orthodontic and implant-supported rehabilitation in the management of secondary malocclusion to maxillofacial trauma: A systematic review. Saudi Dent J. 2021 May; 33(4):177–83. Published online 2020 Dec 16. DOI: 10.1016/j.sdentj.2020.12.004

[15] Sharka R, Alamar M, Alhaider Y, Albakri F, Ezzat Y. Interdisciplinary approach of orthognathic surgery and prosthodontics for the treatment of jaw discrepancies: A report of four cases. Saudi J Oral Sci. 2022;9(3):190. DOI: 10.4103/sjoralsci.sjoralsci_43_22
[16] Zanon G, Contardo L, Reda B. The impact of orthodontic treatment on masticatory performance: A literature review. Cureus. 2022 Oct; 14(10):e30453. Published online 2022 Oct 19. DOI: 10.7759/cureus.30453
[17] Cheong J, Hwang YS, Jung BY. Multidisciplinary approach for full-mouth rehabilitation of an adult patient with collapsed occlusal plane and several missing teeth: A clinical report. J Prosthodont. 2019 Mar;28(3):227–33. DOI: 10.1111/jopr.12778
[18] Domagała I, Przystupa K, Firlej M, Pieniak D, Gil L, Borucka A, et al. Analysis of the statistical comparability of the hardness and wear of polymeric materials for orthodontic applications. Materials (Basel). 2021 May 28;14(11):2925. DOI: 10.3390/ma14112925
[19] Baxi S, Shadani K, Kesri R, Ukey A, Joshi C, Hardiya H. Recent advanced diagnostic aids in orthodontics. Cureus. 2022 Nov; 14(11): e31921. Published online 2022 Nov 26. DOI: 10.7759/cureus.31921
[20] Kalra A, Harrington C, Minhas G, Papageorgiou SN, Cobourne MT. Wearability and preference of mouthguard during sport in patients undergoing orthodontic treatment with fixed appliances: A randomized clinical trial. Eur J Orthod. 2022 Jan 25;44(1):101–9. DOI: 10.1093/ejo/cjab062
[21] Ressler KJ, Berretta S, Bolshakov VY, Rosso IM, Meloni EG, Rauch SL, Carlezon WA Jr. Post-traumatic stress disorder: Clinical and translational neuroscience from cells to circuits. Nat Rev Neurol. 2022;18:273–88. DOI: 10.1038/s41582-022-00635-8
[22] Knibbe W, Lobbezoo F, Voorendonk EM, Visscher CM, de Jongh A. Prevalence of painful temporomandibular disorders, awake bruxism and sleep bruxism among patients with severe post-traumatic stress disorder. J Oral Rehabil. 2022 Nov;49(11):1031–40. DOI: 10.1111/joor.13367
[23] Passardi S, Peyk P, Rufer M, Wingenbach TSH, Pfaltz MC. Facial mimicry, facial emotion recognition and alexithymia in post-traumatic stress disorder. Behav Res Ther. 2019 Nov;122:e103436. DOI: 10.1016/j.brat.2019.103436

Метод покращення мозкового кровообігу за допомогою боксерських та ортодонтичних кап

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Анотація. У зв'язку з активними бойовими діями на території України значно зросли показники загострень хронічних хвороб, травматизації ділянки голови та хребтового стовпа за рахунок як вогнепальних поранень, так і за рахунок підвищеного силового навантаження на опорно-руховий апарат. Питання удосконалення реабілітаційних підходів є актуальним у зв'язку з наявною статистикою патологій кровопостачання головного мозку. Враховуючи потребу в доступних та ефективних методах відновлення опорно-рухового апарату, дане дослідження мало за мету дослідити ефективність впливу ортодонтичних та боксерських кап на стан кровоносних судин головного мозку. На базі Київського обласного центру ментального здоров'я досліджено п'ять пацієнтів з контузією та посттравматичним стресовим розладом в анамнезі за допомогою фізикального обстеження та реоенцефалографії. Застосування ортодонтичних та боксерських кап показало позитивну динаміку у відновленні роботи м'язів щелепно-лицевої ділянки, компенсацію висоти прикусу і задовільне кровопостачання структур головного мозку у порівнянні з вихідними даними. Аналіз реоенцефалограм показав реоенцефалографічні ознаки покращення мозкового кровообігу: виявлено зниження спазму артеріальних стінок мозкових судин, компенсацію дефіциту кровопостачання, поліпшення кровообігу у каротидному басейні та венозного відтоку в дефіцитному режимі. У обстежених осіб з перенесеними травмами, больовим синдромом та постійними механічними навантаженнями на опорно-руховий апарат відмічено зниження больових відчуттів та покращення симетричності роботи м'язів в уражених анатомічних ділянках на фоні носіння ортодонтичних та боксерських кап. Отримані результати можуть бути впроваджені у протоколи реабілітаційного відновлення пацієнтів із контузією, струсом мозку, травмами хребта та черепа. Доступність та ефективність запропонованої методики дозволяє застосовувати її для пацієнтів із хронічними хворобами серцево-судинної системи, особливо ускладненим кровопостачанням структур головного мозку

Ключові слова: медична реабілітація; ортодонтія; кістки черепа; реоенцефалографія; елайнер; посттравматичний стресовий розлад