ISSN2782-4101

INTERNATIONAL JOURNAL of INNOVATIVE MEDICINE

1
2022

EDITOR-IN-CHIEF

EDITORIAL BOARD

EDITORIAL STAFF

'INTERNATIONAL JOURNAL OF INNOVATIVE MEDICINE' (IJIM)

Journal's Website www.ij-im.com
Publishing House Alfmed +7 (495) 616-4800
Box 94, Moscow, 129515, Russia

Editorial Office Office 720, Bldg. 1, 13 Academician Korolev Str., Moscow, Russia
Frequency of publication: 4 issues per year.
Signed for press: 18 April 2022.

Editor-in-Chief of IJIM journal, Doctor of Medical Sciences, Alexander Dolgalev

CONTENTS

DOI:10.33667/2782-4101-2022-1-4-10

POST–STROKE MOTOR IMPAIRMENTS: THE POSSIBILITIES OF INNOVATIVE TECHNOLOGIES AND THE RESULTS OF THE OWN RESEARCH

Kostenko E.V.[1,2], Petrova L.V.[1], Rylsky A.V.[1]

[1]Moscow scientific and practical center of medical rehabilitation, restorative and sports medicine of the Department of health of the city of Moscow, Moscow, Russia
[2]Pirogov Russian National Research Medical University, Moscow, Russia

SUMMARY

Introduction. *The article presents an overview of innovative technologies based on methods sensomotor retraining of the patient using neuromuscular electrical stimulation (NFES) and biofeedback (BFB) as the most promising in the medical rehabilitation (MR) of motor impairment in patients with brain stroke (BS). The results of our own study are also presented.*

The aim of the study *- an assessment of the effectiveness of a comprehensive rehabilitation program with the inclusion of NFES and stabilometric postural control using the BFB method in patients with after-stroke motor disfunction in the chronic ischemic stroke (IS).*

Material and methods. *We examined 87 patients (41 women and 46 men) in the chronic IS, mean age 58.4±6.4 years. The stroke duration was 228.59±31.9 days. The main group included 52 patients who, along with the standard treatment regimen, underwent NFES and BFB-stabilometric training. The comparison group consisted of 35 patients whose rehabilitation complex did not include the above methods.*

Results and conclusion. *Due to comlex rehabilitation with NFES and BFB stabilometric postural training it has been improved the function of walking. The clinical effect was noted 3 weeks after the start of rehabilitation, reaching a maximum by the 5th week. The inclusion of BFB-based methods in the medical rehabilitation leads to earlier motor and social adaptation of the after-stroke patient, restoration of the impairment balance function, which is associated with an increase in neuroplasticity.*

KEYWORDS: *stroke, motor disorders, rehabilitation, neuromuscular electrical stimulation, biofeedback.*

CONFLICT OF INTEREST. *The authors declare no conflict of interest.*

Supporting agencies: *Funding for the study was carried out from the personal funds of the authors.*

Loss of functional movement and coordination are the most common consequences of stroke which lead to disability [1–2]. Muscle weakness, abnormal muscle activity and muscle dyssynergia due to brain stroke (BS) cause walking function asymmetry and gait changes [3]. Motor deficit in central hemiparesis is also determined by the severity of spasticity, contractures and arthralgia.

Balance disorders after BS increase the risk of falls, make it difficult for patients` movement, reduce the level of daily activity and the restoration of walking function [4–6]. In addition, post-stroke cognitive impairment and depressive disorders associated with motor deficits slow down the rehabilitation process [7]. In general, post-stroke motor disfunction is associated with low quality of life and risk of premature death.

The gait of hemiplegic patients has very specific features [8–9]: reduced walking speed, increased double stance phase, and reduced amplitude of movement in the leg joints [10]. The common features of the hemiparetic gait include specific spatio-temporal patterns, including a decrease in the rotation frequency, an increase in the duration of the swing on the paretic side and the duration of the support, an asymmetry of the step length compared with the gait parameters of healthy subjects [11–12], a decrease in walking speed. There are four main gait abnormalities associated with hemiparesis [13]: the drop-foot gait, the circumduction gait, the hip hiking gait, and the back-knee gait.

The relevance of the topic and the current state of the problem

A universal factor in improving post-stroke motor impairments is physical activity, which is associated with the formation of new reciprocal and interhemispheric connections, increased neuroplasticity [1, 3, 14]. When muscle synergy in after-stroke patients were analyzed an improvement in the motor activity of the lower extremities, in particular, the module of the plantar flexor of the ankle joint during the rehabilitation period of BS against the background of walking training was shown [15]. In the most recent study on subacute stroke participants an increased lateral symmetry in muscle synergies while walking, associated with improvements in gait kinematics measurements, was found after 3 weeks of walking training supported by a lower limb exoskeleton [16].

Thus, repeated motor practice and motor activity in a real-world environment have been identified in several prospective studies as a favorable factor for restoring motor activity in after-stroke patients [17].

Neuromuscular functional electrical stimulation (NFES) of paretic muscles is the main additional method of therapy, usually used with kinesiotherapy (functional rehabilitation) and pharmacological treatment in patients after BS [1–4].

The therapeutic effect of electrical stimulation on muscle regeneration after the denervation from the spinal motor neuron

level has been confirmed both in experimental animal studies [18] and in the rehabilitation of patients with upper motor neuron syndrome (consequences of spinal cord injury, BS and cerebral palsy). NFES has been shown to improve motor impairment in BS, probably by modifying neural transmission at the synaptic junctions of the corticospinal tract with spinal motor neurons. [19–20]. In addition, NFES promotes an increase in the number of motor units, which is closely associated with increasing muscle strength [21]. The available literature provides the specific effects of NFES, reflecting its important role in neuromodulation at the spinal and supraspinal levels in patients with BS [22]. Therapeutic applications of NFES include upper and lower limb motor relearning and reduction of poststroke shoulder sublux-ation and pain. Терапевтические аспекты применения НФЭС включают моторное переобучение верхних и нижних конечностей, уменьшение гемиплегической боли в плече, strengthening muscles and muscle atrophy preventing [23]. Stein et al. showed that combination of NFES and other methods reduced of spasticity and improvement of range of motion in patients after BS [24].

Probably, NFES can directly cause the transmission of a nerve impulse through biofeedback (biofeedback), causing modulation of the work of the inhibitory interneurone Ia, which controls the function of the antagonist muscles of the forearm and lower limb. The discoordination of these muscle groups is described as the most significant muscle dysfunction in patients with BS [25].

The effect of NFES of the neuromuscular apparatus on the walking function in after-stroke patients has been shown in many randomized clinical trials (RCTs) of recent years [26–32].

Sharif F et al. selected from 5066 articles of 29 RCTs involving 940 patients. NFES produced a reduction in spasticity (–0.30 [95 % confidence interval,–0.58 to –0.03], n=14 RCTs) and an increase in range of motion compared with controls (2.87 [95 % confidence interval, 1.18–4.56], n=13 RCTs) after BS. Gait training with NFES compared with standard electrical stimulation showed better results in terms of mobility, balance, gait performance and reduction of spasticity in patients with BS [26].

The effectiveness of NFES in combination with other rehabilitation methods has been proven in another review. It was shown the reducing of the spasticity and increasing the range of motion in patients after BS. [24].

In 2018, 21 RCTs were selected from 5759 articles with 1481 participants. The combined analysis showed that NFES has a moderate but statistically significant effect on the motor function of the lower extremities (standard mean difference 0.42, 95 % confidence interval 0.26–0.58), especially when combined with other rehabilitation methods for 6 or 12 weeks trainings. Significant changes in gait speed, balance, spasticity and range of motion were also noted, but there were no differences in walking endurance during NFES [27].

In the most recent studies of Cochrane Library, MEDLINE, EMBASE, CINAHL, AMED, PsycINFO, WOS, Scopus, OpenGrey and 4 Chinese databases with only RCT analysis, the results of the NFES-using in combination with motor activity for the treatment of patients with post-stroke spastic hemiparesis are summarized [28].

Thus, NFES contributes to an increase in muscle strength and a change in the pathological motor stereotype. It allows to restore impaired motor skills by improving muscle condition and correctly performed movements relearning.

The optimal NFES algorithm uses stimulation frequencies of about 15 Hz for applications on the upper extremities and about 20 Hz for applications on the lower extremities. Modified frequencies with proven effectiveness range from 10 to 50 Hz; sessions are usually conducted five times a week for 3–8 weeks [29–32].

Proprioceptive sensory feedback may play an important role in neuromuscular stimulation. This is confirmed by studies of multichannel near-infrared spectroscopy for non-invasive and dynamic measurement of hemoglobin levels in the brain. Cerebral blood flow in the sensorimotor cortex on the injured side was higher during the NFES session than during simple active movement or simple electrical stimulation. [17].

On this point, biofeedback (BFB) technology becomes promising for training the walking function. It involves recording a certain physiological parameter (walking parameters) and presenting it in an obvious form for the patient so that the latter can navigate in its change and correct the given parameter. BFB therapy is currently considered as an effective independent method of MR in patients after BS, successfully combined with other intervention modalities. Biofeedback provides real-time information about physiological processes that may not be visible to the patient, allowing awareness and self-correction of abnormal gait patterns [33]. BFB can be carried out with the help of various sensory organs, such as visual, auditory, tactile or a combination of different methods. Different modes of BFB can have different effects on efficiency and motor skills training [34–35]. Significant progress has been made with the initial use of BFB on single muscle electromyography to improve gait in hemiparesis after BS [36]. Real-time BFB reflecting limb positioning or muscle strength during walking aims to improve walking function when post-stroke hemiparesis [37]. Thus, after two weeks of training on a treadmill with a visual BFB with step length, after-stroke patients demonstrated improvements in step length, incl. at 6-month follow-up [37]. Ki at al. noted a significant improvement in step length and support response of the paretic lower limb during training with BFB while walking in stroke patients [37]. The use of audiovisual BFB targeting anterior ground reaction forces (AGRF) can cause a significant improvement in AGRF in the paretic leg without changing this option in the non-paretic low limb [38]. Despite the proven effectiveness of BFB in restoring specific gait impairments of the paretic lower limb in after-stroke patients, the modes of BFB, as well as strategies for improving gait and motor retraining, are not clearly defined.

According to the literature, the inclusion of NFES or BFB-stabilometric training in the complex rehabilitation of patients in the early recovery period of BS is more effectively increase daily activity compared with standard methods, such as traditional kinesiotherapy [1, 3–4, 24–25].

Our study focused on the use of NFES in combination with BFB-stabilometric postural control in the recovery of patients with post-stroke stato-locomotor disturbances. This approach is not presented in the literature.

Purpose of the study: to evaluate the effectiveness of a complex rehabilitation program with NFES and BFB-stabilometric postural control in patients with post-stroke motor disturbances in the chronic period of ischemic stroke (IS).

Material and methods

The study included 87 patients in the chronic period of IS, 41 women and 46 men, aged 45 to 75 years (mean 58.4±6.4 years). The duration of a stroke ranged from 181 to 356 days, averaging 228.59±31.9 days; patients with a stroke duration of 180–272 days prevailed (71.2 %). Hemispheric localization of the lesion was observed in all patients: in the right hemisphere – in 44.8 %; in the left – in 55.2 %; The diagnosis was verified by CT or MRI of the brain. The main reasons for the development of IS were hypertension, atherosclerosis, and their combination.

The inclusion criteria for the study were: age from 45 to 75 years; the presence of mild or moderate monoparesis of the lower limb/hemiparesis; chronic period of IS, the patient's ability to independently (without support) maintain balance when standing for at least 2 minutes, mild cognitive disorders, the absence of the osteoarticular system pathologies and severe visual impairment that prevent the study; signed informed consent.

The exclusion criteria were: the presence of an implantable pacemaker; benign and malignant neoplasms; epilepsy; somatic diseases decompensation; unstable angina and paroxysmal cardiac arrhythmias; increased excitability of the patient, intolerance to minimal electrical irritations; the impossibility of obtaining a contraction of the muscles of the lower limb under electrical action within the limits of tolerable pain sensations; acute neurological diseases of the spinal cord and its roots; acute infectious diseases; acute thrombophlebitis of deep and superficial veins of low limbs; the muscle contractures in the knee and ankle joints; lower paraparesis; pregnancy and lactation.

All patients received medical therapy according to the standards of specialized medical care; physical therapy, kinesiotherapy, psychotherapy.

The subjects were randomly divided into 2 groups.

The first, *main group* included 52 patients with chronic IS, who underwent NFES and BFB-stabilometric training.

Table 1

Methods used in the study

Studied function	Examination methods
State of the locomotor system	The 6-point Medical Research Council Scale for assessing muscle strength: MRCS; Modified Ashworth Scale: MAS (0 to 4 points), 10 meter walking test
Postural disturbances	Tinetti scale stabilometry
Comprehensive assessment of motor function	Walking Difficulty Global Score – On a scale of 1 (no sign) to 4 (most severe), the following characteristics of the patient's walking are assessed: unsteadiness, effort required to walk, impression of pain, difficulty moving in general; biomechanics of movements
Cognitive functions	MMSE (Mini-Mental State Examination)
Presence and severity of depression	Hospital Anxiety and Depression Scale HADS
Functional independence	Index Barthel
Life quality assessment	EuroQol EQ-5D-5L (version 1.0, 2011)

The second *comparison group* consisted of 35 patients with IS, who did not include the two above–mentioned methods. The main group and the comparison group were the same age-sex composition, clinical manifestations.

The biomechanical study was performed on the Trust-M hardware and software system ('Nevrokor', Moscow). Methods of gait and main stance analysis were used – stabilometry. The gait was studied by temporal, kinematic parameters and support reactions. The NFES technique was carried out on the simulator 'Correction of Movements 'Trust M' ('Nevrokor', Moscow) according to the standard scheme. The duration of the training was 20–30 minutes, 15 sessions (3 times a week, 5 weeks).

The balance and movement impairments were corrected by the method of BFB-exercises on the stabiloplatform 'Trust-M' ('Nevrokor', Moscow). Romberg's test was carried out according to the European version of the installation of the feet (heels together, toes apart at an angle of 30 degrees) in 2 phases: with open (OE) and closed (CE) eyes. Each phase of the study lasted 30 seconds. For the comparison with the norm the general standard values proposed by D. V. Skvortsov were used [39]. It was used static ('Target') and dynamic ('Man') BFB-tests with an exposure of 20–30 minutes, 3 times a week for 5 weeks. The BFB- training was performed in the first half of the day, before the NFES, to minimize the impact of external factors. At the end of the BFB-training course control stabilometry study was performed for dynamics.

The examination was carried out at baseline, before the start of therapy (1st visit), after 3 weeks of therapy (2nd visit), after 5 weeks from the start of rehabilitation (3rd, final visit) using different methods and scales (*Table 1*). Side effects and adverse events were evaluated at each visit.

Statistical analysis of the data included a comparison of dependent and independent series of variables and methods of descriptive statistics. The type of data distribution was assessed using the Shapiro-Wilk test. Parametric quantitative data were represented by mean values and standard error of the mean (M±m). Nonparametric quantitative and rank variables were presented as median and interquartile range: IQR (Me [P25; P75]). The validity of differences was determined using Student's t-test. The differences between qualitative binary traits were assessed using the χ^2 criterion. The statistical significance level was accepted as p=0·05. Nonparametric Spearman correlation test was used to reveal the relationship between two features. The results obtained were processed using the licensed software Statistics 7.0 and Microsoft Excel.

Results

All patients completed the study.

At the initial examination, patients had pyramidal (from reflex to moderate hemi- and monoparesis) and sensory impairments (superficial sensitivity like hypo- and anesthesia), varying severity ataxia, as well as vestibular (both peripheral and central) disturbances.

A manual study revealed a deficiency of muscle function in the quadriceps, gluteal muscles (100 %), leg flexors (73.6 %), tibia (100 %) and gastrocnemius (67.8 %) muscles. Lameness, impaired transfer of the affected limb was noted in 100 % of cases; in 37.9 % of patients, foot rolling was impaired, 42.5 % of patients used additional means of support.

Changes in the biomechanics of gait in patients were nonspecific of a decrease in the pace of the step. In addition, functional consequences of insufficiency of the quadriceps femoral muscle in the form of passive closure of the knee joint and insufficiency of the triceps tibia muscle were found. It was shown a decrease in the amplitude of repulsion of the longitudinal component of the support reaction and a decrease in the amplitude of plantar flexion of the ankle joint; asymmetry of the periods of the step cycle; decreased stability, which was accompanied by a deviation of the center of pressure (CP) to the healthy side. The position of the CP in the sagittal plane was characterized by a forward displacement of about 9 mm. The oscillations of the CP exceeded the norm in both the frontal and sagittal planes; the area of the statokinesiogram exceeded the norm in both phases of the study. Patients' energy consumption was increased, especially during the CE-phase. In patients with lower monoparesis or hemiparesis, a significant changes in the standard deviation of the CP in the frontal plane were regarded as a markers of pathological posture (the transfer of the center of gravity to a healthy 'nonparetic' limb or, in some cases, to the affected limb with a moderate degree of spasticity).

Table 2

Dynamics of indicators of the Global assessment of difficulty in movement scale in complex rehabilitation of post-stroke patients (number of patients, %)

The period of MR	Instability, unsteadiness of gait	Application of efforts	Pain	General walking difficulties
Main group (n=52)				
Before MR				
4 points	–	–	7,1	–
3 points	52,3	81	26,2	47,7
2 points	47,7	19	66,7	52,3
1 point	–	–	–	–
3 weeks				
4 points	–	–	–	–
3 points	45,3	66,7	33,3	42,9
2 points	54,7	33,3	66,7	57,1
1 point	–	–	–	–
p	0,19	1,0	0,46	0,07
χ2	1,67	0,0	0,53	3,13
5 weeks				
4 points	–	–	–	–
3 points	33,3	57,1	9,6	26,2
2 points	66,7	42,9	83,3	73,8
1 point	–	–	7,1	–
p	<0,001*	<0,001*	<0,001*	<0,001*
χ2	7,68	13,4	22,8	7,03
Comparison group (n=35)				
Before MR				
4 points	–	–	8	
3 points	52	80	28	–
2 points	48	20	64	48
1 point	–	–	-	52
				-
3 weeks				
4 points	–	–	4	–
3 points	48	68	28	40
2 points	52	32	68	60
1 point	–	–	-	–
p	0,57	0,052	0,5	0,25
χ2	0,3	3,72	1,455	1,3
5 weeks				
4 points	–	–	–	–
3 points	32	58,0	20	28
2 points	68	42,0	76	72
1 point	–	–	4	–
p	0,005*	<0,001*	0,003*	0,004*
χ2	8,2	0,53	14,33	8,5

Note: the reliability of the differences is p – initially and at a certain point in the study; * p<0.05.

When assessing postural disorders on the Tinetti scale, mild motor disorders were detected in 63.2 % and moderate – in 36.8 % of cases. After a course of medical rehabilitation (MR) positive dynamic was observed in patients of both groups. There were an increase in strength in the paretic limb, its involvement in the process of orthostasis. The difference of tendon reflexes, the severity of the vestibuloatactic syndrome decreased. Balance tests and the patient's stability in the Romberg position were normalized.

After 5 weeks it was shown a decrease in spasticity scores according to the Ashworth scale in the distal lower limb. However, these changes were not statistical significance (p>0.05). At the end of the course of NFES there were the increase in muscle strength averaged 0.5–1 point, in 54.7 % of patients at the time of the procedure, a more correct foot placement on the support.

By the 5th week of therapy, a statistically significant increase in walking speed was observed in patients of the main group (from 73.6 to 56.2 s; p<0.05).

A study of the Global assessment of walking difficulties after 5 weeks MR revealed a statistically significant improvement in all indicators (*Table 2*).

Functional movement improvement was confirmed by the results of the Tinetti scale. In patients of the main group, mild and moderate statolocomotor disturbances were registered in 52.3 % and 9.5 % of cases; normal motor activity was recorded in 38.2 % of patients. In the comparison group, these figures were 68 %, 12 % and 20 %, respectively.

Posturological parameters in the main group after complex NFES and BFB- stabilometric training rehabilitation were presented in Table 3. There was a significant (p<0.05) decrease in the area of the statokinesiogram and a decrease in the deviation of the total CP in the sagittal plane. Such a result can be considered as an objective increase in the stability of patients. The Romberg coefficient decreased, which indicated the restoration of deep proprioceptive sensitivity. In patients with low-limb paresis, the index of the position of the common CP in the frontal plane improved (p<0.05) when performing functional tests (regression of paresis and postural asymmetry). There was a trend towards a decrease in the speed of movement of the CP (indicator of general stability). Thus, the stabilogram restructuring coincided with the clinical regression of statolocomotor impairments.

In the comparison group, a positive dynamics of indicators was also observed (*Table* 3). The CP leveled out in both planes (significantly along the X axis), the area of the statokinesiogram decreased, the speed of CP movement decreased, the Romberg coefficient normalized significantly. These changes indicated a decrease in paresis and an increase in the overall stability of patients. By the end of the study in the main group, the length of the statokinesiogram decreased by an average of 27.4 % with OE and by 30 % with CE (596.77±89.6) and the area of the statokinesiogram decreased by 50.7 % compared with the beginning of treatment (p <0.05). In the comparison group the changes were not statistically significant.

In general, the data obtained indicate a more pronounced improvement in resistance parameters in main group patients.

Table 3

Dynamics of motor disfunction during complex rehabilitation of post-stroke patients of two groups

Data	Before	5 weeks	p
Main group (n=52)			
Tinetti scale, total score	19,3 ± 3,4	27,4 ± 2,8	p=0,045*
Tinetti scale, stability subscale, points	10,2 ± 2,8	15,72 ± 2,65	p=0,2
Tinetti scale, gait subscale, points	9,66 ± 3,45	11,63 ± 3,2	p=0,67
Length of the statokinesiogram, mm	**852,53 ±84,3**	**618,12 ± 91,2***	**0,049**
Area of the statokinesiogram, mm²	**576,7 ± 93,6**	**292,2 ± 100,2***	**0,049**
Area of the statokinesiogram, mm² (CE)	**576,44±53,63**	369,42±62,22	**0,014**
Frequency of oscillations in the sagittal plane, Hz	1,27 ± 0,36	1,14 ± 0,41	0,84
Frequency of oscillations in the frontal plane, Hz	2,78 ± 0,86	2,16 ± 0,92	0,65
Romberg Coefficient	**55,8±6,81**	**95,2±6,47***	**p=0,002**
Группа сравнения (n=25)			
Tinetti scale, total score	19,8 ± 2,8	25,4 ± 2,7	p=0,15
Tinetti scale, stability subscale, points	10,5 ± 3,0	14,58 ± 2,95	p=0,4
Tinetti scale, gait subscale, points	9,8 ± 3,1	11,33 ± 3,0	p=0,7
Length of the statokinesiogram, mm	872,53 ± 92,07	699,71 ± 98,23	0,21
Area of the statokinesiogram, mm²	554,7 ± 100,5	309,47 ± 101,8	0,09
Area of the statokinesiogram, mm² (CE)	581,4±53,63	471,74±58,6	0,17
Frequency of oscillations in the sagittal plane, Hz	1,3 ± 0,42	1,24 ± 0,36	0,92
Frequency of oscillations in the frontal plane, Hz	2,79 ± 1,01	2,30 ± 1,09	0,78
Romberg Coefficient	56,9±6,88	73,1±6,6	0,09

Note: the reliability of the differences is p – initially and at a certain point in the study; * p<0.05.

As a result of the MR, there was a positive dynamics in the neurodynamic (p>0.05) and regulatory functions (p>0.05) in patients of both groups. There were no intergroup differences in the total MMSE score in the two groups throughout the study (p>0.05).

The assessment of psychoemotional disturbances by the HADS scale revealed 12 patients with moderate anxiety (13.7%); 55 patients (63.2%) with mild anxiety and depressive disorders and 12 patients (13.7%) with 'obvious' depression. Moderate impairments of the anxiety-depressive series were present in patients with severe motor disfunctiuon that reduce daily activity and the ability to self-care. After 5 weeks of MR, the average score of anxiety and depression on the HADS scale decreased in most patients (Table 4). Changes in anxiety and depression indicators on the HADS scale were associated with improved walking characteristics.

Statistically significant dynamics of the Bartel index total in patients of the main group was due to an increase in movement criteria scores (climbing stairs – 46% increase in 5 weeks, transplanting – 40%, walking – 80.6%) and self-service skills (eating 54% increase in 5 weeks, taking a bath – 60%, using toilet – 46%). In the comparison group, similar dynamics were observed but were not statistically significance.

A similar dynamic was observed in quality of life questionary. In the main group, the changes reached a degree of statistical significance.

The overall Bartel score significantly correlated with the HADS score (r= –0.68, p<0.05) and MMSE (r=0.49, p<0.05) after 5 weeks of MR The overall score of the EQ-5D scale after 5 weeks significantly correlated with the MMSE score (r=0.47; p<0.05), the HADS depression subscale after 5 weeks of MR(r= –0.28; p<0.05).

During NFES and BFB-training there was no destabilization of systemic hemodynamics. So, this technology can be used in patients with cardiovascular diseases.

Discussion

BS often leads to motor impairments characterized by a mediolateral deviation towards the intact lower limb and greater instability of the PC [40]. These dysfunctions lead to balance disorders [4, 8–11], which are responsible for an increased risk of falls and a lower level of activity and participation in stroke patients [10–11]. Balance is associated with the ability to move and the quality of life [40]. Moreover, balance is a predictor of the possibility of walking recovery, and is also potentially changed by physical activity [4, 8–11, 40]. The development of rehabilitation technologies to improve balance and walking function is relevant for patients with BS.

The necessary stability in the vertical position of post-stroke patients is realized by consistent training of patients in standing and walking conditions. A MR-complex with the inclusion of NFES and BFBstabilometric postural training significantly improve the function of walking by the restoring a motor stereotype and the correct placement of the foot on the support. The clinical effect was observed 3 weeks after the start of MR, reaching a maximum by the 5th week. There was a decrease in the severity of pain in the paretic limb. The game accent during the use of BFB required mental efforts from the patient. Thus, there were shown significant positive changes in impaired cognitive functions, as well as indicators of anxiety and depression after the course of NFES and BFB-training.

In the study, there were improved limb support, increased walking speed, exercise tolerance, improved psychoemotional state and quality of life of the after-stroke patients.

Conclusions

1. The patients in the chronic period of IS demonstrate a pathological type of stance, which is confirmed by deviations in computer stabilometry. Deviation of the common

CP in the frontal plane indicates the presence of paretic disorders; an increase in the area of the statokinesiogram confirms the presence of atactic syndrome.

2. The stabilometric estimation indicates the high effect of rehabilitation training with stabilometric platform in achieving static stability in patients in the chronic period of a IS.
3. The effect of complex NFES and BFB-stabilometric training in the chronic period period of a stroke is confirmed by the Tinetti scale: in 67% of cases, gait and standing process are normalized in patients with mild disorders, which is 2 times higher than in the group comparisons.
4. The BFB-based methods in the complex rehabilitation leads to earlier social adaptation of the patient and restoration of the impaired balance function.

The positive effect of complex rehabilitation with the NFES and BFB-computer stabilometry on statolocomotor disfunction in patients in the chronic period of IS has been proven. The study justifies its use in the MR of an after-stroke motor defect.

References

1. *Langhorne P, Coupar F, Pollock A. Motor recovery after stroke: a systematic review. Lancet Neurol. 2009;8(8):741–754. doi:10.1016/S1474–4422(09)70150–4.*
2. *Berge E, Whiteley W, Audebert H, et al. European Stroke Organisation (ESO) guidelines on intravenous thrombolysis for acute ischaemic stroke. Eur Stroke J. 2021;6(1): I–LXII. doi:10.1177/2396987321989865.*
3. *Rabadi MH. Review of the randomized clinical stroke rehabilitation trials in 2009. Med Sci Monit. 2011;17(2): RA25-RA43. doi:10.12659/msm.881382ю*
4. *Tappakhov AA, Konnikova EE, Argunova OG, Nikanorov VN, Dmitrieva NG. Stabilometry in the diagnosis and treatment of acute disorders of cerebral circulation: a pi lot study. Materials of the III Republican Scientific and Practical Conference 'Improving the Provision of Medical Aid to Patients with Vascular Diseases in the Republic of Sakha (Yakutia)'. 2016;43–46. (In Russ.).*
5. *Norrving B, Kissela B. The Global Burden of Stroke and Need for a Continuum of Care. Neurology. 2013;80(3 suppl 2):5–12.https://doi.org/10.1212/wnl.0b013e3182762397.*
6. *Kleim JA, Barbay S, Cooper NR, et al. Motor learning-dependent synaptogenesis is localized to functionally reorganized motor cortex. Neurobiol Learn Mem. 2002;77(1):63–77. doi:10.1006/nlme.2000.4004.*
7. *Blümle A, Maurer C, Schweigart G, Mergner T. A Cognitive Intersensory Interaction Mechanism in Human Postural Control. Exp Brain Res. 2006;173(3):357–363. https://doi.org/10.1007/s00221–006–0384-z.*
8. *Perry J. Gait Analysis: Normal and Pathological Function. Slack Incorporated; Thorofare, NJ, USA: 1992.*
9. *Chen G., Patten C., Kothari D.H., Zajac F.E. Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds. Gait Posture. 2005;22:51–56. doi: 10.1016/j.gaitpost.2004.06.009.*
10. *Boudarham J., Roche N., Pradon D., Bonnyaud C., Bensmail D., Zory R. Variations in Kinematics during Clinical Gait Analysis in Stroke Patients. PLoS ONE. 2013;8: e66421.doi: 10.1371/journal.pone.0066421*
11. *Roth EJ, Merbitz C, Mroczek K, Dugan SA, Suh WW. Hemiplegic gait. Relationships between walking speed and other temporal parameters. Am J Phys Med Rehabil. 1997;76(2):128–133. doi:10.1097/00002060–199703000–00008.*
12. *Alexander LD, Black SE, Patterson KK, Gao F, Danells CJ, McIlroy WE. Association between gait asymmetry and brain lesion location in stroke patients. Stroke. 2009;40(2):537–544. doi:10.1161/STROKEAHA.108.527374*
13. *Chantraine F, Filipetti P, Schreiber C, Remacle A, Kolanowski E, Moissenet F. Proposition of a Classification of Adult Patients with Hemiparesis in Chronic Phase. PLoS One. 2016;11(6): e0156726. Published 2016 Jun 7. doi:10.1371/journal.pone.0156726.*
14. *Ambrosini E, Parati M, Peri E, et al. Changes in leg cycling muscle synergies after training augmented by functional electrical stimulation in subacute stroke survivors: a pilot study. J Neuroeng Rehabil. 2020;17(1):35. Published 2020 Feb 27. doi:10.1186/s12984–020–00662-w.*
15. *Bowden Mark G., Clark David J., Kautz Steven A. Evaluation of Abnormal Synergy Patterns Poststroke: Relationship of the Fugl-Meyer Assessment to Hemiparetic Locomotion. Neurorehabilitation and Neural Repair. 2009;24(4):328–337. doi: 10.1177/1545968309343215.*
16. *Tan CK, Kadone H, Watanabe H, Marushima A, Yamazaki M, Sankai Y, et al. Lateral symmetry of synergies in lower limb muscles of acute post-stroke patients after robotic intervention. Front Neurosci. 2018;12:1–13. doi: 10.3389/fnins.2018.00276*
17. *Hara Y. Neurorehabilitation with new functional electrical stimulation for hemiparetic upper extremity in stroke patients. J Nippon Med Sch. 2008;75(1):4–14. doi:10.1272/jnms.75.4.*
18. *Kern H., Salmons S., Mayr W., Rossini K., Carraro U. Recovery of long-term denervated human muscles induced by electrical stimulation. Muscle Nerve. 2005;31:98–101. doi: 10.1002/mus.20149.*
19. *Sheffler L.R., Chae J. Neuromuscular electrical stimulation in neurorehabilitation. Muscle Nerve. 2007;35:562–590. doi: 10.1002/mus.20758.*
20. *Monte-Silva K., Piscitelli D., Norouzi-Gheidari N., Batalla M. A.P., Archambault P., Levin M. F. Electromyogram-Related Neuromuscular Electrical Stimulation for Restoring Wrist and Hand Movement in Post-stroke Hemiplegia: A Systematic Review and Meta-Analysis. Neurorehabil. Neural Repair. 2019;33:96–111. doi: 10.1177/1545968319826053.*
21. *Marotta N., Demeco A., Inzitari M. T., Caruso M. G., Ammendolia A. Neuromuscular electrical stimulation and shortwave diathermy in unrecovered Bell palsy: A randomized controlled study. Medicine. 2020;99: e19152. doi: 10.1097/MD.0000000000019152.*
22. *Rushton D. Functional electrical stimulation and rehabilitation: A hypothesis. Med. Eng. Phys. 2003;25:75–78. doi: 10.1016/S1350–4533(02)00040–1.*
23. *Chae J, Sheffler L, Knutson J. Neuromuscular electrical stimulation for motor restoration in hemiplegia. Top Stroke Rehabil. 2008;15(5):412–426. doi:10.1310/tsr1505–412.*
24. *Stein C, Fritsch CG, Robinson C, Sbruzzi G, Plentz RD. Effects of Electrical Stimulation in Spastic Muscles After Stroke: Systematic Review and Meta-Analysis of Randomized Controlled Trials. Stroke. 2015;46(8):2197–2205. doi:10.1161/STROKEAHA.115.009633.*
25. *Huber J, Kaczmarek K, Leszczyńska K, Daroszewski P. Post-Stroke Treatment with Neuromuscular Functional Electrostimulation of Antagonistic Muscles and Kinesiotherapy Evaluated with Electromyography and Clinical Studies in a Two-Month Follow-Up. Int J Environ Res Public Health. 2022 Jan 15;19(2):964. doi: 10.3390/ijerph19020964. PMID: 35055785; PMCID: PMC8775942.*
26. *Sharif F, Ghulam S, Malik AN, Saeed Q. Effectiveness of Functional Electrical Stimulation (FES) versus Conventional Electrical Stimulation in Gait Rehabilitation of Patients with Stroke. J Coll Physicians Surg Pak. 2017;27(11):703–706.*
27. *Hong Z, Sui M, Zhuang Z, et al. Effectiveness of Neuromuscular Electrical Stimulation on Lower Limbs of Patients With Hemiplegia After Chronic Stroke: A Systematic Review. Arch Phys Med Rehabil. 2018;99(5):1011–1022.e1. doi:10.1016/j.apmr.2017.12.019.*
28. *He YL, Gao Y, Fan BY. Effectiveness of neuromuscular electrical stimulation combined with rehabilitation training for treatment of post-stroke limb spasticity. Medicine (Baltimore). 2019;98(39): e17261. doi:10.1097/MD.0000000000017261.*
29. *Sentandreu-Mañó T., Tomás J. M., Ricardo Salom Terrádez J. A randomised clinical trial comparing 35 Hz versus 50 Hz frequency stimulation effects on hand motor recovery in older adults after stroke. Sci. Rep. 2021;11:9131. doi: 10.1038/s41598–021–88607–8.*

Table 4

Dynamics of data on the MMSE, HADS scales, indicators of functional independence and quality of life during MR in patients of the main and comparison groups

Groups	Points		
	Before MR	3 weeks	5 weeks
MMSE			
Main (n=52)	22,9±1,7	24,6±1,6	25,8±1,4
Comparison (n=35)	23,1±1,3	23,6±1,4	24,9±1,2
Anxiety			
Main (n=52)	9,7±2,8	7,9±3,5	7,4±3,3
Comparison (n=35)	9,3±2,9	8,9±3,3	8,7+3,5
Depression			
Main (n=52)	9,9±2,7	8,3±3,4	7,8±3,5
Comparison (n=35)	9,6±3,1	8,7±3,2	8,5+3,2
Index Barthel			
Main (n=52)	58,2±2,8	-	75,5±3,7*
Comparison (n=35)	58,9±2,9	-	62,7±2,7
EQ-5D, VAS			
Main (n=52)	46,3±2,3	-	61,2±3,0*
Comparison (n=35)	46,8±2,4	-	53,4±2,8

Note: the reliability of the differences is p – initially and at a certain point in the study; * p<0.05.

30. Billian C., Gorman P. H. Upper extremity applications of functional neuromuscular stimulation. Assist. Technol. 1992;4:31–39. doi: 10.1080/10400435.1992.10132190
31. Eraifej J, Clark W, France B, Desando S, Moore D. Effectiveness of upper limb functional electrical stimulation after stroke for the improvement of activities of daily living and motor function: a systematic review and meta-analysis. Syst Rev. 2017;6(1):40. Published 2017 Feb 28. doi:10.1186/s13643–017–0435–5.
32. Sabut S.K., Sikdar C., Kumar R., Mahadevappa M. Functional electrical stimulation of dorsiflexor muscle: Effects on dorsiflexor strength, plantarflexor spasticity, and motor recovery in stroke patients. NeuroRehabilitation. 2011;29:393–400. doi: 10.3233/NRE-2011–0717.
33. Stanton R, Ada L, Dean CM, Preston E. Biofeedback improves performance in lower limb activities more than usual therapy in people following stroke: a systematic review. J Physiother. 2017;63(1):11–16. doi:10.1016/j.jphys.2016.11.006.
34. Molier BI, Van Asseldonk EH, Hermens HJ, Jannink MJ. Nature, timing, frequency and type of augmented feedback; does it influence motor relearning of the hemiparetic arm after stroke? A systematic review. Disabil Rehabil. 2010;32(22):1799–1809. doi:10.3109/09638281003734359.
35. Sigrist R, Rauter G, Riener R, Wolf P. Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review. Psychon Bull Rev. 2013;20(1):21–53. doi:10.3758/s13423–012–0333–8.
36. Wolf SL, Binder-MacLeod SA. Electromyographic biofeedback applications to the hemiplegic patient. Changes in lower extremity neuromuscular and functional status. Phys Ther. 1983;63(9):1404–1413. doi:10.1093/ptj/63.9.1404.
37. Liu J, Kim HB, Wolf SL, Kesar TM. Comparison of the Immediate Effects of Audio, Visual, or Audiovisual Gait Biofeedback on Propulsive Force Generation in Able-Bodied and Post-stroke Individuals. Appl Psychophysiol Biofeedback. 2020 Sep;45(3):211–220. doi: 10.1007/s10484–020–09464–1. PMID: 32347399; PMCID: PMC7447533.
38. Genthe K, Schenck C, Eicholtz S, Zajac-Cox L, Wolf S, Kesar TM. Effects of real-time gait biofeedback on paretic propulsion and gait biomechanics in individuals post-stroke. Top Stroke Rehabil. 2018;25(3):186–193. doi:10.1080/10749357.2018.1436384.
39. Skvortsov D. V. Clinical analysis of movements. Gait analysis: Publishing house NPC – 'Stimulus', Ivanovo, 1996.– 344 p.
40. Skvortsov DV, Kaurkin SN, Ivanova GE. A Study of Biofeedback Gait Training in Cerebral Stroke Patients in the Early Recovery Phase with Stance Phase as Target Parameter. Sensors (Basel). 2021;21(21):7217. Published 2021 Oct 29. doi:10.3390/s21217217

Received 16.04.2022
Revised 18.04.2022
Accepted 20.04.2022

INFORMATION ABOUT AUTHORS

Kostenko Elena Vladimirovna – *PhD MD, Professor of the Department of Neurology, Neurosurgery and Medical Genetics Pirogov Russian National Research Medical University, Moscow, Russia; chief Research Officer, neurologist Moscow scientific and practical center of medical rehabilitation, restorative and sports medicine of the Department of health of the city of Moscow; 117997, Moscow, 1 Ostrovityanov St., Tel.: +7905 768 58 56; E-mail: ekostenko58@mail.ru; ORCID ID – https://orcid.org/0000–0003–0629–9659*

Petrova Lyudmila Vladimirovna – *PhD, Senior Researcher, Head of the Neurorehabilitation Moscow scientific and practical center of medical rehabilitation, restorative and sports medicine of the Department of health of the city of Moscow, neurologist,105005, Moscow, 70 Baumanskaya Street; Tel.: +79163940742; E-mail: ludmila.v.petrova@yandex.ru; ORCID ID – https://orcid.org/0000–0003–0353–553X*

Rylsky Alexey Vasilyevich – *neurologist Moscow scientific and practical center of medical rehabilitation, restorative and sports medicine of the Department of health of the city of Moscow; Moscow, 70 Baumanskaya Street; Tel.::+79165850111; E-mail: 79165850111@yandex.ru; ORCID ID https://orcid.org/0000–0002–1023–6426*

DOI:10.33667/2782-4101-2022-1-10-14

CHANGES IN HUMAN ORAL MICROBIOTA AND LOCAL IMMUNITY UNDER ARTIFICIAL CONDITIONS

Ilyin V., Solovyova Z., Sheblayeva A.

Federal State Budgetary Scientific Institution Russian State Scientific Centre – Institute of Medical and Biological Problems of the Russian Academy of Sciences

SUMMARY
The article shows the role of extreme influences on the development of pathological changes in the dento-mandibular system. The possibility of developing a system of preventive measures non-biocidal action, mainly using probiotics, in particular autoprobiotics is considered.

KEYWORDS*: modified environment, oral microbiocinosis, and local humoral immunity.*

CONFLICT OF INTEREST. *The authors declare no conflict of interest.*

Introduction

Habitat can be changed artificially. This happens when a person, driven by a scientific interest tries to know the world around him. This acquires the greatest significance in the conditions of space exploration, the sea depths of the earth's interior. To study these hard-to-reach areas in everyday life, artificial anthropoecosystems with modified habitat parameters are being created. In such changed conditions, the phylogenetically established relationships of the co-actants of the ecological system "man-microorganisms" undergo changes. It takes the form of disordered colonization resistance syndrome [1]. Bacteria are the predominant microorganisms in the resident oral microbiota. The resident microbiota of the oral cavity, the main part of which is formed by bacteria, competes with exogenous pathogens and defeats them, and also contributes to the normal development of tissues and the

immune system. However, the homeostatic balance between the host and microbial communities can be disturbed by many factors that can lead to the development of oral diseases such as caries, gingivitis, periodontitis, pharyngotonsillitis, etc.

The aim of the work was to characterise the three main barriers to infection that form in humans: defence group microflora, covering tissues and immunity, in conditions of isolation in hermetically sealed objects with altered environments in long-duration diving, in conditions simulating several factors of space flight (isolation and hypokinesia) and in spaceflight conditions.

Materials and methods

The determination of immunoglobulins in saliva was carried out using the nephelometric method. The content of immunoglobulins was studied in mixed unstimulated saliva obtained before meals. Monoclonal antibody solutions against sIgA, IgA, IgG antigens were used to determine immunoglobulin concentration. The traditional method of bacteriological analysis was used to identify microorganisms. Bacteriological analysis was performed by seeding on nutrient media (HiCrome Candida Agar, Staphylococcus Agar No10, Columbia Blood Agar Base, Columbia Blood Agar Base + Staph Strepto Supplement, Columbia Blood Agar +Non Spore Anaerobic Supplement).

Results and discussion

Insulation in hyperbaric (up to 40 atmospheres) containment facilities

Under hyperbaric conditions, practically all biotopes, including the periodontal region, become involved in the pathogenization of microflora [2, 3]. There is a quantitative reduction of non-pathogenic protective groups of microorganisms and a quantitative increase in opportunistic ones. Various microorganisms are involved in this process, regardless of their tinctorial properties, relationship to air oxygen, and taxonomic characteristics. A negative correlation between Veilonellae (protective group) and Actinomycetes (causative agents of periodontitis) can be observed (*Table 1*).

Table 1

Quantitative characterisation of Veilonellae and Actinomycetes periodontalis in deep-sea divers

Operator, micro-organism groups	A 24-hour long dive			
	0	3	6	10
Veilonella sp.	7	5	0	0
Actinomyces naeslundii	0	7	7	6
Veilonella sp.	5	5	5	5
Actinomyces naeslundii	0	0	7	5
Veilonella sp.	5	5	5	5
Actinomyces naeslundii	0	0	0	0

The gingival sulcus sediment prior to immersion was found to contain resident microflora consistent with normal. During the experiment an increase in the number of bacteria capable of supporting the inflammatory process and the appearance of parodontopathogenic bacteria *Prevotella melaninogenica, Actinomices israelii, Actinomices naeslundii and Fusobacterium nucleatum* against the background of the disappearance of bacterial groups *(Veillonella spp., Str. salivarius*) constituting normal oral microbiocenosis was shown. The content of immunoglobulins before immersion usually corresponded to the lower limit of normal. During the experiment the number of immunoglobulins increased significantly, which seems to reflect the sensitization of tissues by oral antigens, mainly toxins of microorganisms.

Table 2

Qualitative and quantitative composition of the gingival sulcus microflora in subjects under prolonged submersion by saturation

Identified species	Study time				
	Before the dive	Between the dives	The third day of long diving	End of long diving	30 days after long diving
Subject 1					
Peptostreptococcus anaerobius	8	9	9	6	6
Veillonella.spp	7	5	-	-	6
Streptococcus salivarius	7	5	5	-	7
S.sanguis	6	9	6	8	6
Actinomyces viscosus	6	9	8	-	-
A.naeslundii	-	7	7	6	-
Fusobacterium nucleatum	-	-	6	-	-
S.pyogenes	-	-	6	-	-
Prevotella melaninogenica	-	-	-	6	-
Subject 2					
Peptostreptococcus anaerobius	7	6	6	6	7
Veillonella.spp	7	5	-	-	-
Streptococcus. salivarius	7	5	5	-	-
S.sanguis	6	-	-	7	9
Actinomyces viscosus	6	7	5	-	7
A.naeslundii	-	-	5	5	7
S.pyogenes	-	7	-	-	8
Prevotella melaninogenica	-	-	-	6	8
Subject 3					
Peptostreptococcus apaeobius	7	9		6	6
Veillonella spp	7	7		7	6
Streptococcus salivarius	6	8		-	-
S.sanguis	6	6		8	6
Actinomyces viscosus	6	-		6	6
Staphylococcus.aureus	-	-		-	6

Table 3

Gingival microflora of the subjects before and after their isolation in the germoobject (without hygiene recommendations and special oral hygiene products) (Lg CFU)

Types	Before	After
Subject 1		
S. sanguis	4	4
S. salivarius	3	3
Veillonella parvula	-	3
Prevotella oralis	-	3
P. melaninogenica	-	2
Fusobacterium sp.	2	-
Corynebacterium sp.	3	-
Propionibacterium sp.	-	3
A. naeslundii	2	-
Subject 2		
S. sanguis	4	7
S. salivarius	3	-
P. niger	-	5
Veillonella parvula	2	-
P. melaninogenica	-	6
Corynebacterium sp.	2	4
Actinomyces sp.	-	4
Staphylococcus sp.	-	6
Lactobacillus sp.	2	-
Acinetobacter sp.	-	5
Subject 3		
S. sanguis	5	3
S. salivarius	3	3
S. intermedius	4	-
P. anaerobius	-	2
Veillonella parvula	-	2
Prevotella oralis	4	3
P. melaninogenica	-	3
Lactobacillus. sp	-	2
Subject 4		
S. sanguis	4	4
S. salivarius	2	3
S. intermedius	-	3
P. anaerobius	-	2
Veillonella parvula	2	2
Prevotella oralis	3	-

Table 4

Dynamics of certain immunoglobulin concentrations during the experiment in subjects before and after their isolation in the containment facility (Mg %)

Immunoglobulin	Subject 1		Subject 2		Subject 3		Subject 4	
	Before	After	Before	After	Before	After	Before	After
IgA	5,2	2,0	6,5	6,0	7,5	7,5	7,0	6,0
IgG	26,0	36,0	30,5	61,5	31,0	36,0	25,0	30,5
SIgA	100,0	93,0	83,0	72,0	100,0	32,0	70,5	49,5

In the course of the experiment an increase in the number of bacteria capable of supporting the inflammatory process and the appearance of periodontopathogenic bacteria *Prevotella melaninogenica, Actinomices israelii, Actinomices naeslundii and Fusobacterium nucleatum* against the background of the disappearance of groups of bacteria (*Veillonella spp., Str. salivarius*) (*Table 2*) constituting the normal oral microbiocenosis was shown. The content of immunoglobulins before immersion usually corresponded to the lower limit of the norm. During the experiment the number of immunoglobulins increased significantly, which seems to reflect the sensitisation of tissues by oral antigens, mainly toxins of microorganisms.

Long-term isolation in normobaric containment facilities

The microflora dynamics in four subjects who were in a hermetic chamber for 110 days and used conventional hygiene products are shown below (*Table 3*).

Subject 1 showed multidirectional trends during the experiment: activation of periodontopathogens of the genus *Fusobacterium sp.,* decreased activity of Streptococcus sanguis and elimination of *Peptostreptococcus anaerobius. Antagonist activity of the periodontopathogens S. salivarius, Veillonella parvula* decreased. In subject 2 during the experiment the periodontopathogen antagonist *S. salivarius* became slightly active, but in parallel the pathogen *S. sanguis* (periodontium) and *Prevotella melaninogenica* (back of tongue) became active. In subject 3 during the experiment the activation of the main periodontopathogens (*P. melaninogenica, Fusobacterium sp., Actinomyces naeslundii, S. sanquis*) is observed against the background of a decrease in the number of natural antagonists of periodontopathogenic flora (*S. salivarius Veillonella parvula*). In subject 4 the activation of fusobacteria and actinomycetes was observed during the experiment (*Fusobacterium sp., A. naeslundii, A. israelii, A.viscosus*). The second group showed similar trends. Microorganisms of the species *P. melaninogenica*, which were completely absent in the baseline cultures of all participants in the experiment, were isolated at the end of the experiment in one subject from the periodontal sulcus (10^4 CFU). A continuing trend towards activation of actinomycetes that were absent from the baseline plots should be noted. Two members of the group had *A. naeslundii* (10^5 CFU) and *A. israelii* (10^4 CFU) in their dental cultures.

There was a slight trend towards a lower concentration of immunoglobulin A in the subjects, possibly due to immune system suppression. The concentration of immunoglobulin G, on the other hand, increased in the group as a whole, apparently reflecting signs of inflammation in the context of qualitative changes in oral microbiocinosis, in particular an increase in the colonization of the oral cavity with periodontopathogenic flora.

The secretory immunoglobulin A, which describes the state of local humoral immunity, showed a unidirectional downward trend in this group, which in turn may contribute to further disruption of oral microbiocoenosis (*Table 4*).

Anti-orthostatic hypokinesia

Immunological and microbiological indices reflecting the effect of 60- and 120-day anti-orthostatic hypokinesia on periodontal tissues were studied in the subjects reflected the condition of 60- and 120-day anti-orthostatic hypokinesia (ANOH). During the experiment an increase in the number of periodontopathogenic bacteria *Prevotella melaninogenica, Actinomices naeslundii* and *Fusobacterium nucleatum* against the background of disappearance of bacterial groups (*Streptococcus salivarius* and *Veillonella*

Table 5

Immunoglobulin content (mg/ml) in the oral fluid of subjects with 120 days hypokinesia

Immunogloboulins	Terms of experiment							
	Before	7 days	30 days	60 days	90 days	120 days	7 days after	30 days after
S-IgA	0,23 ± 0,16	0,37 ± 0,12	0,69 ± 0,16	0,10 * ± 0,05	0,37 ± 0,12	0,29 ± 0,06	0,35 ± 0,05	0,23 ± 0,05
IgA	0,01 ± 0,01	0,03 ± 0,01	0,07 * ± 0,03	0,04* ± 0,03	0,05 * ± 0,01	0,03 * ± 0,04	0,02 * ± 0,03	0,02 ± 0,03
IgG	0,02 ± 0,02	0,02 ± 0,02	0,09 ± 0,05	0,09 * ± 0,05	0,22 * ± 0,04	0,10 * ± 0,03	0,10 * ± 0,03	0,09 * ± 0,01

* – significant difference compared to data before the experiment, p * 0.05.

Table 6

Species and quantitative composition of the gingival sulcus in subjects undergoing 60-day hypokinesia

Microflora	Terms of experiment					
	Background	7 days	30 days	60 days	+ 7 days	+ 30 days
	Subject A					
Streptococcus sanguis	6	6	8	7	6	6
S.salivarius	4	4	-	-	-	5
Peptostr. anaerobius	5	5	6	7	5	5
Actinomyces naeslundii	4	4	6	6	4	4
Fusobacterium sp.	4	4	6	5	4	-
Prevotella. melaninogenica	-	3	4	5	-	-
	Subject B					
Streptococcus sanguis	6	6	8	8	8	5
Peptostr. Anaerobius	5	4	5	5	5	5
Prevotella.melaninogenica	-	-	7	6	-	-
Veillonella	4	-	-	-	-	4
Peptostr. intermedius	5	4	5	5	5	5
	Subject C					
Streptococcus sanguis	7	6	6	7	6	4
Peptostr. anaerobius	6	5	5	6	5	3
Fusobacterium sp.	4	4	4	5	5	-
Peptostr. intermedius	4	4	-	5	-	3
	Subject D					
Streptococcus sanguis	5	7	6	6	6	6
Peptostr. anaerobius	5	7	5	6	5	4
Actinomyces.naeslundii	4	6	4	-	4	4
Fusobacterium sp.	4	6	5	-	-	-
Prevotella.melaninogenica	-	6	6	-	-	-
Veillonella	4	-	-	4	4	4

spp.) which constitute normal oral microbiocenosis was shown. The content of immunoglobulins before the experiment was normal. During the experiment the number of immunoglobulins increased significantly, which seems to indicate sensitization of tissues by oral antigens, mainly toxins of microorganisms (*Tables 5* and *6*).

Thus, the studies give reason to consider the extreme influences we studied, defined mainly as a specifically altered environment, as a set of factors triggering the development of pathological changes in the dentoalveolar system. These changes can eventually transform into manifest forms of disease. 60- and 120 – day ANOH leads to unidirectional changes on the part of the microbiocenosis and immunity, which is expressed in the appearance and progressive quantitative increase in periodontopathogenic bacteria and an increase in the content of immunoglobulins in the oral fluid.

Microflora and local periodontal immunity in astronauts

As a result of long-term orbital flight, the composition of oral microbiocenosis was significantly disturbed [5, 6], both qualitatively and quantitatively, which was expressed in the appearance of a number of periodontopathogenic species, in particular *Actinomices naeslundii, Prevotella melaninogenica, Fusobacterium nucleatum* and a significant increase in the number of bacteria species that can support the inflammatory process (*Table 7*). These changes were mostly pronounced on the first day after completion of the flight and gradually disappeared by the 14 day. As a result of spaceflight factors, including landing, there was an increase of immunoglobulins in the oral fluid on the first day: S-IgA from 0.07 ± 0.04 to 0.27 ± 0.09 (mg/ml); IgA from 0.06 ± 0.01 to 0,07 ± 0.04 (mg/ml); IgG from 0.1 ± 0.02 to 0.22 ± 0.04 (mg/ml) and especially the seventh day: S-IgA, 0.35 ± 0.11 (mg/ml); IgA, 0.19 ± 0.04 (mg/ml); IgG, 0.37 ± 0.10 (mg/ml). Decrease of

Table 7

Gingival sulcus microflora in astronauts (lg CFU neck of the 6th lower tooth left and right)

Astronauts	Terms	Microorganisms								
		Streptococcus sanguis	*S.salivarius*	*Veillonella spp.*	*Prevotella melaninogenica*	*P. ogalis*	*P.anaerobius*	*Actinomyces naeslundii*	*A. israelli*	*Fusobacterium nucleatum*
1	-15 days.	7	6	5	-	5	5	-	-	-
	+1 day.	7	6	-	4	5	5	4	5	-
	+7 days	7	7	-	-	-	6	-	5	-
	+14 days	6	7	-	-	5	6	-	6	-
2	-15 days.	6	6	-	-	5	5	-	-	-
	+1 day.	7	6	-	-	6	6	5	-	5
	+7 days	6	5	-	-	6	6	-	-	5
	+14 days	7	6	5	-	-	7	-	-	5
3	-15 days.	7	6	5	-	5	6	-	-	-
	+1 day.	7	6	-	6	5	6	5	5	5
	+7 days	7	6	4	-	5	7	-	5	-
	+14 days	7	7	-	-	5	7	-	5	-
4	-15 days.	6	6	5	-	5	5	-	-	-
	+1 day.	6	5	-	-	5	6	5	-	6
	+7 days	7	5	-	5	-	6	-	-	-
	+14 days	6	5	6	-	-	6	-	-	-
5	-15 days.	6	7	-	-	-	6	-	-	5
	+1 day.	6	-	-	-	5	7	-	-	6
	+7 days	7	7	-	-	6	6	-	-	5
	+14 days	6	7	5	-	5	6	-	-	5

* –15 days – pre-flight; +1, +7, +14 days – post-flight.

immunoglobulin level occurred on 14 day S-IgA – 0,13 ± 0,03 (mg/ml); IgA – 0,08 ± 0,01 (mg/ml); IgG – 0,06 ± 0,04 (mg/ml) with normalization of oral microbiocenosis.

Conclusion

Thus, the experience of the conducted researches testifies to development of infringements of colonization resistance of periodontium practically in all cases of use by the person of the artificially changed environment of an inhabitancy. At the same time, determinants for the development of this syndrome were both specific factors, i.e. factors of altered environment, and nonspecific, presumably, stressinduced factors.

These circumstances make it necessary to develop a system of non-biocidal preventive measures, mainly using probiotics, in particular autoprobiotics.

References

1. *Ilyin V.K., Volozhin A.I., Vikha G.V. Colonization resistance in altered environmental conditions. Moscow: Nauka. 2005. C. 276.*
2. *Tsarev V.N. et al. Oral microbiology, virology and immunology / V.N. Tsarev, ed.*
3. *Tsarev V.N., Nikolaeva E.N., Ippolitov E.V. Periodontopathogenic bacteria – the main factor of the origin and development of periodontitis. Journal of microbiology, epidemiology and immunobiology. 2017; (5): 101–112.*
4. *Ilyin V.K., Tsarev VN, Skedina MA, Solovieva ZO, Nikolaeva EN, Kovalev AA, Rykova MP, Antropova EN, Usanova NA, Morozova SA Status of the barriers of microbial colonization of the dentoalveolar system in conditions of simulated weightlessness // Pathological Physiology and Experimental Therapy. 2020. T. 64, № 1, C. 76–83*
5. *Ilyin V.K., Shumilina G.A., Solovyova Z.O., Nosovsky A.M., Kaminskaya E.V. Some indicators of oral and dental condition of cosmonauts during flights on ISS // Aerospace and Environmental Medicine. T. 50, № 6, C. 25–30*

Received 16.03.2022
Revised 28.03.2022
Accepted 10.04.2022

INFORMATION ABOUT AUTHORS

***Ilyin Vyacheslav Konstantinovic**, MD, Professor, Head of the department of sanitary and Hygienic Safety in Artificial Environment of Federal State Budgetary Scientific Institution Russian State Scientific Centre – Institute of Medical and Biological Problems of the Russian Academy of Sciences, Head of the laboratory of human microbial ecology, e-mail: piton2004@bk.ru, +7–499–195–00–25*

***Solovieva Zoya Olegovna**, Candidate of Biological Sciences, leading researcher at the laboratory of human microbial ecology, e-mail: soloviova@imbp.ru, +7–499–195–65–09*

***Sheblayeva Anna Sergeevna**, Junior Researcher at the Laboratory of human microbial ecology, e-mail: anya_zhilyaeva@mail.ru, +7–499–195–65–09*

DOI:10.33667/2782–4101–2022–1-15-18

SEVERE ASYMMETRICAL ATROPHY OF THE MAXILLA, COMBINED TRANS–ZYGOMATIC IMPLANT PROTOCOL. CLINICAL CASE

Put V.[1,2], Kononov I.[2], Mamedov S.[2], Gladyshev M.[2]

[1]Department of Oncology radiology and plastic surgery of the Federal State Autonomous Educational Institution of Higher Education I. M. Sechenov First Moscow State Medical University of the Ministry of Health of the Russian Federation (Sechenov University), 6 Bolshaya Pirogovskaya str., bld. 1, Moscow, 119991, Russian Federation.
[2]Department of oral rehabilitation of the Private Educational Institution of Higher Professional Education Moscow Witte University, 2-nd Kozhukhovskiy proezd, Moscow, 115432, Russian Federation.

SUMMARY

Angular and trans-zygomatic implantation is an alternative to most maxillary augmentations with severe deformations and extreme atrophy. The usage of the frontal section of the maxilla for implantation surgery after tooth extraction provides effective stability for implants and prostheses. This is the most frequently used protocol for intraoperative direct replacement with traditional and trans-zygomatic implants after extraction of the frontal teeth. Immediate functional loading with provisional restorations is always guaranteed. This saves a considerable amount of treatment time. Augmentations on the maxilla are not necessary. We present a clinical case of implant prosthetic rehabilitation using conventional and trans-zygomatic implants in extreme atrophy and deformations of the maxillary frontal region.

KEY WORDS: *implant-prosthetic rehabilitation, intraoperation immediate prosthetics, angular, zygomatic implants, single-stage implantation, maxillary atrophy, immidiate loading, deformity of the upper jaw.*

CONFLICT OF INTEREST. The authors declare no conflicts of interest

Funding. *This work was done without any sponsorship support.*
The authors express their sincere gratitude to interpreter V. M. Avanisyan and Editor-in-chief A. A. Dolgalev for their help in preparing the publication.

Introduction

In reconstructive osteoplastic surgery of the area of the atrophied maxilla specialists face a lack of bone and soft tissues, and the problem of their discrediting due to previous treatment. The main difficulties for specialists are instability of the obtained result, additional thermal trauma of surrounding soft tissues, resulting from rotating instruments due to the forced enlargement of the operative access. [1–3]. These factors influence tissue healing in the maxillofacial region, especially in persons with major surgical procedures. Severe and extreme atrophy of the upper jaw is an indication for the usage of trans-zygomatic implants. Basic rehabilitation protocols have been developed for patients with maxillofacial atrophy using trans-zygomatic implant techniques. [4–8]. The term «angular implantation» means the placement of implants at a certain angle in relation to the vertical axis (plane) of the alveolar process and the vertical vector of functional load. This eliminates the need for sinus lifts and bone block transplants. The rehabilitation period is accelerated and the cost of treatment is reduced. One-stage implantation and intraoperative direct prosthetics take the major, priority place. [9–13]. This article presents a clinical case with extraction of retained maxillary teeth, cystectomy and subsequent angular and trans-zygomatic implantation in the frontal and lateral areas of the maxilla along with the protocol for a modern immediate intraoperative prosthetic treatment with implant placement. All necessary informed consent for the treatment was obtained from the patient.

The aim of the study is to evaluate the effectiveness of implant-prosthetic rehabilitation of a patient with severe asymmetric maxillary atrophy using traditional and trans-zygomatic implants.

Patient, materials and methods

Patient S., who was born in 1957, came to the clinic in October 2019 to receive help with implants and dentures on the maxilla. The patient's main complaints were difficult eating and speaking. The patient has a strong gag reflex. Treatment attempts with removable dentures on the maxilla had no positive effect. There were roots of teeth 1.7, 1.6, 2.6, 2.7 in the oral cavity. Teeth 1.3, 1.2 were covered with metal-ceramic crowns (*Fig. 1*).

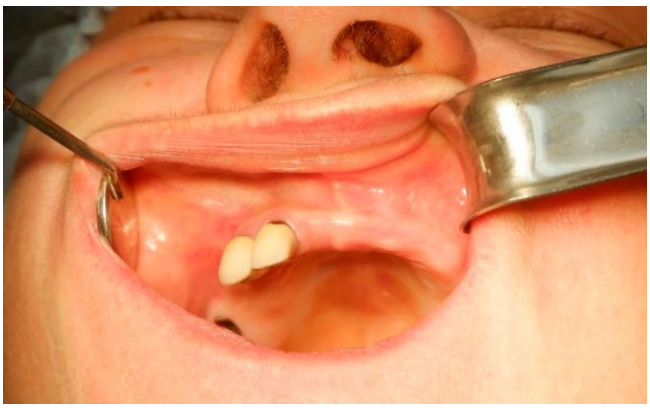

Fig. 1. Condition before treatment.

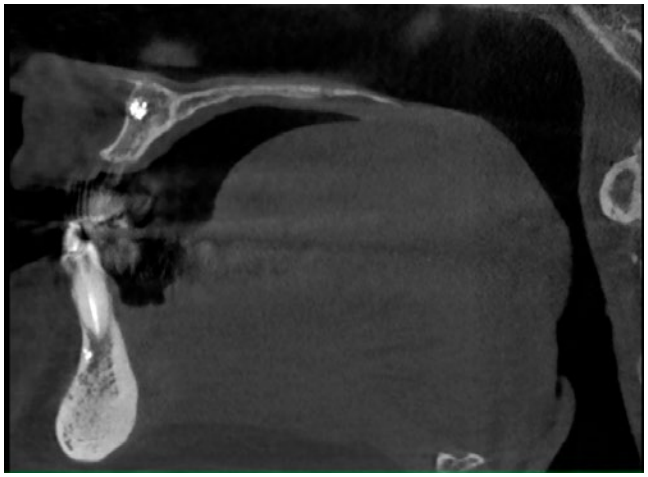

Fig. 2. Foreign material in area of the tooth 1.1.

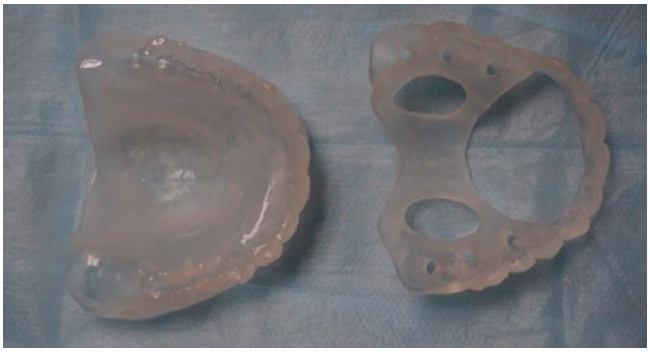

Fig. 3. Surgical template for the upper jaw and empty-prosthesis (impression module – bite template).

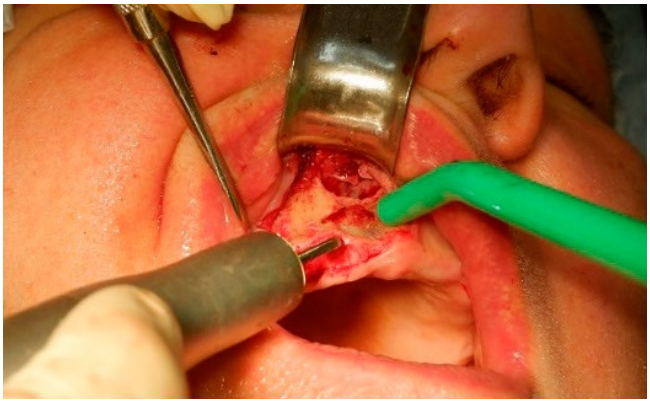

Fig. 4. Bone defect in the area of the teeth 1.1–1.2.

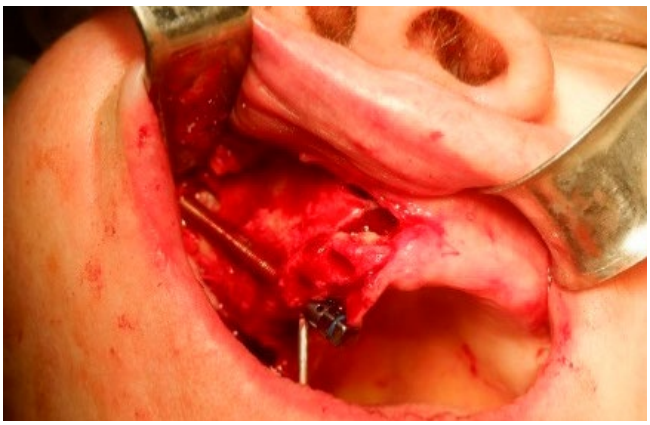

Fig. 5. A S.I.N. trans-zygomatic implant sized IMZ 4152–52 mm was placed in area of the tooth 1.5.

The patient has a partial denture on the upper jaw. CT scan detected a cyst in the area of tooth 1.2. There is a foreign filling material in the apical area of the missing tooth 1.1 (*Fig. 2*).

The patient has been wearing a removable denture for more than 10 years. The denture is unstable, due to the minimal number of support elements and strong dysocclusion of the denture and mandible's teeth. Patient has the second stage of hypertension, the second type stabilised diabetes mellitus for more than 10 years, BMI is 32. Proposal: extraction of retained teeth and roots, foreign filling material in the area of the tooth 1.1, placement of implants in the area of the teeth 1.2 and 1.3 and trans-zygomatic implants in the area of the teeth 1.5, 2.3 and 2.5.

Current design and prototyping protocols for the final treatment result include a combination in a single design:

- Condition of bone and soft tissues of the maxilla
- Prosthodontic planning data – wax up
- Computerised radiological data
- Most likely locations of implants

The result of successful design and prototyping is the patient's consent to the proposed treatment plan and the receiving of the surgical template.

The dental models have been obtained and the bite relationships have been fixed. The wax up was prepared. An upper jaw oriented surgical template and an empty-prosthesis impression module and bite template were prepared according to traditional dental techniques. The Empty-prosthesis combines the taking of an impression, checking and fixation of the occlusion and checking the aesthetics of the future denture (three in one) (*Fig. 3*).

We usually use a stereolithographic model for more successful intraoperative navigation. The surgical protocol is agreed; implant sizes, type and size of tapered screw abutments are established. The steps of surgical accesses and techniques are agreed. We apply the fast track surgery concept and protocols and ERAS (Enhanced recovery after surgery), including complex anaesthesia-ambulatory sedation [14]. The Zygomatic Anatomy Guided Approach (ZAGA) technique meets these requirements in this clinical case [15]. Diagnosis revealed a cyst in the region of the tooth 1.2 and a foreign material in the region of the tooth 1.1, bounded by the alveolar process of the upper jaw. The cyst and the material were removed with using piezosurgery and bone grafting was performed in the area of the defect *(Fig. 4*).

An extensive bone defect forced us to modify the rehabilitation project and the planned position of the implants in the area of the extracted teeth 1.3 and 1.2. S.I.N. implants were placed in the sockets of extracted teeth 1.2 and 1.4, with dimensions of 3.8–13 mm and 4.5–13 mm, respectively. A high level of primary stability of more than 50 N/cm^2 was obtained. An S.I.N. trans-zygomatic implant sized IMZ 4152–52 mm was inserted in the area of the tooth 1.5 *(Fig. 5*).

Two trans-zygomatic «Zygomatic» S.I.N. implants with dimensions IMZ 4152–52 mm and IMZ 4147–47 mm were placed in parallel in the region of maxilla on the left side. A high primary stability of the implants over 60 N/cm^2 was obtained. Here is a prosthodontic platform area of implants 2.3 and 2.5 (*Fig. 6, 7*)

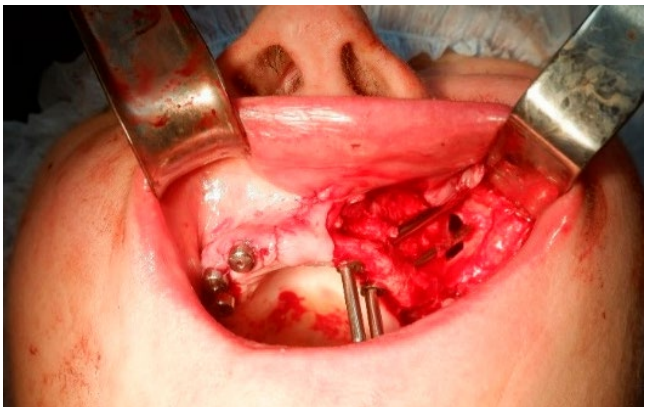

Fig. 6. The Guide «Try-in» has been set.

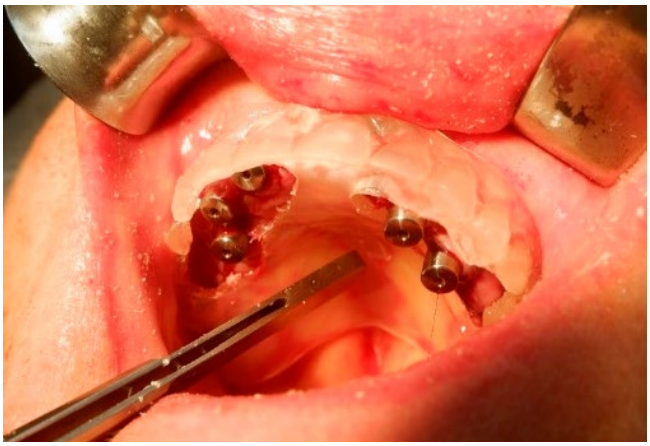

Fig. 8. The Fitting an empty-prosthesis in the mouth

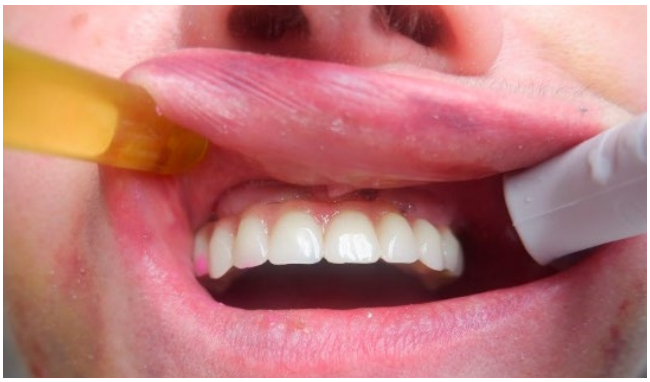

Fig. 9. View of a temporary screw-retained denture in the mouth. Metal-framed denture.

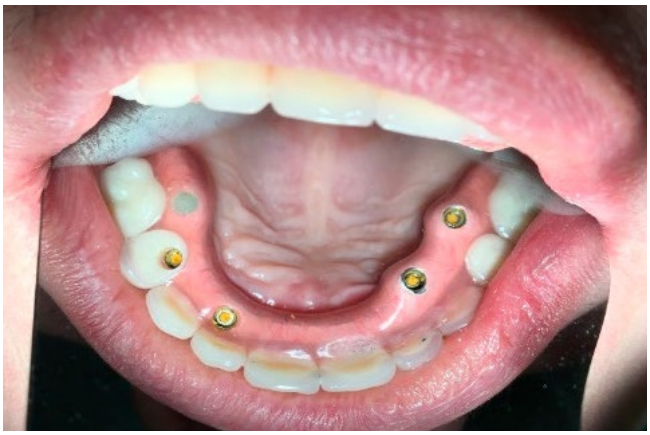

Fig. 10. Implant-supported permanent denture. The oral cavity's view.

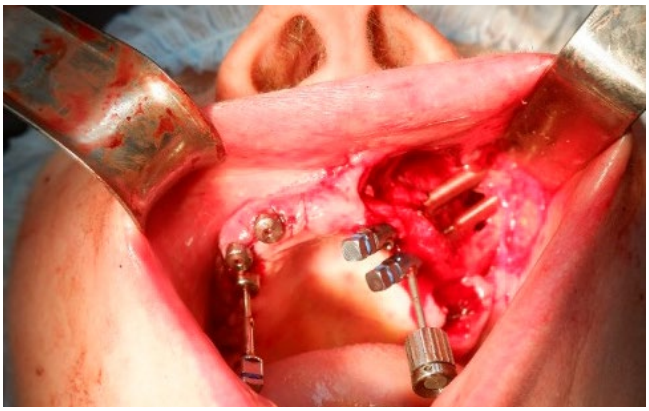

Fig. 7. Two trans-zygomatic «Zygomatic» S.I.N. implants with dimensions IMZ 4152–52 mm and IMZ 4147–47 mm were placed in parallel in the region of maxilla on the left side.

Trans-zygomatic implant placement protocol

With the traditional insertion protocol, a window is formed anterior to the anterior edge of the zygomatic bone for the landmark – the area where the apex of the implant will enter. We used the traditional protocol on the right and a combination of the traditional and ZAGA method in the anterior implant area on the left. Membrane perforation is not a significant problem, but careful delamination of the membrane is essential. The torque was set to more than 60 N/cm. The angled 170 tapered screw abutments were inserted in the conventional implants. On the prosthodontic platforms of the trans-zygomatic implants, 3 mm tapered screw abutments and shaping caps were placed. The different types of sutures were staggered with «Monosin 5.0 Resorba» resorbtionable monofilament. The tapered screw abutments are fitted with impression modules for the closed tray. An empty-prosthesis was adapted in the oral cavity (*Fig. 8*).

Empty-prosthesis impressions of the upper jaw were taken and the occlusion and aesthetic parameters of the future restoration were checked. The surgical and prosthodontic protocols were performed under ambulatory sedation, pulse oximetry and intraoperative monitoring of the patient. The duration of the surgical phase was 140 min, the prosthodontic phase – 30 min. Total procedure time was 2 h and 50 min. After 48 hours, the frame of the future prosthesis was cast, which was passively fixed on titanium cylinders using the adhesive fixation method. One day later, the temporary denture with plastic liner was fixed with screws. The screw chambers were sealed with silicone. (*Fig. 9*).

Results

High (50 N/cm^2) and great primary stability of the implants in the bone areas of the maxilla frontal region is obtained during the placement phases, due to atraumatic tooth extraction, correct bed preparation, implant shape and thread design. The trans-zygomatic implants are provided with primary stability through a tight fixation in the zygomatic bone. A temporary screw-retained denture with plastic veneer and garnished teeth was fabricated within 72 hours. The patient was monitored on day 7–10 after surgery for correction of the prosthesis, checking the occlusion and borders of the prosthesis, checking the screw fixation force at the stage of suture removal, «repositioning» of the denture, correction of

the cervical areas of the fixed structure 3–4 weeks, without removing the denture. Correction of occlusion was held in 2, 3, 4–6 months after surgery. At the final stage, we managed to restore the patient's chewing and speech function. No loosing of the screws fixing the denture was observed during the monitoring. After half a year a permanent denture was fabricated on the maxilla. (*Fig. 10*). The patient is satisfied with the treatment results and appreciates the high quality of life with the denture.

Discussion

The need to minimise surgical implant placement in the area of atrophy and discredited tissue after multiple surgical interventions is realised. [16]. This is justified and consistent with the ideology of «fast track surgery» and applied in dentistry and maxillofacial surgery [14, 15]. In the presented case, there was a high risk of unsatisfactory implant fixation in the area of the teeth 1.2–1.3 due to the extensive defect after removal of the cyst and foreign material in the area of the tooth apexes. As a result, an implant was placed in area of the tooth 1.4. It was easier to perform the quad zygomatic protocol. However, a significant bone reduction was required in the area of the teeth 1.1–1.4, which compromised the treatment protocol.

Conclusion

The most challenging and responsible element of treatment in our case is the precise adherence to the stages and controls of surgical and prosthetic protocols, implant placement and functional load control. This is particularly important in patients with significant defects and deformities. [16, 17]. Dental anesthesiology has made it possible to speed up and optimise complex surgical techniques. [18]. The key success factor in this case was the planning and prototyping of treatment protocols, the use of pattern guides, and the execution of the protocols. In severe asymmetrical maxillary atrophy and total implant-prosthetic rehabilitation, a systematic approach and dental outpatient sedation as a factor of treatment safety and efficacy is a priority.

References

1. *Epstein JB, Sciubba JJ., Abt E. Evidence base, epidemiology, correlations, and cause and effect: dental caries and head and neck cancer. Oral Surg Oral Med Oral Pathol Oral Radiol. 2014; 118(1):1–4. https://doi.org/10.1016/j.oooo.2014.03.011*
2. *Narayan TV, Revanna GM, Hallikeri U, Kuriakose MA. Dental Caries and Periodontal Disease Status in Patients with Oral Squamous Cell Carcinoma: A Screening Study in Urban and Semiurban Population of Karnataka. J Maxillofac Oral Surg. 2014;13(4):435–443. https://doi.org/10.1007/s12663–013–0540–5*
3. *Dholam KP, Gurav SV. Dental implants in irradiated jaws: A literature review. J Can Res Ther. 2012; 8: 85–9.*
4. *Engelhardt S, Papacosta P, Rathe F, Özen J, Jansen JA, Junker R. Annual failure rates and marginal bone-level changes of immediate compared to conventional loading of dental implants. A systematic review of the literature and meta-analysis. Clin Oral Implants Res. 2015;26(6):671–87. https://doi.org/10.1111/clr.12363*
5. *Boyes-Varley JG, Lownie JF, Howes DG, Blackbeard GA The Zygomatic Implant Protocol in the treatment of the Severely Resorbed Maxilla SADJ 2004; 58:3; 106–114*
6. *3. A proposed classification for zygomatic implant patient based on the zygoma anatomy guided approach (ZAGA): a cross-sectional survey. September 2011. European Journal of Oral Implantology 4(3):269–75*
7. *4. Pietro Salvatori1, Antonio Mincione, Lucio Rizzi, Fabrizio Costantini, Alessandro Bianchi, Emma Grecchi, Umberto Garagiola, and Francesco Grecchi. Maxillary resection for cancer, zygomatic implants insertion, and palatal repair as single-stage procedure: report of three cases Maxillofacial Plastic and Reconstructive Surgery (2017) 39:13. DOI 10.1186/s40902–017–0112–6*
8. *Boyes-Varley JG, Lownie JF, Howes DG, Blackbeard GA Surgical Modifications to the Branemark Zygomaticus Protocol.COIR 2002; Vol 13:4; xxxii*
9. *Howes DG, Boyes-Varley JG, Blackbeard GA An Angulated Implant for the Anterior Maxilla; Development and Evaluation COIR 2004; Vol 15:4 xi. Poster Presentation; EAO; Paris; 2004*
10. *Runyan CM, Sharma V, Staffenberg DA, Levine JP, Brecht LE, Wexler LH, et al. Jaw in a day: state of the art in maxillary reconstruction. J Craniofac Surg. 2016;27(8):2101–4. https://doi.org/10.1097/scs.0000000000003139*
11. *Chrcanovic BR, Albrektsson T, Wennerberg A. Survival and complications of zygomatic implants: an updated systematic review. J Oral Maxillofac Surg. 2016;74(10):1949–64.9. https://doi.org/10.1016/j.joms.2016.06.166*
12. *Boyes-Varley JG, Lownie JF, Howes DG, Blackbeard GA The Zygomatic Implant Protocol in the treatment of the Severely Resorbed MaxillaSADJ 2004; 58:3; 106–114*
13. *Hall JAG, Payne AGT, Purton DG, Torr B, Duncan WJ, Kumara R Immediate Restored, single-tapered implants in the anterior maxilla: Prosthodontics and Aesthetic outcomes after 1 year. Clin Implant Dent Relat Res 2007; 9:1; 34–45*
14. *Grigoraş I./ Fast-trach surgery – a new concept – the perioperative anesthetic management. // Jurnalul de Chirurgie, Iasi, 2007, Vol. 3, Nr. 2 – p.89–91*
15. *Aparicio C, Manresa C, Francisco K, et al. Zygomatic implants placed using the zygomatic anatomy-guided approach versus the classical technique: a proposed system to report rhinosinusitis diagnosis. Clin Implant Dent Relat Res. 2014;16:627–42.*
16. *K Moiduddin, A Al-Ahmari, M Al Kindi, ESA Nasr, A Mohammad, Customized porous implants by additive manufacturing for zygomatic reconstruction …Biocybernetics and biomedical engineering 2016 36 (4), 719–730 https://doi.org/10.1016/j.bbe.2016.07.005*
17. *Pellegrino G, Tarsitano A, Basile F, Pizzigallo A, Marchetti C. Computer-aided rehabilitation of maxillary oncological defects using zygomatic implants: a defect-based classification. J Oral Maxillofac Surg. 2015;73(12):2446. e1-.e11 https://doi.org/10.1016/j.joms.2015.08.020*
18. *Zaitsev A. Y., Svetlov V. A., Dubrovin K. V. Sedation in dentistry and outpatient maxillofacial surgery. Theory and practice // Vestnik anesthesiologii i reanimatologii.– 2018.– V. 15, № 3.– P. 62–73. DOI: 10.21292/2078–5658–2018–15–3–62–73*

Received 20.03.2022
Revised 28.03.2022
Accepted 28.03.2022

INFORMATION ABOUT AUTHORS

***Put Vladimir Anatolievich**, Professor, Department of Oncology radiology and plastic surgery of the Federal State Autonomous Educational Institution of Higher Education I.M. Sechenov First Moscow State Medical University of the Ministry of Health of the Russian Federation (Sechenov University), 6 Bolshaya Pirogovskaya str., bld. 1, Moscow, 119991, Russian Federation, e-mail: pout-prof@mail.ru, +79167393344 ORCID: 0000–0003–4150–9885.*

***Kononov Igor Nikolaevich**, Assistant of the Department of oral rehabilitation of the Private Educational Institution of Higher Professional Education Moscow Witte University, 2-nd Kozhukhovskiy proezd, Moscow, 115432, Russian Federation, e-mail: kononovigor77@yandex.ru, +7950665502*

***Mamedov Samir Sabirovich**, Assistant of the Department of oral rehabilitation of the Private Educational Institution of Higher Professional Education Moscow Witte University, 2-nd Kozhukhovskiy proezd, Moscow, 115432, Russian Federation, e-mail: samirsm@mail.ru*

***Gladyshev Mikhail Vladimirovich**, Assistant of the Department of oral rehabilitation of the Private Educational Institution of Higher Professional Education Moscow Witte University, 2-nd Kozhukhovskiy proezd, Moscow, 115432, Russian Federation, e-mail: Gladent@mail.ru, +79103501877*

DOI:10.33667/2782–4101–2022–1-19-23

MINIMALLY INVASIVE TRANS–ZYGOMATIC AND PTERYGOID IMPLANT SURGERY TECHNIQUE IN THE REHABILITATION OF PATIENTS WITH SEVERE MAXILLARY ATROPHY

Gladyshev M.[1], Put V.[2], Dolgaev A.[3], Gladysheva A.[4], Kalashnikova O.[5], Kononov I.[1]

[1]Department of oral rehabilitation of the Private Educational Institution of Higher Professional Education Moscow Witte University, 2-nd Kozhukhovskiy proezd, Moscow, 115432, Russian Federation.
[2]Department of Oncology radiology and plastic surgery of the Federal State Autonomous Educational Institution of Higher Education I. M. Sechenov First Moscow State Medical University of the Ministry of Health of the Russian Federation (Sechenov University), 6 Bolshaya Pirogovskaya str., bld. 1, Moscow, 119991, Russian Federation.
[3]Department of General Practice and Pediatric Dentistry, Stavropol State Medical University, Ministry of
Health of the Russian Federation, Stavropol, Russian Federation
[4]Medical Centre «Gladent», 3 Cosmonauts str., bldn. «A», Lipetsk.
[5]Medical clinic «MedSwiss», Moscow.

SUMMARY

Angular and trans-zygomatic implants are an alternative to most augmentation procedures on the upper jaw. Priority application of trans-zygomatic, pterygoid and traditional implants on the upper jaw in different techniques and combinations. Extensive possibilities for rehabilitation of patients with severe and extreme atrophy and post-traumatic changes of the upper jaw. Trans-zygomatic implants provide immediate functional loading with prosthetic constructions according to the protocol of intraoperative direct prosthetics. Treatment time, cost and the need for augmentation procedures are reduced. Specialists strive to reduce the risks and invasiveness of techniques by optimising surgical access techniques.

KEY WORDS: *angular and trans-zygomatic implantation, intraoperative direct prosthesis, trans-zygomatic implant protocol, intraoperative implant positioning, conical screw abutments, screw fixation of prostheses, minimally invasive technique.*

CONFLICT OF INTEREST. *The authors declare no conflict of interest.*

Introduction

With the long-term absence of teeth and reduced functional load, the volume and density of the bone tissue in the distal part of the maxillary sinus decreases and is insufficient for the placement of traditional dental implants [1]. Clinicians use the method of maxillary sinus floor elevation (sinus lifting surgery) to solve this problem. The use of sinus lifts is widespread in modern dental practice. [2]. A variety of surgical protocols, the anatomy and functional features of the maxillary sinuses, associated pathology and unfavourable factors lead to the development of complications that reduce the effectiveness of the technique or lead to the absence of predictable results [3, 4, 5]. Trans-zygomatic and angulated implantation protocols are now widely used in practice and are progressive and demanded designs by dental professionals and maxillofacial surgeons [6, 7]. Often, trans-zygomatic implants are used, in independent solutions – the «quad zygoma» or «4+» protocol, when there is extreme atrophy of the upper jaw, flattened and atrophied upper jaw frontal region with minimal bone [8, 9]. Rehabilitation of laterally atrophied regions of the upper jaw in various combinations with standard, angular and pterygoid implants is more often in demand [10, 11]. [10, 11]. A large number of studies are devoted to implantation in the extraction site of the maxillary teeth, surgical sanation, and peculiarities of implant positioning in this area. [12]. The literature discusses the effectiveness of tilted and angled implantation protocols in the lateral zone of the maxilla. The anatomy and the presence of a bone supply have of great importance, which is so telling for these protocols. [12]. Surgical protocols, depending on the prosthetic platform of the implant, involve both bicortical as well as multicortical fixation of the implant. A large proportion of the structure ends up in the zygomatic bone thickness, which significantly improves the quality and strength of the anchoring of the structure. [13].

The angular and trans-zygomatic implant protocols fall under the category of the intraoperative direct prosthetic technique. A denture with an individual metal or composite framework is placed on the day of surgery or 24–72 hours after the intervention. This depends on the individual indication, the INP protocol and the capacity of the clinic and dental laboratory [14]. Modern prosthodontic planning of this surgical protocol minimises surgical trauma and avoids flap detachment. This leads not only to an accelerated, simplified surgical protocol, but also to improved treatment quality. [15]. The literature compares different techniques and protocols for transsseous and angular implantation: classic technique (Branemark), advanced extrasinus techniques (Sinus Slot technique, Stella &

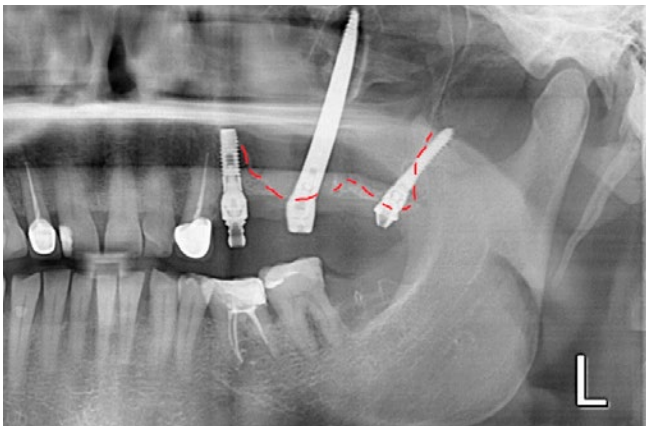

Fig.1. Height of the maxillary alveolar process laterally to the floor of the maxillary sinus on the left

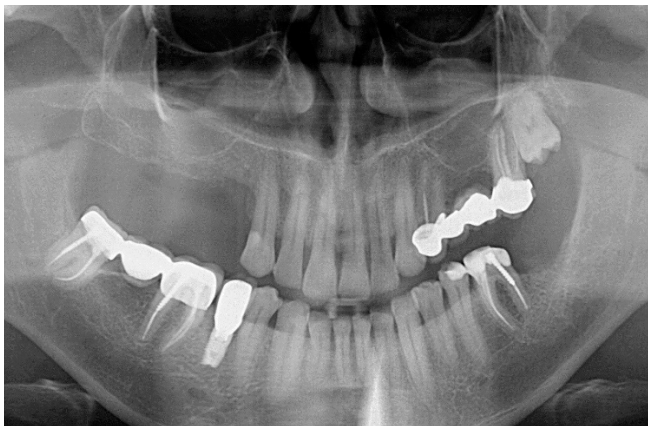

Fig.2. Height of the maxillary alveolar process in the maxillary sinus area on the right.

Warner 2003., Migliorança et al. 2005, 2006,. and intrasinus, extramaxillary technique., Malevez C. et al. 2004, ZAGA Carlos Aparicio 2005, 2011). The preparation, design and implementation of the above treatment protocols should be performed by a team of specialists with extensive surgical experience in maxillofacial surgery and implant-supported prosthetics [16, 17]. This article presents clinical experience with trans-zygomatic angular implantation protocols in the lateral region of the upper jaw using the original minimally invasive protocol, followed by intraoperative prosthetics.

The aim of the study is to improve angular and trans-zygomatic implantation protocols for the rehabilitation of atrophied maxillary lateral regions, minimising surgical access.

Patients, materials and methods

The patient group consisted of 44 patients (21 females and 23 males) aged between 37 and 73 years, from 2014 to March 2020. The patients were divided into two groups. The first group included 20 patients with severe maxillary alveolar atrophy who underwent the classic Branemark trans-zygomatic implant technique with mucosal-periosteal flap folding, opening of a window on the anterior surface of the zygomatic bone, Schneider membrane detachment and placement of trans-zygomatic implants. Fifty trans-zygomatic implants and 31 standard implants were placed. Three trans-zygomatic implants and 2 standard implants were rejected. [17]. In the second group, we used our improved minimally invasive technique of angular and trans-zygomatic implantation in the rehabilitation of 24 patients with severe atrophy of the maxillary alveolar process. Fifty-two trans-zygomatic implants and 35 standard implants were placed. Two trans-zygomatic implants and one standard implant were rejected. We used the ZAGA accesses and technique of implant placement without reclining the mucosal-periosteal flap through punctures or soft tissue incisions to minimise hard tissue atrophy, postoperative complications and to reduce the surgical time. [18].

In preparation for the surgery, a CBCT of the patient's head was carried out and an individual stereolithographic maxilla model was produced using a 3-D printer. The maxilla prototype was used for the development of intraosseous canals for titanium structures using osteotomes, piezosurgical technique, diamond cutters and conical drill, implant insertion routes and optimal positioning parameters for the prosthesis.

Clinical examples. The maxillary alveolar process in the lateral region to the floor of the maxillary sinus was 1 mm to 3 mm in height and 2 mm to 4 mm in width (*Fig.1–2*).

Depending on the anatomical features of the pterygoid-mandibular region, the implant was positioned either in the medial lamina of the pterygoid process of the sphenoid bone or directly in the body of the pterygoid process of the sphenoid bone. *(Fig. 3–4*)

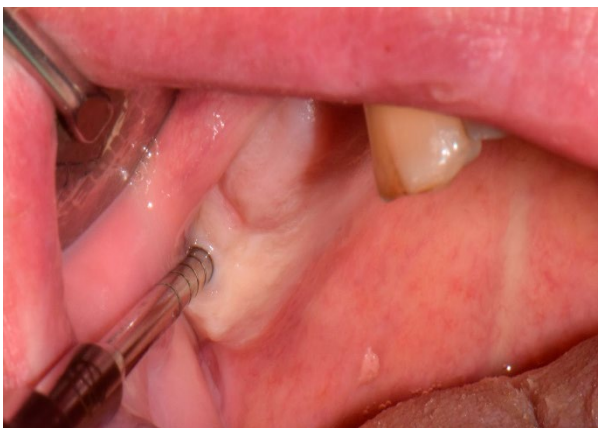

Fig. 3. Minimally invasive bone canal formation for pterygoid implantation with an osteotome.

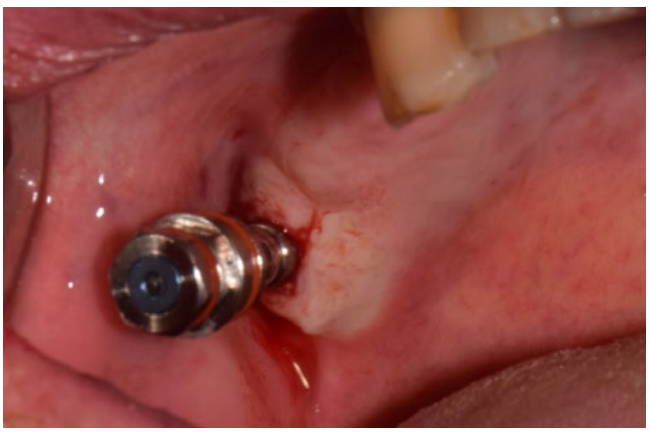

Fig. 4. Placement of a pterygoid implant without retracting the mucosal-periosteal flap.

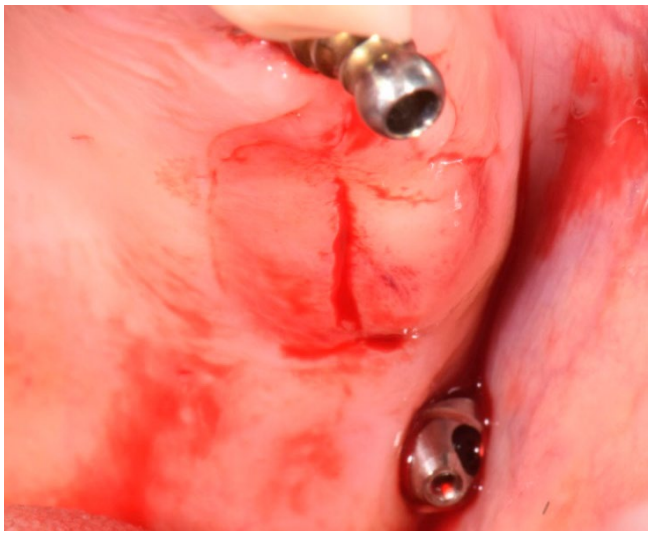

Fig. 5. Full-thickness soft tissue incision along the alveolar ridge of the maxilla for placement of a transcuneal implant.

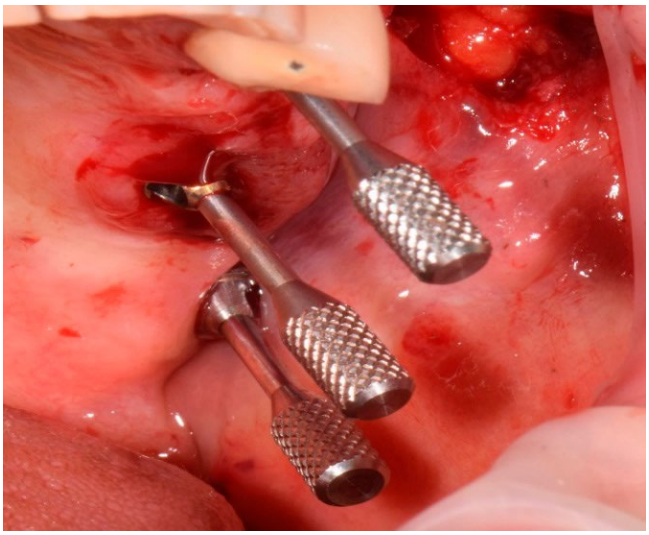

Fig. 6. View of the transitional fold incision on the upper jaw for inserting a trans-zygomatic implant.

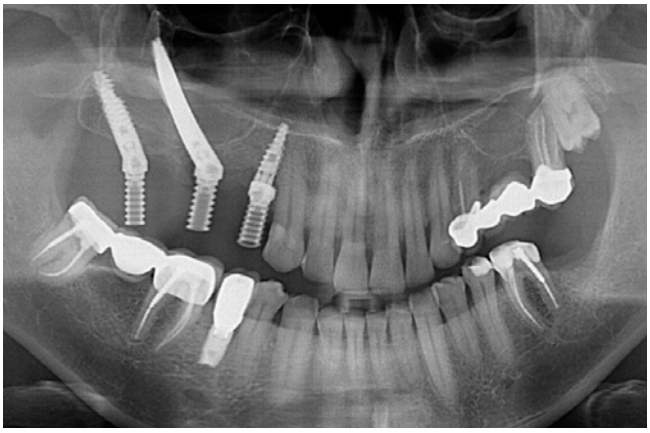

Fig. 7. Orthopantomogram with 3 implants on the maxilla, placed for immediate denture loading.

In the first stage of surgery a pterygoid implantation was performed. If the pterygoid implant was unsuccessful, a second option with two trans-zygomatic implants up to 60 mm long was used. We use a double soft-tissue incision technique of 10 mm each for insertion. The first incision was made along the apex of the maxillary alveolar process at a distance of 5 mm from the border of the attached and movable mucosa of the vestibule of the mouth. (*Fig. 5*) The second incision was made according to the Caldwell-Luke method in the projection of the premolars (*Fig. 6*).

Infiltrative anaesthesia was enough in the surgical area in the first stage. In the case of unilateral missing teeth with severe maxillary alveolar ridge atrophy, 3 implants were desirable for immediate loading. (*Fig. 7*) Implants were less overloaded compared to a 2-implant construction.

If the implants are not in parallel to each other and the implant abutments are not in line with the alveolar ridge, they form a triangle between them, which reduces the functional overload during lateral masticatory movements (*Fig. 8*). Increasing the area of this triangle within the dental arch area reduces the risk of complications.

When inserting a third implant, if at all possible, we minimise the incision or use a set of osteotomes for the subsequent insertion of a classic implant through the soft tissue puncture.

The success of rehabilitation of patients with severe maxillary alveolar atrophy using the immediate loading method depends on primary stability, optimal positioning of abutments in the dental arch area, splinting with titanium skeleton for the entire structure. (*Fig. 9*)

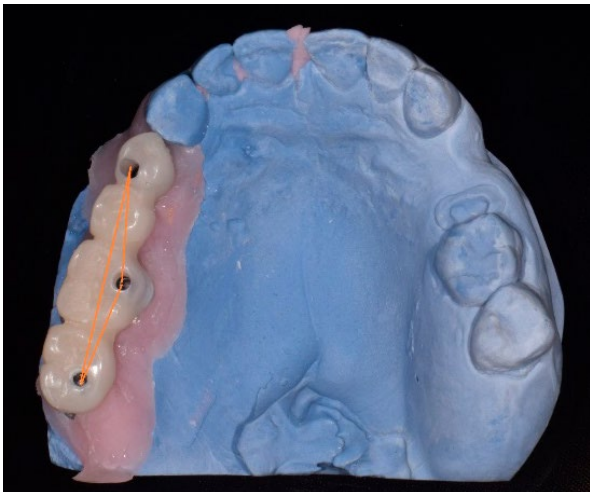

Fig. 8. Positioning of the mines exits for triangular screw fixation of the denture.

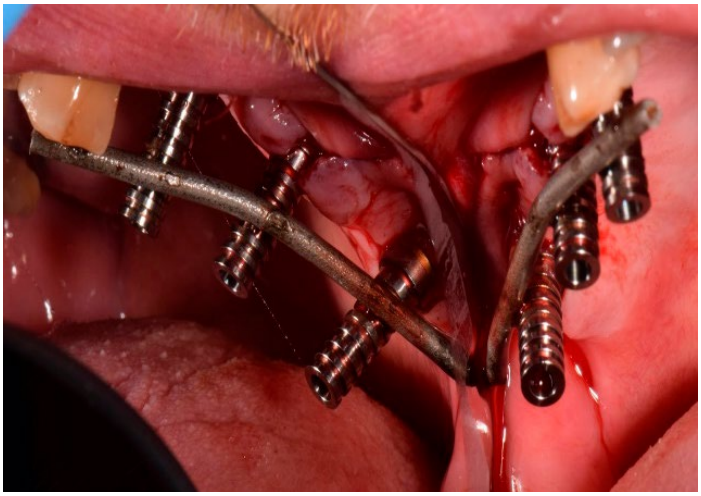

Fig. 9. Structural splinting with intraoral contact welding.

Table 1

Analysis of the clinical status of patients after surgery

	Classic trans-zygomatic implant technique	Minimally invasive trans-zygomatic implant technique
Pain syndrome	Up to 5 days	one day
General medical condition on a 5-point scale	3	4
Swelling (oedema)	Up to 10 days	one or two days
Restriction of mouth opening	in 40% of cases	0
Surgery time	Up to two hours	30–40 min
Anaesthesia	narcosis	infiltrative anaesthesia

The upper and lower jaw rows must be fully restored with dentures to prevent uneven distribution of the chewing load.

Results

The evaluation was based on clinical assessment of the implants and prostheses, postoperative patient questionnaire and radiographic analysis of the patients. *Table 1* presents an analysis of the clinical status of the patients after surgery. Based on the clinical assessment of the implants and radiographic analysis of the patients who underwent minimally invasive angular and trans-zygomatic implantation compared to the patients rehabilitated using the classic Branemark technique, no worsening of the postoperative condition was detected.

Conclusion

Trans-zygomatic implants have been clinically used for the past 30 years in the rehabilitation of patients with severe maxillary atrophy. They allow predictable support for screw-retained prostheses. Guided surgical approaches are used for optimal placement of the prosthetic platform of such implants. [20]. The formation of this access is sufficient for visualisation of the surgical field, objective assessment of the situation and minimally invasive placement of implants. An undeniable advantage of this method is the minimisation of factors that provoke hard tissue atrophy by preserving the integrity of the periosteum. There is virtually no haematoma or pain in the postoperative period. Due to the absence of the necessity to fold back the complete mucosal-periosteal flap, additional hemostasis of the damaged vessels in this area, finishing repositioning and double-row suturing of the flap to prevent divergence of the wound edges, the intervention time is reduced and the operation itself is simplified. This has been confirmed by other researchers. [21, 22, 23]. When passing a rotary cutter, depth gauge or implant near the orbital floor, it is very important to have bilateral contact with the patient. This makes it possible to change the insertion trajectory in time and avoids possible complications. The minimally invasive technique of implant placement in the treatment of patients with severe maxillary alveolar atrophy can be used by the surgeon on an outpatient basis and makes it possible to achieve a predictable result in 1 day. [24].

References

1. *Nocini PF, D'Agostino A, Chiarini L, Trevisiol L, Procacci P. Simultaneous Le Fort I osteotomy and malar implant placement with delayed prosthetic rehabilitation. J Craniofac Surg. 2014;25:1021–4.*
2. *Aghaloo TL, Moy PK. Which hard tissue augmentation techniques are most successful in providing bone support for implant placement? Int J Oral Maxillofac Implants. 2007;22(Suppl):49–70.*
3. *Testori T, Drago L, Wallace S, Capelli M, Galli F. Prevention and management of postoperative infections after sinus elevation surgery: a clinical consensus and recommendations. Int J Dentistry. 2012;2012:365809.*
4. *Kasabah S, Krug J, Simůnek A, Lecaro MC. Can mucosal perforation of the maxillary sinus be predicted? Acta Med (Hradec Kralove). 2003;46(1):19–23.*
5. *Danesh-Sani SA, Loomer PM, Wallace SS. A comprehensive clinical review of maxillary sinus floor elevation: anatomy, techniques, biomaterials and complications. Br J Oral Maxillofac Surg. 2016;54(7):724–30.*
6. *Aparicio C, Ouazzani W, Hatano N. Use of zygomatic implants for orthopaedic rehabilitation of severely resorbed maxilla. Periodontol. 2008;47:162–71.*
7. *Aparicio C, Manresa C, Francisco K, et al. Cheek implants placed using the zygomatic anatomical approach versus the classical technique: a proposed system for rhinosinusitis diagnosis. Clin Implant Dent Relat Res. 2014;16:627–42.*
8. *Davó R, Pons O. 5-year results of four zygomatic implant-supported, immediately-loaded cross-retained prostheses: a prospective case series. Eur J Oral Implantol. 2015;8:169–74.*
9. *Way V. A. Reshetov I. V., Solodkiy V. G., Ilyichev E. A., Kalashnikova O. Yu. The protocol of zygomatic implantation Quad – a protocol for the installation of «quadruple» transosseous implants. Opportunities, prospects. Dentist Minsk 2017. no. 1(24) p. 38–41*
10. *Alzoubi F, Bedrossian E, Wong A, Farrell D, Park C, Indresano T. Outcome evaluation of fully edentulous patients with an implant-supported fixed profile prosthesis using a graft-free approach. Part 1: clinically related outcomes. Int J Oral Maxillofac Implants. 2017;32:897–903.*
11. *Candel E, Peñarrocha D, Peñarrocha M. Rehabilitation of the atrophic posterior maxilla with pterygoid implants: a review. J Oral Implantol. 2012;38(S 1):461–6.*
12. *Engelhardt S, Papacosta P, Rathe F, Özen J, Jansen JA, Junker R. Annual failure rates and marginal bone-level changes of immediate versus conventional loading of dental implants. A systematic literature review and meta-analysis. Clin Oral Implants Res. 2015;26(6):671–87. https://doi.org/10.1111/clr.12363*
13. *Esposito M, Worthington HV. Interventions to replace missing teeth: zygomatic dental implants for rehabilitation of the edentulous upper jaw with severe deficit. Cochrane Database Syst Rev. 2013;9.*
14. *Chow J, Hui E, Lee PK, Li W. Cheek implants – immediate occlusal loading protocol: a preliminary report. J Oral Maxillofac Surg. 2006;64:804–11.*
15. *Schiroli G, Angiero F, Silvestrini-Biavati A, Benedicenti S. Placement of zygomatic implants using computer-guided flapless surgery: a proposed clinical protocol. J Oral Maxillofac Surg. 2011;69:2979–89.*
16. *Davo R, Malevez C, Rojas J. Immediate function in atrophic maxilla with zygomatic implants: a preliminary study. J Prosthet Dent. 2007;97: S44–51.Schiroli G, Angiero F, Silvestrini-Biavati A, Benedicenti S. Zygomatic implant placement with flapless computer-guided surgery: a proposed clinical protocol. J Oral Maxillofac Surg. 2011;69:2979–89.*
17. *Brånemark PI, Gröndahl K, Ohrnell LO, et al. Zygoma fixation in the management of advanced atrophy of maxilla: technique and long-term results. Scand J Plast Reconstr Surg Hand Surg. 2004;38:70–85.*
18. *Gladyshev M. V., Gladyshev A. M., Path V. A., SPEED FOR INSTALLATION OF SCULAR IMPLANTATES No. 2020122645/14(038967)*
19. *Duarte LR, Filho HN, Francischone CE, Peredo LG, Brånemark PI. Establishment of a protocol for complete rehabilitation of an atrophic maxilla using four zygomatic retainers in an immediate loading system – 30-month clinical and radiographic follow-up. Clin Implant Dent Relat Res. 2007;9:186–96.*
20. *Alzoubi F, Bedrossian E, Wong A, Farrell D, Park C, Indresano T. Outcome evaluation of fully edentulous patients with a fixed implant-supported profile prosthesis using a graft-free approach. Part 1: clinically related outcomes. Int J Oral Maxillofac Implants. 2017;32:897–903.*

21. Boyes-Varley JG, Howes DG, Lownie JF, Blackbeard GA. Surgical modifications of the Brånemark zygomaticus protocol in the treatment of severely resorbed maxilla: a clinical report. Int J Oral Maxillofac Implants. 2003;18:232–7.
22. Stella JP, Warner MR. The axillary gap technique to simplify and improve the orientation of zygomatic dental implants: a technical note. Int J Oral Maxillofac Implants. 2000;15:889–93.
23. Tulasne JF. Osteointegrated fixators in the pterygoid region. In: Worthington P, Branemark PI, editors. Advanced osseointegration surgery: applications in the maxillofacial region. Chicago: Quintessence Publishing; 1992. p. 182–8.

Received 16.02.2022
Revised 18.03.2022
Accepted 01.04.2022

INFORMATION ABOUT AUTHORS

Gladyshev Mikhail Vladimirovich, *Assistant of the Department of oral rehabilitation of the Private Educational Institution of Higher Professional Education Moscow Witte University, 2-nd Kozhukhovskiy proezd, Moscow, 115432, Russian Federation, e-mail: Gladent@mail.ru, +79103501877*

Put Vladimir Anatolievich, *Professor, Department of Oncology radiology and plastic surgery of the Federal State Autonomous Educational Institution of Higher Education I.M. Sechenov First Moscow State Medical University of the Ministry of Health of the Russian Federation (Sechenov University), 6 Bolshaya Pirogovskaya str., bld. 1, Moscow, 119991, Russian Federation, e-mail: pout-prof@mail.ru, +79167393344 ORCID: 0000–0003–4150–9885.*

Dolgalev Alexander Alexandrovich, *PhD, MD, Head of the Center for Innovation and Technology Transfer, Professor of the Department of General Practice Dentistry and Pediatric Dentistry of Stavropol State Medical University of the Ministry of Health of the Russian Federation, Professor of the Department of Clinical Dentistry with a course of OS and MFS of Pyatigorsk Medical and Pharmaceutical Institute-branch of the Volgograd State Medical University, Stavropol, Russian Federation, e-mail: dolgalev@dolgalev.pro, + 7–962–440–48–61, ORCID: https://orcid.org/0000–0002–6352–6750*

Gladysheva Anastasia Mikhailovna, *Dentist at the medical Centre «Gladent», Lipetsk. +7980539148, e-mail: Gladent@mail.ru*

Kalashnikova Oksana Yurievna, *Dentist at the medical clinic «MedSwiss», Moscow, +79166054685*

Kononov Igor Nikolaevich, *Assistant of the Department of oral rehabilitation of the Private Educational Institution of Higher Professional Education Moscow Witte University, 2-nd Kozhukhovskiy proezd, Moscow, 115432, Russian Federation, e-mail: kononovigor77@yandex.ru, +7950665502*

DOI:10.33667/2782-4101-2022-1-23-27

SINUS LIFTING SURGERY WITH SIMULTANEOUS SANATION OF THE LOWER SECTIONS OF THE MAXILLARY SINUS

Yamurkova N.[1], Ivanov S.[2], Mukhametshin R.[2], Trubushkina E.[3], Kutsenko A.[3]

[1]State budgetary health care institution of Nizhny Novgorod Region Municipal Clinical Hospital № 39, Nizhny Novgorod, Russian Federation
[2]Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya St., Moscow, Russian Federation
[3]Stavropol State Medical University of the Ministry of Health of the Russian Federation, Stavropol, Russian Federation

SUMMARY

This article presents a new method of reconstruction of the atrophied distal alveolar process of the maxilla in patients with chronic polyposis sinusitis that we have developed and introduced into clinical practice. The method provides for bone grafting using open sinus inlay technique with simultaneous removal of polyps from the maxillary sinus and immediate or delayed placement of dental implants. Previously, the presence of extranasal sinus polyps was a contraindication to sinus lifting surgery. Treatment required an additional stage of the sinus sanation, which is possible only in the in-patient department, prolongs the rehabilitation time for patients with tooth loss, and extends the prosthetics period for dental implants. Moreover, it is not always possible to predict the exact time of the in-patient stage of treatment because of the individual characteristics of the body and the risk of possible complications, which in turn can increase the total period of surgical treatment. The developed method makes it possible to exclude the stage of in-patient treatment involving sanation of the maxillary sinus in this category of patients and thus reduces the duration of surgical treatment by 3–4 months.

KEY WORDS: *bone grafting, reconstruction, distal maxillary process, bone atrophy, maxillary sinus, sinus lifting surgery, chronic polyposis maxillary sinusitis, dental implantation.*

CONFLICT OF INTEREST. *The authors declare no conflict of interest.*

Introduction

Reconstruction of the alveolar process of the maxilla (APM) is performed to eliminate bone atrophy before denture supported by dental implants [1, 2, 3, 4–8, 9]. This method of prosthodontic treatment is modern and up-to-date and allows a fundamentally new level of quality of life and complete rehabilitation of patients with partial or total loss of teeth [1, 2, 4–8, 9].

It has been clinically established that in 35 % of patients, dental implantation is not possible without prior reconstructive surgery to restore bone volume in the alveolar process of the upper jaw. In 65 % of patients, a sinus lift is needed to restore the height and in 20 %, both the height and width of the alveolar process in the distal upper jaw are increased [2].

Sinus lifting surgery (SL) is the basic method of reconstruction in cases of insufficient bone volume in the lateral regions of the APAJ [1, 2, 4–8, 9–11].

Chronic polyposis maxillary sinusitis (MS) is a contraindication for sinus lifting surgery. If a patient has this pathology, the perinasal sinuses are preliminarily sanitized, followed 3–4 months later by SL surgery and, if indicated, additional reconstruction of the maxillary alveolar process, which increases the patient's rehabilitation time, but makes subsequent dental implantation (DI) possible [1–3, 6–8, 10–12].

The most important factor determining the positive outcome of subantral augmentation and subsequent or simultaneous dental implantation after maxillary sinus sanation in chronic polyposis maxillary sinusitis is the anatomical feature of the «key» area of the nasal cavity, namely the ostiomeatal complex (OMC), which determines the patency of the natural maxillary sinus junction [8–11].

Studies of the structures of the ostiomeatal complex show numerous anatomical variations, which confirms Messerklinger's concept of chronic sinusitis pathogenesis, according to which the presence of narrow gaps and spaces formed between the anatomical structures included in the OMC, when an inflammatory process occurs, promotes the contact of swollen opposing mucosa areas, disruption of mucociliary transport and blockage of sinus arteries. This leads to the reduction and termination of their aeration, impaired secretion evacuation, decreased partial oxygen pressure in the sinus, development and transition of the inflammatory process to the chronic one [13]. In this regard, sanation of the paranasal sinuses is recommended for all patients with possible dysfunction of the natural axillary artery before the sinus floor elevation operation [4–10].

Thus, the problem of increasing the bone volume of the distal maxillary alveolar bone with maxillary sinus pathology remains relevant.

The aim of the study was to improve the surgical treatment of patients with tooth loss complicated by maxillary distal atrophy and limited inflammatory changes in the maxillary sinus floor by simultaneous sinus sanation and bone grafting to improve rehabilitation using dental implants.

Patients, materials and methods

The study was conducted at the clinical base of the State budgetary health care institution of Nizhny Novgorod Region Municipal Clinical Hospital № 39 (Nizhny Novgorod), Centre of dental and maxillofacial implantology of the Clinical Diagnostic Centre of the Federal State Autonomous Educational Institution of Higher Education «Peoples' Friendship University of Russia» (Moscow), The North-Caucasus Medical Training and Methodological Centre» Ltd. (Stavropol).

28 patients, including 18 women and 10 men aged 32 to 56 years, with tooth loss in the lateral maxilla and bone atrophy were enrolled in the study and were scheduled for SL surgery and dental implants.

The patients underwent a standard preoperative examination. A cone beam computed tomography (CBCT) of the upper jaw with the inclusion of an osteomeatal complex was performed. The examination revealed limited inflammatory changes in the mucosa of the maxillary sinus (MS) in the form of cysts and/or polyps; the patency of the natural MS artery (osteomeatal complex) was not compromised.

Chronic polyposis maxillary sinusitis, which occupies the lower third of the sinus volume was diagnosed in 16 patients, retention cysts of the mucous membrane of the lower wall of the maxillary sinus were found in 8 patients, foreign bodies (root apex migrated into the sinus cavity during tooth extraction; filling material taken out earlier during endodontic treatment of teeth) were found in 4 patients. The height of the alveolar process in the projection of the missing teeth was between 2 mm and 6 mm.

Delayed dental implantation is performed when the height of the alveolar bone is less than 3 mm. After sanation of the MS and subantral augmentation, the surgical wound is sutured. After 6 months, dental implants are placed in the reconstruction area and after another 7 months, prosthetics are fitted. Statistical data processing methods were applied to estimate the level of marginal bone resorption around the implant neck and to evaluate the results of volumetric reconstruction of the alveolar bone. The correlation of measurement results was determined using Pearson's correlation coefficient. Implementationhas been carried out in Python, SciPy library.

Results

All patients underwent surgery according to the proposed method: open sinus lifting surgery, sanation of the inferior maxillary sinus, and anthroplasty. At the initial height of more than 3 mm, sufficient for primary stabilisation of the implant, direct dental implantation was performed in 17 patients. Delayed implant placement was performed in 11 patients. There were no complications in the early postoperative and long-term period (follow-up period of 3 years). The average level of cervical resorption around the implants over 3 years was 0.5 mm (standard deviation 0.234, median 0.5, confidence interval: 0.030–0.522). No implant loss was observed.

Clinical case

Patient D., 45 years old, came to the CDMI RUDN University Clinical Diagnostic Centre of the Medical Centre (Moscow) with the diagnosis: partial tooth loss (K08.1), atrophy of the adentulous alveolar ridge (K08.2).

Examination of the oral cavity: teeth 2.5, 2.6, 2.7, 2.8 are missing; mucosa is without signs of inflammation in the area of the missing teeth. Distance from the alveolar ridge to the

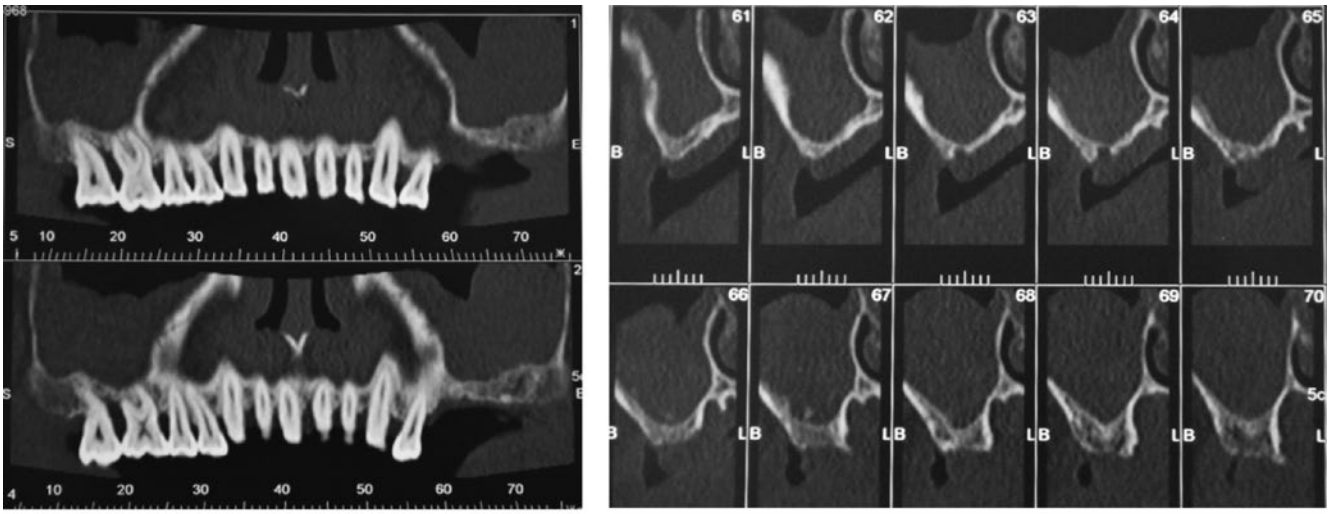

Fig. 17. CT scan of patient D., right and left maxillary alveolar process atrophy and polyp of the maxillary sinus are visualised.

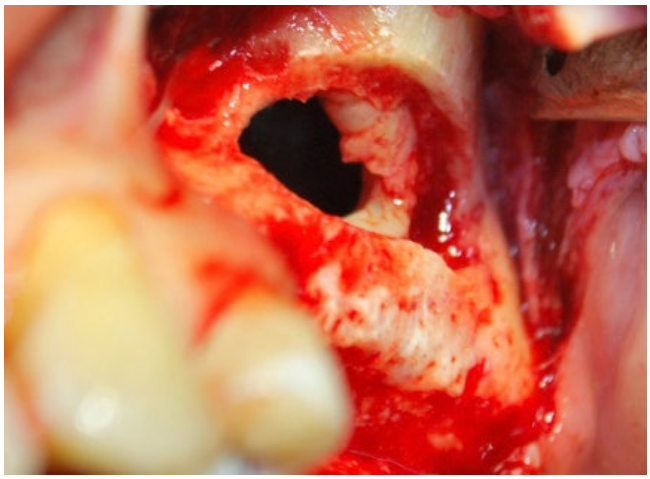

Fig. 24. Surgical step. A sinus lifting surgery was performed and a polyp was extracted through an incision in the MS mucosa. Visualisation of the mucosal defect with measures of 12 x 5 mm.

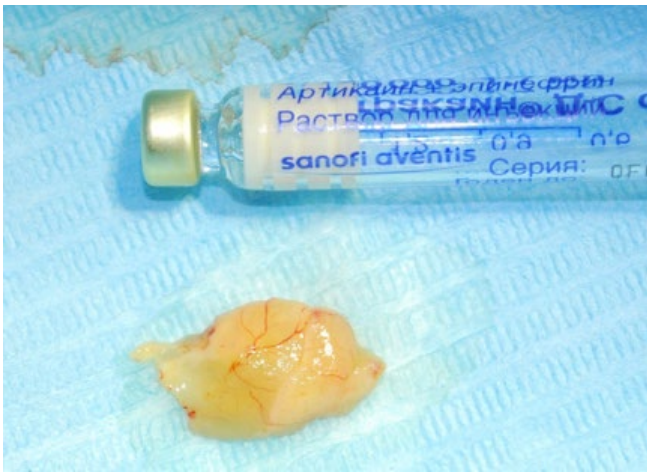

Fig. 25. External view of the polyp.

floor of the maxillary sinus in the area of missing teeth 2.5, 2.6 is not more than 2.5 mm. A preoperative CBCT scanning revealed a polyp in the region of the lower wall of the left sinus with measures of 18 x 24 mm.

The patient was proposed to correct the defect with dental implants. Informed consent to the operation was obtained. The patient underwent maxillary sinus resection and reconstruction of the maxillary alveolar process on the right side using a sinus lifting surgery and intercortical splitting, followed by delayed dental implantation using a two-stage protocol (Fig. 17–35).

A CT control scanning of the surgical procedure was performed. After 6 months, there were no complaints and

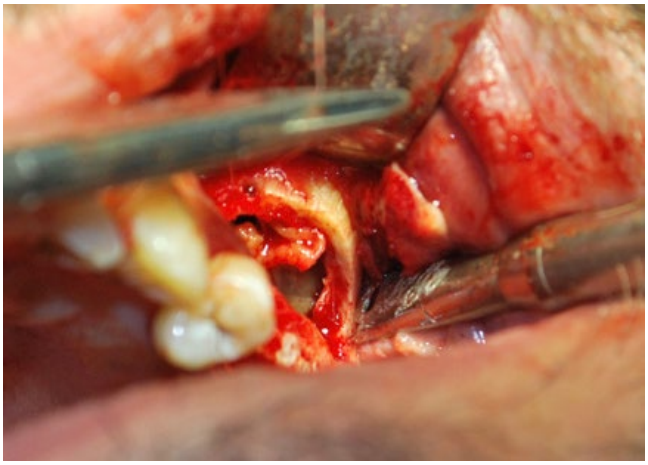

Fig. 26. The mucosa of the MS is mobilised and fixed with the nodular suture Vicryl 6–0 to the upper bone wall. The mucosal defect is closed.

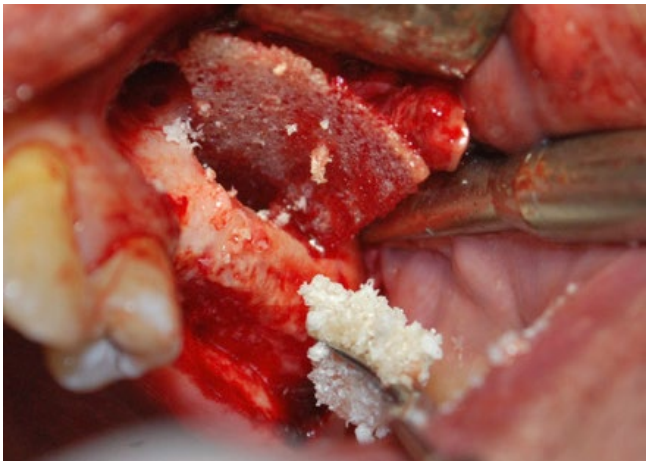

Fig. 27. The mucosa of the MS is additionally isolated with collagen membrane «Osteoplast».

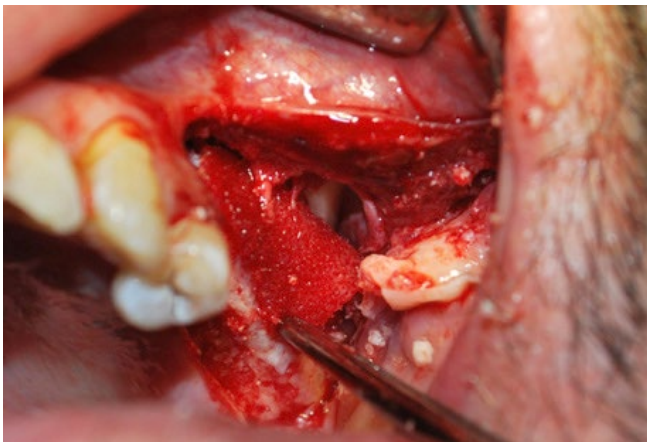

Fig. 28. «BioplastDent Deproteinised» osteoplastic material for filling the cavity in the area of the sinus floor.

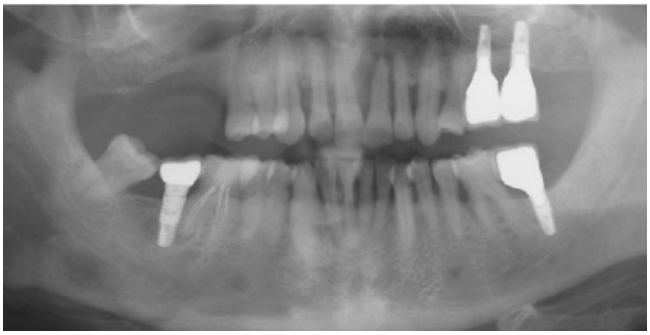

Fig. 34. One-year OPTG after prosthetics.

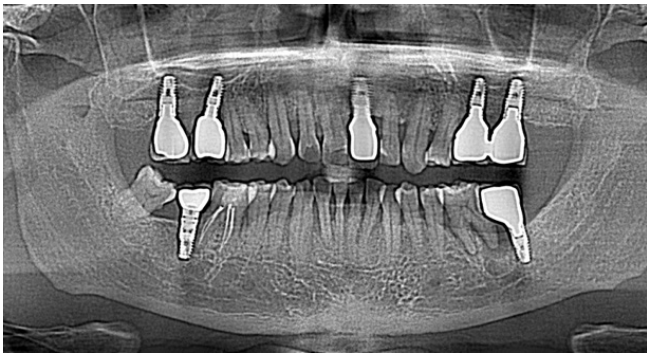

Fig. 35. 7-years OPTG after prosthetics.

nasal breathing was free. A CT scanning confirmed new bone formation in the area of the reconstruction: bone height 13.7 mm and width 7.1 mm.

Four «Friadent Xive» implants were placed in 6 months after surgery: in teeth areas 2.4 and 2.5 with diameter 3.8 mm and length 11.0 mm; in teeth areas 2.6 and 2.7 with diameter 4.5 mm and length 11.0 mm. Gingival shapers were placed 6 months after implantation and prosthodontic treatment commenced after another 1 month.

Thus, the developed method allows to carry out complex treatment of patients with tooth loss and atrophy of the distal alveolar process of the maxilla in chronic polyposis maxillary sinusitis. This increases the efficiency of bone grafting of the maxilla, prevents possible complications, reduces the treatment period, expands indications for dental implants and allows to achieve a complete dental rehabilitation with application of prosthodontic constructions fixed on dental implants.

The developed method is recommended for using in other diseases of the maxillary sinus, especially cysts and foreign bodies, such as tooth roots, filling material, brought into the sinus cavity.

Discussion

The presence of maxillary sinus wall polyps used to be a contraindication to sinus lifting surgery and required an additional step of sinus sanation, which increased the rehabilitation time of patients with tooth loss and extended the period of prosthesis on dental implants.

In this study, we presented the results of our study, which suggests that the proposed technique allows us to reduce the treatment time of patients with tooth loss in the distal parts of the upper jaw and cope not only with the elimination of bone volume deficit, but also to perform sanation of the lower sections of the maxillary sinus.

In the available literature there are different opinions on how to deal with this issue. The traditional approach involves the classical Claudoed-Luc surgery, which according to modern concepts is undesirable in terms of further open sinus lifts [6, 14].

An alternative approach to radical maxillary sinus surgery that reduces damage to the healthy sinus mucosa is revision of the maxillary sinus through the inferior nasal passage [13].

Maxillary microsinusotomy using a trocar has also been suggested to reduce the volume of the operation and the resulting defect of the sinus mucosa [15, 16].

Developments in endoscopic techniques have also made it possible to minimise trauma to the maxillary sinus during revision. Many papers have been written on the removal of cysts, polyps and foreign bodies using the endoscopic method [6, 13, 16, 17, 18, 19]. It should be noted that endoscopic surgeries are performed under the narcosis.

However, all these works describe methods of revision of the maxillary sinus, without increasing the height of the maxillary alveolar process. Therefore, our proposed method of bone grafting has the following advantages. Firstly, it makes possible to sanitise the lower sections of the maxillary sinus through a small incision of the maxillary sinus mucosa and then restore the integrity of the mucosa and perform anthroplasty. If the height of the alveolar bone is 3 mm and more, dental implants can also be inserted. The proposed method is performed as an outpatient procedure under balanced anaesthesia. The authors received a patent for the method of maxillary distal alveolar process plastic surgery in chronic polyposis maxillary sinusitis (RU 2714169) [21].

References

1. *Vishnyakov V. V. Comparative analysis of the effectiveness of different types of surgical treatment in chronic odontogenic maxillary sinusitis / V. V. Vishnyakov, V. N. Talalaev, D. L. Yalymova // Vestn. otorhinolaryngology.– 2015.– № 5.– P. 77–79.*
2. *Romankov, I. A., et al. «Significance of peculiarities of the ratio of the maxillary sinus floor with dental roots as preconditions for the formation of odontogenic sinusitis (literature review).» Ukrainian Morphological Almanac of Professor VG Koveshnikov 15.4 (2017): 82–91.*
3. *Diagnostic significance of computed tomography for detection of odontogenic maxillary sinusitis and effectiveness of preimplantological augmentation of alveolar ridge / S. Y. Maksyukov, N. V. Boyko, D. S. Scheplyakov [et al] // Chief Doctor of Southern Russia.– 2016.– № 52.– P. 8–11.*

4. *Clinical results of different osteoplastic materials in sinus lift / S. Y. Ivanov, E. A. Bazikyan, M. V. Lomakin [et al.] // New in stomatology.– 1999.– № 5.– P. 75.*
5. *Lazareva A. Yu. Possibilities of CT study in diagnostics of polyposis rhinosinusitis / A. Yu. Lazareva // Bulletin of otolaryngology.–2008.– № 1.– P. 37–38.*
6. *Daminov R. O. Inflammation of maxillary sinus after dental implantation and sinus-lifting operation / R. O. Daminov // Dentistry.–2010.– № 5.– P. 59–62.*
7. *Zernitskiy A. Yu. Factors influencing the favorable outcome of sinus-lifting operation / A. Yu. Zernitskiy, I. V. Kuzmina // Institute of Stomatology.– 2012.– № 3.– P. 56–57.*
8. *Amkhadov, Islam Sultanovich. «Pathology of maxillary sinuses as a risk factor for the development of sinusitis during sinus lift surgery.» (2020).*
9. *Yaryomenko A. I. The maxillary sinus floor elevation operation at its chronic inflammation / A. I. Yaryomenko, S. Y. Vinogradov // Institute of stomatology.– 2008.– № 1.– P. 68–70.*
10. *Korkmazov, M. Yu. «Effect of low-frequency ultrasound cavitation on the severity of clinical symptomatology in the complex therapy of exacerbations of chronic rhinosinusitis.». Russian Otorhinolaryngology 19.4 (107) (2020): 39–47.*
11. *Aperture width of the osteomeatal complex as a predictor of successful treatment of odontogenic maxillary sinusitis / N. Tomomatsu, N. Uzawa, T. Aragaki, K. Harada // Int. J. Oral Maxillofac. Surg.– 2014.– Vol. 43.– P. 1386–1390.*
12. *Kato, Shingo, et al. «Sinus mucosa thinning and perforation after sinus augmentation. A histological study in rabbits.» Oral and Maxillofacial Surgery (2021): 1–9.*
13. *Chaker, Adam M. «Biologicals in der Rhinologie-Individualisierte Konzepte der Zukunft.» Laryngo-Rhino-Otologie 97.S01 (2018): S142-S184.*
14. *Kurbonov, Shukhrat Jurajonovich, Shavkat Ergashevich Amonov, and Shahlo Khamidullaevna Bakieva. «Efficacy of surgical methods of treatment of chronic inflammatory diseases of the maxillary sinus.» Responsible editor (2020): 22*
15. *Daiches, Nikolai Arkadyevich, et al. «A method of surgical treatment of odontogenic maxillary sinusitis by endoscopic infraturbinal access with plastic closure of an anthrostoma.» (2018).*
16. *Nerovny, Alexander Ivanovich, and Tatiana Aleksandrovna Ryabova. «A device for microgaemorotomy for maxillary sinus pathology.» (2018).*
17. *Pokrovskaya, E. M. «Variants of surgical accesses for maxillary sinus pathology.» Practical Medicine16.5 (2018).*
18. *Zakirov, T. M. «Variants of surgical treatment of cystic-polyposis formations of paranasal sinuses. «Kyrgyz State Medical Academy named after IK Akhunbaev. IK Akhunbaev (2019): 87.*
19. *Gurina, T. I., Sergey Sergeevich Berveno, and K. N. Parkhomenko. «Features of preparing patients with chronic maxillary sinusitis for sinuslift and dental implantation. «Pacific Medical Journal 2 (80) (2020).*
20. *Khasanov, Ilhom Ikromovich, and Nodira Ganievna Achilova. «A technique for dental implantation in patients with sinusitis of the maxillary sinus.» Internauka 44 (2020): 65–68.*
21. *Yamurkova N. F., Ovsyannikov K. V., Muraev A. A. Method of plasty of the distal alveolar process of the maxilla in chronic polyposis maxillary sinusitis, Patent for invention RU 2714169 C 1, 12.02.2020. Application number 2019112015 dated 19.04.2019.*

Received 10.03.2022
Revised 18.03.2022
Accepted 20.03.2022

INFORMATION ABOUT AUTHORS

***Yamurkova Nina Fedorovna**, Doctor of Medical Sciences, Associate Professor, Honored Doctor of the Russian Federation, maxillofacial surgeon of the highest category of State budgetary health care institution of Nizhny Novgorod Region Municipal Clinical Hospital № 39, 603028, Nizhny Novgorod, Moscow highway, 144; e-mail: yamurkova@yandex.ru, +7–969–603–75–55.*

***Ivanov Sergey Sergeevich**, The Peoples' Friendship University of Russia, 6 Miklukho-Maklaya St., Moscow, 117198, Russian Federation. / 117198, Moscow, Mikluho-Maklaya 10, Medical center, e-mail: ivan-swim@yandex.ru, +7–916–970–51–45; ORCID 0000–0002–4058–1706*

***Mukhametshin Roman Flaridovich**, Lecturer of the department, Oral and Maxillofacial surgery department, The Peoples' Friendship University of Russia, 6 Miklukho-Maklaya St., Moscow, 117198, Russian Federation; e-mail:, mukhametshin_rf@pfur.ru, +7915–216–30–40, ORCID: 0000–0002–1637–0503*

***Trubushkina Ekaterina Mikhailovna**, Candidate of Medical Sciences, Assistant of the Department of Otorhinolaryngology, Plastic Surgery with the course of APE of the Stavropol State Medical University of the Ministry of Health of the Russian Federation, Stavropol, Russian Federation, e-mail: paramon.83@mail.ru, +7–962–741–39–05 ORCID: https://orcid.org/0000–0002–5689–5697*

***Kutsenko Anton Pavlovich**, Correspondence post-graduate student of the Department of General Dentistry and Pediatric Dentistry, Stavropol State Medical University of the Ministry of Health of the Russian Federation, Stavropol, Russian Federation, e-mail: kutsenko126@gmail.com, +7–928–378–33–62.*

Cardioplant®

Биоматериалы для управляемой регенерации

Изделия серии bioOST, bioPLATE и FibroMATRIX разработаны инженерами в соответствии с требованиями ведущих отечественных клиницистов. Это материалы для мягкотканой и костной пластики с управляемым поведением и надежным прогнозируемым результатом. Среди нашей линейки Вы сможете найти продукт, необходимый для решения индивидуальной клинической задачи любой сложности.

bioOST

Костные гранулы с коллагеном
XENOGRAFT Collagen
XCol-1-05 | 0.25-1.0 мм | 0.5 см³
XCol-1-1 | 0.25-1.0 мм | 1.0 см³
XCol-1-3 | 0.25-1.0 мм | 3.0 см³
XCol-2-1 | 1.0-2.0 мм | 1.0 см³
XCol-2-3 | 1.0-2.0 мм | 3.0 см³

Костные гранулы без коллагена
XENOGRAFT Mineral
XMn-1-05 | 0.25-1.0 мм | 0.5 см³
XMn-1-1 | 0.25-1.0 мм | 1.0 см³
XMn-1-3 | 0.25-1.0 мм | 3.0 см³
XMn-2-1 | 1.0-2.0 мм | 1.0 см³
XMn-2-3 | 1.0-2.0 мм | 3.0 см³

Кортикальные гранулы
XENOGRAFT Cortical
XCr-1-05 | 0.5-1.0 мм | 0.5 см³
XCr-1-1 | 0.5-1.0 мм | 1.0 см³

Губчатый блок CUBE Collagen
Cb-10 | 20x10x10 мм

Кортикальная пластина
CORTICAL Lamina
Cl-25 | 25x25x1 мм

Кортикальная мембрана
CORTICAL Membrane
CM-20 | 25x20x0.2 мм

bioPLATE

Мембрана bioPLATE Barrier
MB-15 | 15x20 мм
MB-25 | 25x25 мм
MB-30 | 30x40 мм

Мембрана bioPLATE Contur
MBC-15 | 15x20 мм
MBC-25 | 25x25 мм
MBC-30 | 30x40 мм

Коллагеновый 3D-матрикс
FibroMATRIX
FB-15 | 15x20 мм
FB-30 | 30x40 мм
FB-8 | 8 мм

ООО «Кардиоплант»
Пенза, ул. Центральная, 1в, к.2
info@cardioplant.ru
+7 8412 20-58-24
cardioplant.ru