DOI 10.18019/1028-4427-2019-25-3-368-377

Results of using a functional corrective Cheneau type brace in complex rehabilitation of children and teenagers with idiopathic scoliosis

V.F. Nikolaev, I.A. Baranovskaya, A.O. Andrievskaya

Federal Scientific Center of Rehabilitation of the Disabled named after G.A. Albrecht, Saint Petersburg, Russian Federation

Introduction Scoliosis is one of the most common and severe deformities of the human spine, ranking first among all orthopedic pathology in children. Idiopathic scoliosis accounts for 70–90 % of all scoliotic deformities. **Purpose** The article presents the technique of orthosis and the results of using a functionally correcting Cheneau brace in complex rehabilitation of patients with idiopathic scoliosis. **Materials and methods** Orthotic application in 300 children (over 3 years old) and adolescents (up to 18 years old) with idiopathic scoliosis within the period from October 2013 to October 2017 was analyzed. Patients were divided into three groups depending on the Cobb angle and the features of orthosis: the first group was 100 subjects with the angle of 18°–35°, the second group had the angle of 36°–45° and included 150 patients, and the third one was 50 individuals with the angle of 46° or more. Clinical and radiological methods of examination were used in the study. A functionally correcting brace of the Cheneau type was used for fixation based on the technique of the Center. **Results** Correction of deformity was achieved in all children (300), and more than one half (53.3 %) had a complete correction. In the group with spinal deformity of 18°–35° according to Cobb, deliberate hypercorrection of -5° was achieved (in 15 patients for three years, and in 5 children also in the fourth year of treatment). **Conclusion** The use of functional correcting brace of the Cheneau type in the complex rehabilitation of children and adolescents with idiopathic scoliosis provides good outcomes in most patients of all three groups. The best results of treatment were obtained in the first group of patients. Orthosis application should be performed according to the treatment technology, be individual, taking into account the peculiarities of the spinal deformity and the prospects of its progression, age, as well as growth potential of the spine; systematic exercise therapy, including Schroth gymnastics, is necessary.

Keywords: rehabilitation, idiopathic scoliosis, orthosis, Cheneau brace

INTRODUCTION

Comprehensive treatment of patients with spinal deformities, including orthosis application, is of great medical and social importance. This issue has not lost its relevance at present due to the fact that scoliosis is one of the most common and severe deformations of the human spine and takes first place among all orthopedic pathologies in children. According to various reports, idiopathic scoliosis accounts for 70–90 % of all scoliotic deformities [1–3].

The growth of scoliosis incidence in children and adolescents above the national average was recorded in 2014 in 29 regions of the Russian Federation. The highest levels were, in particular, in St. Petersburg [2]. Preventive medical examinations of children and adolescents under the age of 17 years showed that the number of children with scoliosis at the end of their first year at school increased by 1.78 times when compared with their examination before entering school (2012–2013 by 1.85 times; 2011–2012 by 1.66 times; 2010–2011 by 1.67 times, respectively) [2].

According to available studies, progression of scoliosis is reported in 27-50 % of cases [4].

Correction and stabilization of scoliotic deformity have not been completely resolved issues yet.

The first reports on the use of braces in patients with spinal deformities in order to alleviate the condition and to prevent aggravation of deformities appeared in the first half of the 19th century [1, 5]. Subsequently, various versions of corrective braces have been designed; the principles of bracing for the treatment of scoliotic deformity in children and adolescents have changed. In scoliosis of the grades 2–3, semi-rigid and rigid braces were recommended. Today, active corrective braces of the Cheneau type have been recognized as the most effective [6, 7].

However, feasibility and timing of bracing therapy in the system of complex conservative treatment have been still discussed [8, 9].

Improving the treatment of children and adolescents with scoliotic spinal deformities is associated with the improvement of the orthosis application methods. It seems relevant to show the results of the use of the functional corrective Cheneau bracing in the comprehensive rehabilitation of patients with idiopathic scoliosis.

Nikolaev V.F., Baranovskaya I.A., Andrievskaya A.O. Results of using a functional corrective Cheneau type brace in complex rehabilitation of children and teenagers with idiopathic scoliosis. *Genij Ortopedii*, 2019, T. 25, No 3, pp. 368-377. DOI 10.18019/1028-4427-2019-25-3-368-377. (In Russian)

MATERIAL AND METHOD

A retrospective analysis of the results of the use of the functional corrective brace of the Cheneau type in the comprehensive rehabilitation of patients with idiopathic scoliosis was conducted. The studies were approved by the ethics committee and were done at the Federal Scientific Center for Rehabilitation of Persons with Disabilities named after G.A. Albrecht."

The inclusion criteria were a clinically established diagnosis of idiopathic scoliosis of grades 2 to 3; age from 3 to 18 years; Cobb angle from 18° to 46° or more.

Exclusion criteria were age younger than 3 years and older than 18 years; Cobb angle less than 18° and more than 60°; patients who underwent spinal surgery; concomitant pathology with a pronounced dysfunction of the cardiovascular and respiratory systems, diseases of the trunk skin and pelvis, which do not allow mechanical pressure; organic diseases of the central nervous system and psychoemotional intolerance to the treatment method.

Children and adolescents with idiopathic scoliosis who underwent orthotic treatment at the Federal State Budget Scientific Albrecht Center of the Ministry of Labor of Russia in the period from October 2013 to October 2017 were material of the study. Clinical and radiological methods were used to examine them.

Clinical examination was regular. Patient's complaints and anamnesis were recorded, their orthopedic status and the nature of static and dynamic functions were studied.

Visual diagnosis of scoliosis was based on the deviation of the line of the spinous processes from the middle position and the displacement of the anatomical structures relative to the midline of the trunk. In a standing position with straightened legs, the asymmetry of the shoulders, shoulder blades, waist triangles, buttock folds, muscle cushion, and pelvic inclination was detected [10, 11].

During measurements, bone landmarks were marked on the patient's body (spinous processes of the vertebrae, the lower corners of the scapula and their medial edges, the wings of the ilium). Deformity mobility was determined by the change in the line of the spinous processes when the body is tilted in the frontal plane. The presence or absence of asymmetry of the paravertebral muscles and deformity of the ribs was revealed. Torsion was evaluated with the Adams test: in the standing position on straightened legs and by leaning forward, we measured symmetrically the distance of the paravertebral muscles or ribs from the spinous process from the horizontal line [1, 11].

X-ray examination of the spine was performed to clarify the diagnosis, main components of the deformity, curvature in degrees, and the prognosis of progression of the deformity [12].

In domestic practice, the classification of V.D. Chaklin (1962) is officially recommended for use. He proposed using the Cobb method to measure the angles of spinal deformity, where grade 1 corresponds to deformity up to 10 °, grade 2 to 11°–30°, grade 3 to 31°–60 °, and grade 4 to more than 60°. In later works, this classification underwent minor changes: the upper limit of the grade 2 is considered to be 25°, and grade 4 starts with 45°–50° (V. I. Sadofieva, 1990) [13]. The last of these changes is due to the fact that this magnitude of the scoliotic arc is crucial for decision on the need of surgical correction.

Radiographs of thoracic and lumbar spine in the direct and lateral projections were taken in the “lying” and “standing” positions. Radiography was performed with maximum capture of the entire spine from Th1 to S1 vertebra and the iliac wings. Maturity of the skeleton was assessed according to the Risser test and the state of the apophyses of the vertebral bodies. When the patient was supplied with the corrective brace, the control radiography of the patient in the brace was performed 1.5–2 months after the start of the use of the orthosis, i.e. at the stage of the first correction, more precisely immediately after it. Also, radiographic control was necessarily performed during a follow-up examination or repeated correction (once every 6 months). Based on the results of x-ray and examination data, a decision was made on further management of the patient or the need for additional brace fitting.

The medical technology of brace correction of spinal deformities in scoliosis using an active corrective brace was proposed by the French orthopedist J. Cheneau in the 1970-80s and has been widely used for more than 30 years in the world practice of conservative treatment of scoliosis [1, 5–7, 14–19].

The treatment of scoliosis is time consuming; orthosis application is multi-stage, divided into periods: adaptation to brace, primary correction, retention of correction with the brace, brace cancellation and further follow-up examinations after the completed bracing [14, 17].

However, the approaches to the manufacture of braces and management of patients by specialists differ [14, 17, 18]. To date, a large number of different technical solutions and options for the manufacture of orthoses and clinical application techniques have been proposed.

Patients were applied the Cheneau-type brace with the technique proposed at the Center, the roadmap of which is shown in Figure 1.

Let us focus on some important points. At the delivery of the brace, the patient is trained to use it for a test time of 2 hours or more. The mode of using the brace is appointed for the period of adaptation. During the first 1-2 weeks the patient gets used to it by gradually increasing the time of wearing the brace up to 21 hours a day. The brace is applied to the body with the Velcro tape (tightened to the level of the preliminary marks to maintain relative comfort). In the future, the effect on the spinal deformity is executed gradually increasing the tension of the attachment to the main mark [14]. At the end of this period, there is a control inspection (with the product on and without it). The need to perform correction of the brace is determined by the doctor after studying clinical findings and subjective sensations of the patient, that should imply absence of significant discomfort and limitations when performing daily exercises. Upon correction of the brace, which consists in increasing the pressure of the pelottes, anterior-posterior radiography while patient is the "standing" position is taken with the brace on. The material from which the orthosis is made transmits X-rays, therefore, X-rays are taken in the brace. According to the results of the study, the brace is being finalized.

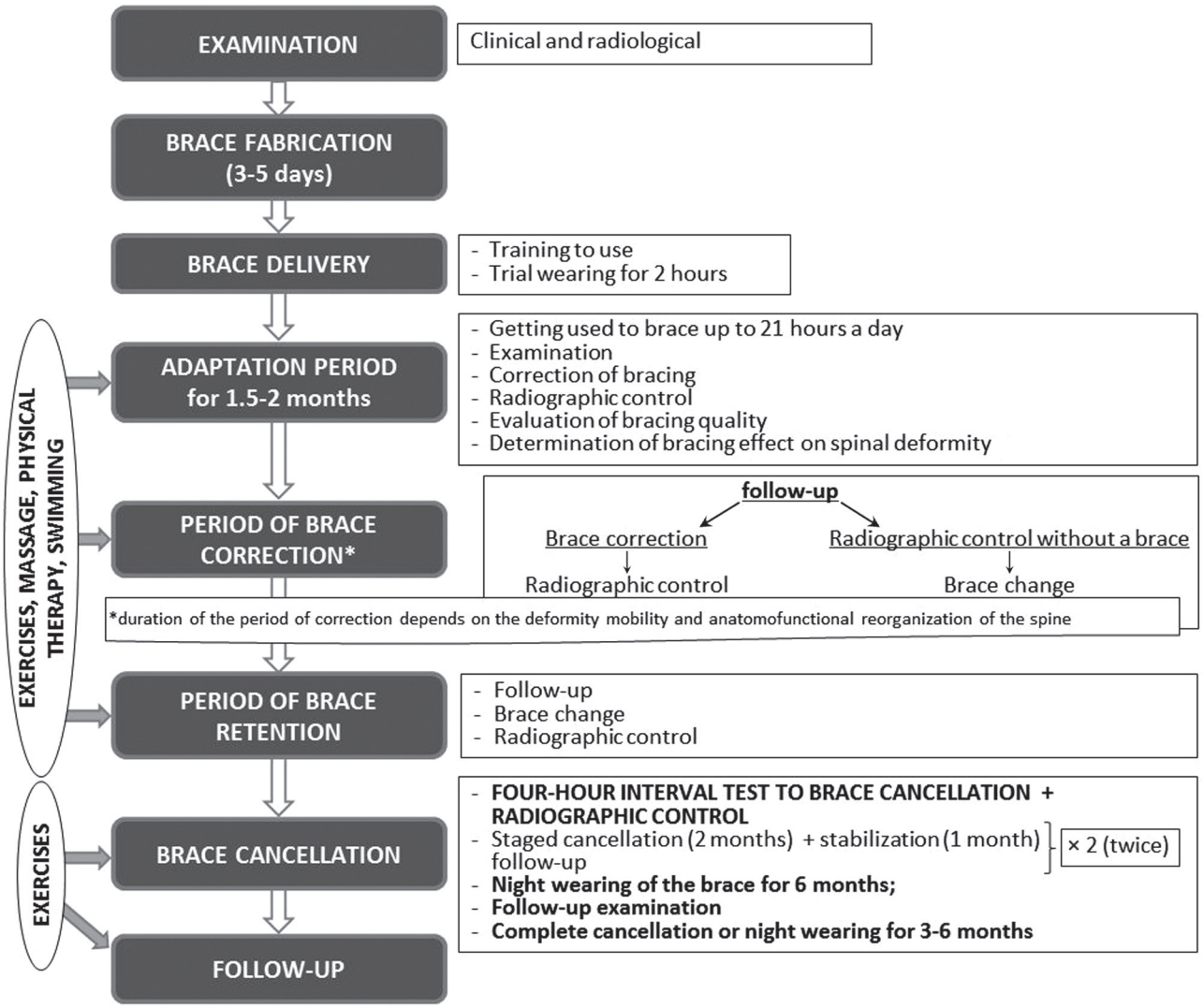

Fig. 1 Diagram of the Cheneau-type bracing methodology used at the Federal State Medical Research Center named after G.A. Albrecht of the Ministry of Labor of Russia

To maintain and enhance the effectiveness of brace therapy, a dosed increase in pressure at the main points of application of force is necessary. During the period of brace correction, anatomical and functional restructuring of the spine and chest begins. After about 5-6 months, a control examination is performed, an AP X-ray checks of the spine in the brace in standing position. Based on changes in the radiograph (reduction or elimination of lateral curvature, detorsion effect at the level of the apical vertebra, etc.), a decision is made on correction adequacy. If necessary, an additional correction of the bracing is done.

The period of bracing is an important stage, since there is a gradual transformation of the chest at this time with filling in the expansion zones in the brace, stretching of fibro-altered paravertebral tissues on the concave side of scoliotic deformity. As unloading of the apophyses of the vertebral bodies on the concave side of the spine occurs, blood circulation conditions of these areas improve, which stimulates growth, and in combination with the detorsion effect of the brace, the vertebrae are restored structurally. As a result, the deformity decreases, and the patient's height changes over time. When the height and the expansion zones in the brace are filled, the brace is replaced. Depending on the age of the patient, deformity grade and fexibility of the deformity to correction, it might be necessary to fabricate one to 4 braces or more. In the future, the patient continues to use the corset, observing the recommended corrective mode, and goes into the period of brace retention. Its duration depends on the state of the dynamics of the growth of the spine, which is checked radiographically [5, 14, 15, 20].

During this period (provided that the deformity is corrected), hypercorrection of deformation is maintained within 5°–8 ° in the age from 16 to 17 years [14]. At follow-ups, compliance with the brace use regimen and the need for a new orthosis are estimated The term of use of each brace is determined individually for each patient, taking into account age, deformity severity, its progression or stabilization. Indications for changing the brace are the mismatch of the position of the brace pelottes to the deformed parts of the trunk as a result of the child's vertical growth with the displacement of the borders of the pelottes by more than one apical vertebra and/or as a result of an increase in the volumetric parameters of the patient's trunk; impossibility to perform remodeling or correction to eliminate complications that arose during brace therapy; low efficiency of bracing, confirmed by x-ray control data and the inability to carry out correction and remodeling; mismatch of the shape of the brace to the patient's parameters as a result of deformity development.

The period of brace withdrawal begins after the completion of bone growth of the spine, usually it is the age of 18–20 years [14, 17]. This period is quite long, difficult and decisive. At follow-up, a four-hour interval test is performed to cancel the bracing: the corset is removed for 4 hours, then the AP X-ray is taken in the "standing" position. Further management depends on its results. If deformity hypercorrection regresses with respect to the previous image by no more than 5 °, then it is recommended to reduce the wearing time of the brace by 30 minutes every week for two months. Subsequently, for one month, the patient continues to use the brace without reducing the time spent in it, to consolidate the achieved correction result. After a follow-up if stability is retained, the time spent in the brace is decreaed again according to the above scheme. Next, for 6 months, the patient is transferred to the night mode of using the brace [21]. At the next follow-up, if there is no further regression of deformity after clinical and radiographic control without a corset, it is recommend that the corset be completely canceled or used in the night mode (for the duration of a night's sleep) for 3-6 months. In some cases, it is possible to switch to night mode, without waiting for full bone maturity of the spine.

After the completion of brace treatment, a period of clinical observation begins. Patients are advised to comply with the orthopedic regimen, continue exercise therapy and be followed-up by an orthopedic trauma doctor. If, radiographic checking detects regression of overcorrection to 6° or more, then bracing must be continued for 18-21 hours a day for 6–10 months with the condition of active exercise therapy. Follow-ups are conducted once every six months. In the future, with a favorable course wearing a brace is cancelled according to the above algorithm. During bracing period, all patients were prescribed to strictly follow physiotherapy exercises, including Schrot gymnastics, based on the principle of asymmetric breathing, which contributes to correction and derotation of the chest [22]. Sessions

were held for 30–40 minutes individually or in small groups [23].

Both in traditional methods of exercise therapy, and in the method of three-dimensional respiratory correction, the main types of physical exercises were the static tension of individual muscle groups in correction poses. Stretching exercises were used only as self-extension of the spine, without the influence of external forces or body weight. If necessary, stretching was forceв only to half-suspension on the Swedish wall in correction poses. As an independent exercise or as the main element of special correction techniques, breathing exercises in diaphragmatic breathing and volitional controlled localized so-called "rotational-angular breathing" were used. Exercises for twisting the body and parts of the spine were recommended extremely rarely, since there is a danger of increased pathological rotation. Additional treatment methods were general massage (4 courses per year for 20–25 procedures), physica procedures (medication electrophoresis of microelements, electrical stimulation of the back muscles, etc.) [11, 15]. Massage was used in the treatment complex in order to increase muscle strength, improve trophism and blood supply to weak muscles. It is specific for each patient. Swimming was recommended (mainly breaststroke with an extended slip phase) in the pool (2-3 times a week). The crawl and butterfly styles were not used in their pure form, exercises were individually selected [24, 25].

Data analysis was carried out using statistical methods (calculation of an extensive indicator, indicators of the variation series, etc.). Diagrams were used in reflecting the results of the statistical study.

RESULTS

At the beginning of the study, all patients or legal representatives gave their informed consent for examination and treatment.

For the period from October 2013 to October 2017, three hundred children and adolescents with idiopathic scoliosis who did not have any previous treatment or received episodic conservative treatment were braced at the clinic of the experimental production laboratory of the G.A. Albrecht Institute of Prosthetics and Orthosis of the Ministry of Labor of Russia. The maximum follow-up period from the start of treatment was four years.

All patients were treated with rigid active-correcting braces according to the method of Jacques Cheneau, which has been used at the Albrecht institute since 2006.

Children and adolescents aged 3 to 18 years (average age 12.25 ± 4.5 years) were studied. The distribution of patients with a Cheneau type functional corrective brace by age and gender is shown in Figure 2.

More often, patients aged 9 to 16 years were referred to bracing. There were four times as many girls as boys.

Combined S-shaped scoliosis with right-sided thoracic and left-sided lumbar arches prevailed (n=148), right-sided thoracic scoliosis was 70 people, thorathic and lumbar one was detected in 62 people (59 of them had right-sided and 3 had left-sided), and 20 subjects had left-sided lumbar.

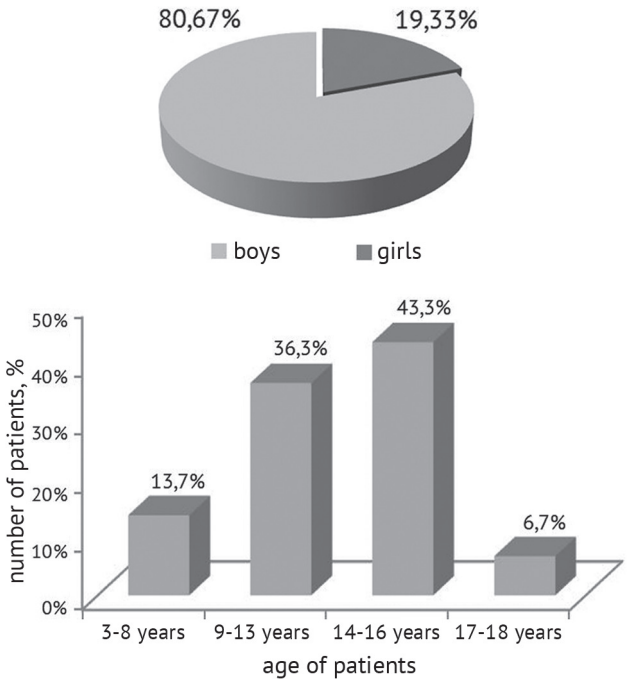

Fig. 2 Patients according gender and age

Children with scoliotic spinal deformity grades 2 and 3 according to Chaklin were often referred for bracing. The average value of the angle was 40.0° ± 10.8°.

In our study, the patients were divided, taking into account the Cobb deformation angle, into the following groups: group I (18°–35°) consisting of 100 subjects, group 2 (36° –45°) involved 150 individuals, and group 3 (46° or more) were 50 persons (Fig. 3) and according to similar principles of orthosis and

management, as well as depending on the reaction of the spine and chest to the effects of the bracing.

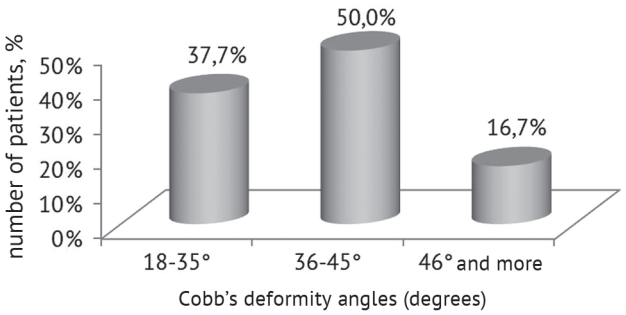

Fig. 3 Patients according deformity grade, Cobb's angle (degrees)

The effect of medical rehabilitation of patients participating in the study was evaluated comprehensively basing on clinical, instrumental and radiographic findings.

The results of deformity correction in percentage ratio (% of the initial deformity) in children in the groups according to the X-ray examination are shown in Figure 4.

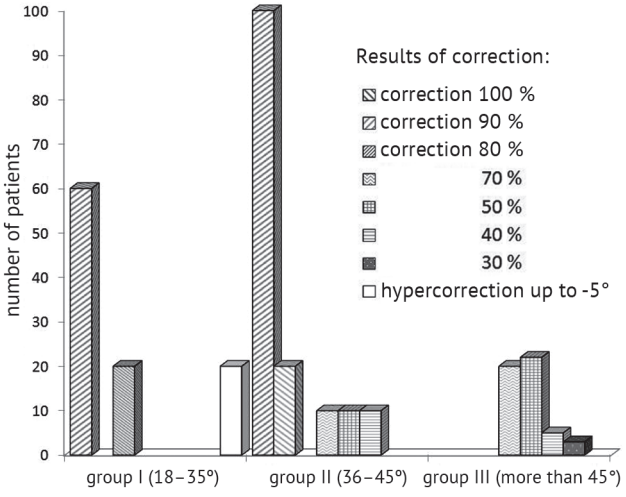

Fig. 4 Results of correction in percentage ratio (% of initial deformation) in children in the groups studied

Correction of the deformity was achieved in all children. Moreover, more than a half (160 people) of them had complete correction. The use of a functional corrective brace of the Cheneau type in complex rehabilitation allows for maximum correction of spinal deformity in children of groups 1 and 2. The ideal result of treatment was recognized as complete correction of deformity without wearing the brace, evaluated clinically and radiographically, or hypercorrection achieved at the stages of treatment.

Our studies showed that complete deformity correction was achieved in 80 (80 %) children in the first group (Cobb's angle of 18°–35°) and in 100 children (66.7 %) in the second group (Cobb's angle of 36°–45°).

Correction of deformity in a percentage of the initial one up to 80% was achieved in 20 children (20 %) in the first and up to 90% in 20 patients (13.3 %) in the second group, respectively. All of them were followed-up for no more than 2 years.

We also noted that in the second group, ten children with a 40 % correction of deformity, nine had clear signs of non-compliance with the brace wearing regime, and parents recognized the violation by their children.

Absence of progression in the group of the angle of 46° and higher according to Cobb can be considered as a positive result [1]. However, even in this group, deformities decreased in all patients. In the third group (Cobb's angle of more than 46° degrees), correction as percentage of the initial one up to 50 % and 70% was achieved in 42 children (44 % and 40 %, respectively) and 30 and 40 percent in 8 children (6 % and 10 % respectively). Consequently, even in severe scoliotic deformities, the use of a functionally corrective brace can contribute to the regression of spinal deformity, especially if treatment starts in children under 12 years of age.

The group of patients with spinal deformity of 18°–35° according to Cobb is of particular interest, in which good results were with hypercorrection to -5° were achieved. Patients of this group (average age 9.88 ± 3.76 years) were distributed by age as follows: 3 to 6-year old were two patients; 7 to 10-year old were six children; 11 to 13-year old were eight and four were in the age of 14 to 15 years.

Fifteen of them achieved complete correction of spinal deformity within three years; five children during the fourth year of correction. The results obtained correspond to the results of other authors [1, 14]. Hypercorrection must be performed deliberately, taking into account the fact that there is some reverse regression towards the initial deformation after removing the brace. As a result, proper management of the patient ends up with complete correction of spinal deformity. Children of this group were recommended to use a brace at night, regular monitoring by an orthopedic trauma surgeon (orthosis specialist). In our opinion, an additional prerequisite for transferring the patients to the night mode is his active physical therapy.

Provided that complete correction with restoration of the correct vertebral shape and planned hypercorrection of scoliotic deformation was confirmed clinically and radiographically, as well as with continuous sufficient motivated and conscious physical therapy, patients were transferred to night mode of brace wearing prior to full bone maturity of the spine. It can be confirmed by a clinical case (Fig. 5).

Case report Patient V., born in 2005; diagnosis: idiopathic scoliosis of grade 3. At the age of 8, he was consulted at the Federal Research Albrecht Center. An initial clinical and radiological examination revealed scoliotic deformity in the thoracic spine, equal to Cobb's angle of 33.8°. It was recommended to use a functional corrective brace according to the Cheneau technique (Fig. 5a) at least 20 hours per day. The first follow-up took place after two months. Then, if necessary, he was followed once every 2–4 months; the brace was adjusted and changed as the child grew. From November 2013 to June 2017, the child received five functionally corrective braces. Rehabilitation measures resulted in complete correction of scoliotic deformity in the thoracic spine and hypercorrection to minus 4.0° according to Cobb (Fig. 5b–5f). Since June 2017, the child was transferred to brace retention mode. He is followed up by an orthopedic trauma surgeon (orthosis specialist) once every three months.

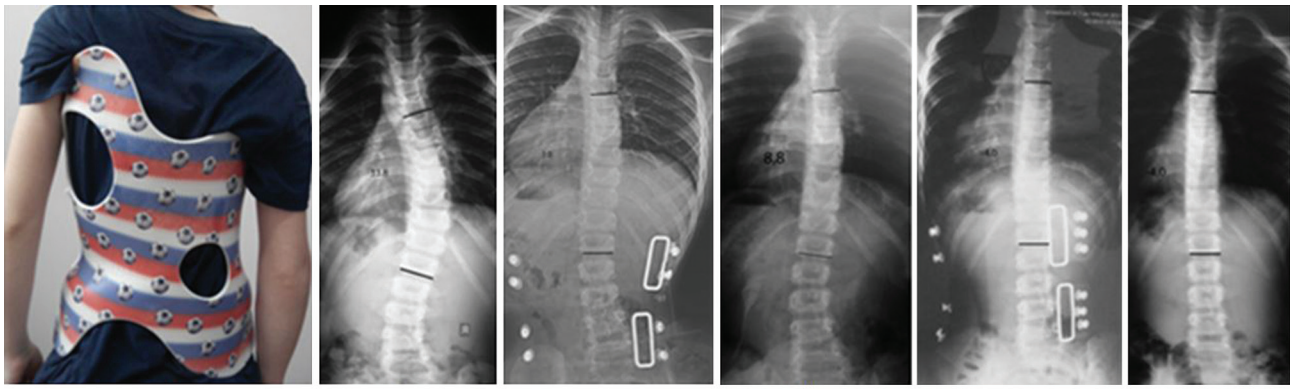

Fig. 5 Patient B.: ***a*** photo in a brace (rear view); ***b*** radiograph of the spine at the beginning of treatment (November 2013, without a brace); ***c*** in March 2014 (in brace); ***d*** in April 2015 (without brace); ***e*** in June 2016 (in brace); ***f*** in June 2017 (without brace)

DISCUSSION

Scientific literature shows that scoliosis is one of the most common pediatric orthopedic diseases [8, 11, 26]. This pathology is more common in girls than in boys (4:1, respectively) [10]. The pathological condition is characterized by a progressive course and it is very difficult to stop its progression [27]. According to the literature, ten out of every 100 patients require specialized conservative treatment, and two children out of every thousand need operative correction of scoliosis [26].

There is a connection between the deformation and the growth of the skeleton. Most frequently, idiopathic scoliosis occurs during periods of growth spurts between the ages of six to 24 months, five to 8 years and 11 to 14 years [26, 28].

Associated severe deformations of the chest and pelvis affect the internal organs, disrupt the function of the respiratory and cardiovascular systems [11]. The consequences could be a respiratory failure and degenerative changes in the myocardium. As a rule, disability due to scoliosis occurs in childhood and adolescence and, according to the literature, ranges from 5% to 12%, which determines a great social significance of the problem studied [29, 30].

It should be noted that the available literature reflects a description of the medical technology for the use and a design of a Cheneau-type corrective brace, which allows improving treatment results and reducing the disability rates in children with spinal deformities [5, 7, 14, 18, 19].

Braces of this type not only maintain the correction achieved, but also have a three-plane effect on it, unloading the apophyses of the vertebral bodies on the concave side and creating biomechanically correct directions of forces that reverse the curvature without restriction of the natural growth [17, 19, 31]. Directional trained breathing creates the conditions for expansion of the volume of the lung tissue, which

influences on the deformity of the chest and spine from the inside.

Orthoses of this design are quite technically difficult to fabricate and they are customized for each patient, taking into account the specific type of curvature of his/her spine [32, 33]. Innovative technologies for manufacturing the product are being developed, including using 3D scanning [34]. The Federal Center for Scientific and Technical Research named after G.A. Albrecht initiated improving the technology of manufacturing braces. The issue of the material characteristics which the future product can be made of is being addressed. Materials that meet medical and technical requirements are selected and used (light weight, resistance to sanitary processing, nontoxicity, hypoallergenicity, etc.), taking into account the individual characteristics of patients.

The main criteria for evaluating the results of bracing therapy are, as we have already indicated above, the findings of clinical and radiographic examination. The literature describes additional criteria for diagnosing and evaluating orthosis application results using optical topography techniques [35, 36, 37], electrophysiological indicators of changes in skeletal muscles [38], evaluation of external respiration function (vital capacity of the lungs, VC) and cardiovascular system (ECG) [11, 37]. At this stage, the data obtained are insufficient for complete analysis and we have not presented them in this study. We plan to apply the results of additional examinations in future research and clinical practice.

Most researchers opine that the main goal of orthopedic treatment in patients with idiopathic scoliosis is correction and stabilization of spinal deformity [37, 39, 40].

The clinical recommendations of the All-Russia public organization "Association of Orthopedic surgeons and Traumatologists of Russia" (AOTR) on the management of patients with idiopathic scoliosis indicate that the treatment of this pathology should be comprehensive regardless of the surgical treatment if planned and include the use of brace therapy, and non-drug conservative treatment (rational orthopedic and motor regime, adequate nutrition, general strengthening, physical exercises, hydrokinesitherapy, massage, electric stimulation of muscles) [26, 29]. According to various authors, this approach to treatment could prevent further progression of the deformity, strengthen the muscles, improve the function of external respiration and the state of the cardiovascular system [37, 39, 40].

Based on the fact that in addition to the manufacture, a thorough observance of all the nuances of treatment periods is necessary to solve this goal, the article provides a detailed description of the Cheneau-type technique used at the center.

The results of bracing therapy at our center showed the effectiveness of the proposed approach to the treatment of patients with idiopathic scoliosis.

CONCLUSION

The use of functional corrective brace of the Cheneau type in complex rehabilitation of children and adolescents with idiopathic scoliosis provides good outcomes in most patients of all three groups distributed according to Cobb's angle. The best results of treatment were obtained in the first group of patients with the angle of 18°–35°.

Brace application should be performed according to the treatment technology, be individual, taking into account the peculiarities of spinal deformity and its progression, age, as well as growth potential of the spine; systematic exercise therapy, including Schroth gymnastics, is necessary. The treatment regime should be strictly followed consciously.

A multidisciplinary team should participate in the treatment process that includes the family of the patient and highly qualified specialists such as a pediatric orthopedist, orthopedic and orthosis specialist, exercise therapy instructor, physical therapy specialist, pediatrician, radiation diagnostics specialists, and psychologist, orthosis technicians and methodologists if necessary.

It is possible to switch to wearing the brace at the night upon a full clinical and radiological correction with restoration of the correct vertebral shape and planned hypercorrection of scoliotic deformity, as well as if patient continues sufficient, motivated and conscious physical therapy until complete bone maturity of the spine.

REFERENCES

1. Lein G.A. *Meditsinskaia reabilitatsiia patsientov shkolnogo vozrasta, stradaiushchikh idiopaticheskim skoliozom*. Avtoref. Diss. kand. med. nauk [Medical rehabilitation of school age patients suffering from idiopathic scoliosis. Synopsis Cand. med. sci. diss.]. SPb., 2013, 18 p. (in Russian)
2. *O sostoianii sanitarno-epidemiologicheskogo blagopoluchiia naseleniia v rossiiskoi federatsii v 2015 godu : gos. dokl*. [On the state of sanitary-and-epidemiologic well-being of the population in the Russian Federation in 2015: State report]. Federalnaia Sluzhba po Nadzoru v sfere zashchity prav potrebitelei i blagopoluchiia cheloveka [Federal Service for Supervision of Protecting Consumer Rights and Human Wellfare]. Available at: https://rospotrebnadzor.ru/documents/details.php?ELEMENT_ID=6851 (Accessed 12.05.2018). (in Russian)
3. Mikhailovskii M.V., Sadovoi M.A., Fomichev N.G. Klinicheskii diagnoz patsienta s deformatsiei pozvonochnika [Clinical diagnosis of a patient with the spine surgery]. *Khirurgiia Pozvonochnika*. 2017, vol. 14, no. 1, pp. 24-30. (in Russian) DOI: 10.14531/ss2017.1.24-30.
4. Szwed A., Kołban M., Jałoszewski M. Results of SpineCor dynamic bracing for idiopathic scoliosis. *Ortop. Traumatol. Rehabi*l., 2009, vol. 11, no. 5, pp. 427-432.
5. Roskov R.V., Andrievskaia A.O., Smirnov A.V., Petrova N.S. *Ortezirovanie pri travmakh konechnostei i ikh posledstviiakh i patologii pozvonochnika: ucheb. posobie* [Orthotics for limb injuries and their consequences, as well as for the spine pathology: manual]. 2-nd Ed. SPb., 2009, 530 p. (in Russian)
6. Shmelev V.V., Goncharova L.A., Rasulov M.D. Sovremennaia korsetoterapiia v lechenii idiopaticheskogo skolioza [Modern brace therapy in the treatment of idiopathic scoliosis]. *Astrakhanskii Meditsinskii Zhurnal*, 2016, vol. 11, no. 1, pp. 63-71. (in Russian)
7. Tesakov D.K. Primenenie korsetoterapii pri idiopaticheskom skolioze [The use of corset-therapy for idiopathic scoliosis]. *Vestnik Travmatologii i Ortopedii im. N.N. Priorova*, 2011, no. 3, pp. 9-21. (in Russian)
8. Mikhailovskii M.V., Sadovoi M.A., Novikov V.V., Vasiura A.C., Sadovaia T.N., Udalova I.G. Sovremennaia kontseptsiia rannego vyiavleniia i lecheniia idiopaticheskogo skolioza [The modern concept of early detection and treatment of idiopathic scoliosis]. *Khirurgiia Pozvonochnika*, 2015, vol. 12, no. 3, pp. 13-18. (in Russian) DOI: 10.14531/ss2015.3.13-18.
9. Voitenkov V.B., Minkin A.V., Skripchenko N.V., Samoilova I.G., Klimkin A.V., Aksenova A.I., Petrova N.S., Petrova D.A. Vliianie grudo-poiasnichno-kresttsovogo korseta ORTO® na neirofiziologicheskie pokazateli, myshechnuiu silu i osanku u detei [The effect of ORTO® thoracic lumbosacral brace on neurophysiological parameters, muscle strength and posture in children]. *Genij Ortopedii*, 2017, vol. 23, no. 2, pp. 168-171. (in Russian) DOI: 10.18019/1028-4427-2017-23-2-168-171.
10. Roskov R.V., Andrievskaia A.O. *Skolioticheskaia bolezn, lechenie, ortezirovanie, MSE i reabilitatsiia: ucheb.-metod. posobie* [Scoliotic disease, treatment, orthotics, MSE and rehabilitation: technique manual]. SPb., 2009, 90 p. (in Russian)
11. Shelykhmanova M.V. *Kompleksnyi podkhod v lechenii i reabilitatsii detei s displasticheskim skoliozom II-III stepeni*. Avtoref. Diss. kand. med. nauk [The complex approach in treatment and rehabilitation of children with II-III degree dysplastic scoliosis. Synopsis Cand. med. sci. diss.]. Samara, 2017. 24 p. (in Russian)
12. Reinberg S.A. *Rentgenodiagnostika zabolevanii kostei i sustavov: v 2 ch. 4-e, ispr. i dop. izd*. [Roentgen diagnosing diseases of bones and joints: in 2 parts. 4th Ed.]. M., Meditsina, 1964, part 2, 572 p. (in Russian)
13. Sadofeva V.I. *Normalnaia rentgenoanatomiia kostno-sustavnoi sistemy u detei*. L., Meditsina, 1990, 220 p. (in Russian)
14. Tesakov D.K., Alzoba S.V., Beletskii A.V., Volkov I.N., Mukhlia A.M., Petrosian I.N., Tesakova D.D., Malsagov D.M., Urev G.A. Meditsinskaia tekhnologiia korsetnoi korrektsii deformatsii pozvonochnika [Medical technology of the spine brace correction]. *Khirurgiia Pozvonochnika*, 2010, no. 4, pp. 30-40. (in Russian)
15. Nikolaev V.F., Baranovskaia I.A., Andrievskaia A.O. Ispolzovanie funktsionalno-korrigiruiushchego korseta v lechenii bolnykh idiopaticheskim skoliozom [Use of a functional correcting brace in treatment of patients with idiopathic scoliosis]. *Genij Ortopedii*, 2016, no. 1, pp. 44-47. (in Russian) DOI: 10.18019/1028-4427-2016-1-44-47.
16. Tesakov D.K. Korsetnoe lechenie detei i podrostkov s deformatsiiami pozvonochnika IV stepeni [Brace treatment of children and adolescents with IV degree deformities of the spine]. *Khirurgiia Pozvonochnika*, 2010, no. 2, pp. 25-34. (in Russian)
17. Lein G.A., Gusev M.G., Pavlov I.V., Vissarionov S.V., Alzoba S.V. *Osnovy aktivno-korrigiruiushchego ortezirovaniia v lechenii zabolevanii i travm pozvonochnika: metod. posobie* [Basics of active correcting orthotics in treatment of the spine diseases and injuries: technique manual]. SPb., Izd-vo S.-Peterb. Nauch.-prakt. Tsentra Mediko-Sotsialnoi Ekspertizy, Protezirovaniia i Reabilitatsii Invalidov im. G.A. Albrekhta [Publishing House of St. Petersburg Albrecht Scientific-practical Centre of Medical-and-social Examination, Prosthetics and Rehabilitation of the Disabled], 2012, 68 p. (in Russian)
18. *Ortopedicheskoe i reabilitatsionnoe lechenie podrostkovogo idiopaticheskogo skolioza: metodicheskie rekomendatsii* [Orthopedic and rehabilitation treatment of adolescent idiopathic scoliosis]. SOSORT, 2011. (in Russian) Available at: http://sosort.ru/advanced-stuff/konservativnoe-lechenie.-metodicheskie-rekomendacii.html (accessed 12.05.2018).
19. Chêneau J. *Das original Cheneau-Skoliosen-Korset*. Dortmund, Orthopädie-Technik, 1997.
20. Tesakov D.K. Vozrastnaia dinamika rentgenologicheskikh kharakteristik aktivnosti kostnogo rosta taza i pozvonochnika u bolnykh idiopaticheskim skoliozom [Age-related dynamics of roentgenological characteristics of the activity of bone growth of the pelvis and spine in patients with idiopathic scoliosis]. *Vestnik Travmatologii i Ortopedii im. N.N. Priorova*, 2011, no. 1, pp. 60-67. (in Russian)
21. 3D scoliosis-therapy with the nBrace night time brace. Ortholutions. Bracing at its Highest Level. Available at: http://www.ortholutions.com/tlso-trunk-orthoses-brace-orthotics/scoliosis-night-brace-rigo-cheneau-ortholutions/ (accessed 12.05.2018).
22. Sheno Zh. Gimnastika pri skolioze. *Osnovnye pravila i nauchnoe obosnovanie* [Gymnastics for scoliosis. Basic rules and scientific ratioonale]. Vestnik Vserossiiskoi Gildii Protezistov-ortopedov, 2009, no. 2 (36), pp. 13-21. (in Russian)
23. *Gimnastika Katariny Shrot pri skolioze: osnovnoi printsip deistviia i vypolneniia uprazhnenii* [Katarine Shrot gymnastics for scoliosis: the main principle of action and exercise performing]. SpinaTitana. Spina gotova k podvigu [The back is ready for a feat]. (in Russian) Available at: https://spinatitana.com/pozvonochnik/grudnoj-otdel/skolioz/gimnastika-katariny-shrot-pri-skolioze-osnovnoj-printsip-dejstviya-i-vypolneniya-prazhnenij.html (accessed 22.10.2018).

24. Tesakov D.K., Voronovich I.R. Klassifikatsiia metodov lecheniia bolnykh s deformatsiiami pozvonochnika pri idiopaticheskom (displasticheskom) skolioze [Classification of the methods of treating patients with the spine deformities for idiopathic (dysplastic) scoliosis]. *Meditsinskie Novosti*, 2008, no. 10 (162), pp. 82-85. (in Russian)
25. Epifanov V.A. *Lechebnaia fizicheskaia kultura i massazh: uchebnik. 2-e izd*. [Medical physical culture and massage]. M., GEOTAR-Media, 2016, 528 p. (in Russian)
26. Mikhailovskii M.V., Fomichev N.G. *Khirurgiia deformatsii pozvonochnika* [Surgery of the spine deformities]. Novosibirsk, Sibirskoe Universitetskoe Izdatelstvo, 2017, 424 p. (in Russian)
27. Dudin M.G., Pinchuk D.Iu. Idiopaticheskii skolioz [Idiopathic scoliosis]. *Ortopediia, Travmatologiia i Vosstanovitelnaia Khirurgiia Detskogo Vozrasta*, 2014, vol. 2, no. 1, pp. 70-77. (in Russian)
28. Dudin M.G., Mikhailovskii M.V., Sadovoi M.A., Pinchuk D.Iu., Fomichev N.G. Idiopaticheskii skolioz: kto vinovat i chto delat? [Idiopathic scoliosis: who is in fault and what to do?]. *Khirurgiia Pozvonochnika*, 2014, no. 2, pp. 8-20. (in Russian)
29. Batrshin I.T., Sadovoi M.A., Mikhailovskii M.V., Sadovaia T.N. Sovremennye printsipy dispanserizatsii detei s deformatsiiami pozvonochnika v otdalennykh regionakh strany [Modern principles of prophylactic medical examination of children with the spine deformities in remote regions of the country]. *Khirurgiia Pozvonochnika*, 2006, no. 4, pp. 70-74. (in Russian)
30. Shabanova O.A. *Mediko-sotsialnye aspekty invalidnosti i reabilitatsii bolnykh skoliozom*. Avtoref. Diss. kand. med. nauk [Medical-and-social aspects of disability and rehabilitation of patients with scoliosis. Synopsis Cand. med. sci. diss.]. SPb., 2011. 27 p. (in Russian)
31. Rigo M., Weiss H.R. The Chêneau concept of bracing – biomechanical aspects. *Stud. Health Technol. Inform*., 2008,vol. 135, pp. 303-319.
32. Negrini S., Grivas T.B., Kotwicki T., Rigo M., Zaina F.; International Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT). Guidelines on "Standards of management of idiopathic scoliosis with corrective braces in everyday clinics and in clinical research": SOSORT Consensus 2008. *Scoliosis*, 2009, vol. 4, pp. 2. DOI: 10.1186/1748-7161-4-2.
33. Grivas Th.B. *European Braces for Conservative Scoliosis Treatment*. Dr. Tarun Goswami, editor. 2012. DOI: 10.5772/19509.
34. Shavyrin I.A., Kolesov S.V., Kudriakov S.A. *Primenenie sovremennykh 3D-tekhnologii korsetirovaniia po tipu Sheno pri lechenii idiopaticheskogo skolioza* [The use of modern 3D-technologies of bracing by Cheneau type for idiopathic scoliosis treatment]. Rossiiskii Korsetnyi Tsentr. Izgotovlenie korsetov Sheno po 3-D-tekhnologii po vsei Rossii [Russian Brace Centre. Cheneau Brace making according to 3-D technology throughout Russia]. (in Russian) Available at: http://russiancorset.ru/paczientam/korset-sheno.html (accessed 22.10.2018).
35. Sarnadskii V.N., Sadovoi M.A., Fomichev N.G. Sposob kompiuternoi opticheskoi topografii formy tela cheloveka i ustroistvo dlia ego osushchestvleniia [The way of computed optical topography of human body shape and device for its implementation]. Eurasian Patent, no. 199600068, 1996. (in ussian)
36. Bagrinovskaia I.L. Sopostavimost otsenki uglov skolioticheskoi deformatsii pozvonochnika nachalnykh stadii po dannym rentgena i kompiuternoi opticheskoi topografii [Comparability of the estimated angles of the spine scoliotic deformity at the initial stages according to X-ray and computed optical topography]. *Khirurgiia Pozvonochnika*, 2014, no. 3, pp. 32-37. (in Russian) DOI: 10.14531/ss2014.3.32-37.
37. Skinder L.A., Gerasevich A.N., Poliakova T.D., Pankova M.D. *Fizicheskaia reabilitatsiia detei s narusheniiami osanki i skoliozom: ucheb.-metod. posobie* [Physical rehabilitation of children with posture disorders and scoliosis: technique manual]. Brest, BrGU, 2012, 210 p. (in Russian)
38. Shmelev V.V., Vorontsova O.I., Goncharova L.A., Rasulov M.D. Elektrofiziologicheskie kriterii effektivnosti lecheniia idiopaticheskogo skolioza korsetom Sheno i iglorefleksoterapiei [Electrophysiological criteria for the effectiveness of idiopathic scoliosis treatment using Cheneau brace and acupuncture]. *Fizioterapiia, Balneologiia i Reabilitatsiia*, 2016, vol. 15, no. 6, pp. 301-304. (in Russian)
39. Idiopaticheskii skolioz: klinicheskie rek. Assotsiatsiia travmatologov-ortopedov Rossii [Idiopathic scoliosis: clinical recommendations. Association of Traumatologists-orthopedists of Russia]. Entsiklomediia. Meditsinskaia baza [Encyclomedia. Medical database]. 2015. Available at: https://bz.medvestnik.ru/nosology/Idiopaticheskii-skolioz.html/recomendations (accessed 28.10.2018).
40. Newton P.O., O'Brien M.F., Shufflebarger G.L., Betz R.R., Dixon R.A., Harms Y. Idiopaticheskii skolioz. Issledovatelskaia gruppa Kharmsa. Rukovodstvo po lecheniiu [Idiopathic scoliosis. The Harms Study Group. Treatment Guide]. *Laboratory of Knowledge*, 2018, 479 p. (in Russian)

Received: 29.11.2018

Information about the authors:

1. Veniamin F. Nikolaev, M.D., PhD., assistant professor,
Federal Scientific Center of Rehabilitation of the Disabled named after G.A. Albrecht, Saint Petersburg, Russian Federation,
Email: doc.nikolaev@mail.ru
2. Irina A. Baranovskaya,
Federal Scientific Center of Rehabilitation of the Disabled named after G.A. Albrecht, Saint Petersburg, Russian Federation,
Email: doc.bari@mail.ru
3. Alla O. Andrievskaya, M.D., PhD., assistant professor,
Federal Scientific Center of Rehabilitation of the Disabled named after G.A. Albrecht, Saint Petersburg, Russian Federation,
Email: alandrievskaya@yandex.ru