ORTHOPTICS

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Abstract. *First part of presentation reminds basic strabismus terms as amblyopia, eccentrically fixation or anomaly retinal correspondence. After that we will discuss processes and methods of treatment these pathological conditions, which precedes orthoptic training. Briefly we will talk about pleoptic treatment with occlusion and treatment with many pleoptic devices. Last part of presentation is dedicated to orthoptic training – prerequisites of orthoptic training, methods, which we use in Czech Republic – therapy with a troposcope, therapy with cheiroscope, training with stereoscopes, Remy's separator, diploscope and training of stereo vision of simple binocular vision, consolidation of simple binocular vision by reading with image divider, and also training of motility and convergence. Part of this section is specialized to introducing orthoptic workplaces in Czech Republic for these patients. After that we will discuss how you can gain the license for providing the orthoptic therapy in Czech Republic.*

Key words:
orthoptic training, troposcope, simple binocular vision, orthoptic therapy, Czech republic

1. Introduction

The world orthoptics has his origin in Greek words orthos (straight) and optikos (ocular). Orthoptics is method which should lead to renewing of simple binocular vision (SBV). SBV has two components – motor and sensorial. Renewing of both eyes cooperation is possible only in case of earlier SBV existence. During the orthoptics training we can use many different instruments, which helps to renew of SBV and to improve eye motility and position. In case of congenital and acquired eye disorder orthoptics training helps to rehabilitate of SBV. Training must be leaded by the orthoptics specialist.

2. Basic terms

Simple binocular vision

Simple binocular vision (SBV) is coordinated sensorial and motor activity of both eyes, which provides creation of simple image of observed object. We can see simple image of observed object only if images from right and left eye are connected in one visual perception.

Degrees of SBV

a) Superposition – It is an ability to cover two unequal images of both eyes
b) Fusion – It is ability to connect two same images of both eyes in one vision perception
We can distinguish 3 types of fusion:

- Peripheral
- Macular
- Foveolar
- Fusion is also motor and sensor

c) Stereopsis – It is ability to create deep visual perception with stimulation of lightly disparate places of retina. Stereopsis allows to see objects in 3 dimensional space.

Simple binocular vision conditions:

a) Sensor part

- Normal or almost normal vision of both eyes
- Approximately same size of retinal image
- Central fixation of both eye
- Normal retinal correspondence
- Ability to fusion
- Normal function of optical nerve, tractus opticus and optical radiation

b) Motor part
- Parallel eyes position
- Free movements of eyes in nine basic directions
- Normal function of motor path and centers
- Coordination of accommodation and convergence

Retinal correspondence

Every part of retina share common vision directions with specific part of retina of the other eye. These two parts of retina are located at the same distance from fovea centralis. We call them corresponding points of retina. Normal retinal correspondence (NRC) is physiological condition, when certain parts of retina have common relationship to fovea centralis – they share common subjective vision direction. Analogically we can say that both foveas are the main corresponding points of retinas.

Retinal disparity

All other points of retina, which do not have corresponding relationship to other points of retina we call disparate points of retina. Objects, which are projected on disparate points of retina, are in certain case seen doubled (diplopia).

Horopter, Panum´s area

Horopter (horizon of vision) is the sum of all points in space, which are projected on corresponding points of retina. Objects near the horopter, which stimulate lightly correspondent points on the retina, are seen simply and lies in co called Panum's area. This area allow to subjects to have 3-dimensional vision (3D). Deep of 3D vision rise from fixation point to periphery.

Physiologic diplopia

Objects, which are in front of and behind the horopter projected on disparate points of retina, are seen in certain case doubled. This effect is called physiological diplopia. Usually we do not aware this diplopia, but we can induce it. We distinguish crossed diplopia (object is projected temporally form macula) and uncrossed diplopia (object is projected nasally from macula).

Dominant eye

Dominant eye has stronger projection in binocular perception in comparison with the second eye. Dominancy is not congenital. It is built in early childhood. This dominancy is not related to hand dominancy and visual acuity of dominant eye need not to be better than visual acuity of the other eye.

Suppression

Suppression is state, when visual perception of the eye is not fully accepted and processed by the visual centers in visual cortex in occipital lobe of the brain. Suppression usually appears if both eyes are open and accept the visual information. The cause of suppression is disability to perceive single binocular image. With suppression our brain protects us against the diplopia. Pathological suppression usually appears by children with strabismus in their early childhood (from 2 to 8 years), but it is not fixed yet. Adults have no ability to suppress diplopia, because their SBV is already fixed. Suppression can be divided between macular and peripheral and usually manifest like visual field scotoma.

Amblyopia

Amblyopia is usually defined like reduction of visual acuity of the eye, although anatomy of the eye is correct. Correction of refractive error usually has no effect of increasing of visual acuity. It could be unilateral or bilateral. Amblyopia could be connected with fixation disorder, disorder of distance and difference estimating. We can divide amblyopia into these groups:

- *Congenital amblyopia* – It rises from birth, usually is connected with albinism, nystagmus, the chance of increasing of visual acuity is very small
- *Amblyopia ex anopsia* – It develops if vision stimulation of the eye is missing, e.g. with cataract or hemophthalmus
- *Anisometropic amblyopia* – It is caused by high refraction difference between both eyes
- *Ametropic amblyopia* – It is caused by high refractive error of the eye
- *Meridional amblyopia* – It is cause by high astigmatism of the eye

- *Relative amblyopia* – It is no so usual and is caused by small organic defect on retina
- *Amblyopia by strabismus* – It is caused by active suppression of fovea on deviated eye

We can also distinguish amblyopia according to amount of visual acuity:
- *Light/simple* – visual acuity from 6/8 to 6/18
- *Medium/intermediate* – visual acuity from 6/18 to 6/60
- *Heavy/gravis* – visual acuity under 6/60

Fixation disorders

We usually distinguish 3 types of fixation disorders – central, eccentric and lost fixation (is not stable)

- *Eccentric fixation* (EF) – Our brain uses other point of retina for fixation (not fovea). This point is called as pseudomacula. Distance from pseudomacula to real macula depends on angle of eye deviation. EF could be parafoveolar, paramacular and peripheral. If the direction of eccentricity is not the same as deviation of the eye, we can speak about fixation paradox
- *Disorder of space localization* – It occurs if EF become a dominant point of eye fixation. This leads to anomaly retinal correspondence (ARC) development. Pseudomacula creates functional relationship with macula of the other eye.
- *Crowding phenomenon* – It is disorder of objects differentiation, patient can easily recognize isolated letters than letters in line.

Pleoptics

Pleoptics is treatment of amblyopia. It is usually connected with orthoptics treatment. During the pleoptics treatment we try to cover/occlude healthy eye to improve the visual acuity of the amblyopic eye. Passive treatment is leaded with orthoptist, who uses special instruments like euthyscop, pleoptofor, CAM method etc. Successful pleoptics treatment leads to successful orthoptics training and together they can rehabilitate SBV.

Anomaly retinal correspondence (ARC)

When false macula/pseudomacula cooperates with real macula of leading eye, we speak about ARC. ARC we can divide into 2 groups:

- *Harmonic (HARC)* – Angle of strabismus is equal to angle of anomaly, fovea of leading eye cooperates with false macula of deviated eye
- *Disharmonic (DARC)* – Angle of strabismus differ from angle of anomaly

Angle of anomaly

It is the difference between objective and subjective angle of strabismus (more in capture of troposcope)

Needed predispositions for orthoptics training

- Equal or nearly equal visual acuity of both eyes (maximal difference of 3 optotype lines)
- Both eye central fixation
- Normal retinal correspondence
- Normal eyes motility
- No or minimal deviation of the eye
- Age between 4 and 8 years
- Patient's compliance

3. Procedures of orthoptics training

The base of diagnosis and indications of orthoptics training is precise examination of patient's visual function (visual acuity, cover test, test of eye motility etc.). In case of positive diagnosis ophthalmologist/orthoptist suggests procedures of treatment, which depends on degree of SBV development and age of child. Really important is child's motivation to training, which makes treatment much easier and effective. Training should be performed with optimal spectacle correction. Procedures of orthoptics training are these:

- Un-suppressing of eye and training of superposition
- Training of fusion

- Training of stereopsis
- Training of eye motility
- Training of convergence
- Training of relationship between accommodation and convergence

4. Orthoptics instruments

All of orthoptics instruments are based on dissociation of both eyes perception. We create virtual infinity with help of the instrument. But there are psychological proximity reactions, which could negatively influence the perception of infinity.

4.1. Troposcope/Synoptophore

Troposcope or synoptophore is basic and the most used instrument for diagnosis and treatment of disorders of SBV. Troposcope is based on principles of Wheaston's mirror stereoscope and Worth's amblyoscope. The name synoptophore is used for this instrument usually in Great Britain. Modern types of synoptofore are based on mechanical and electrical principles. Synoptophore has many programs for removing of eye suppression. The basic principal of this instrument is called haploscopy. It means that every eye has its own perception of image, which could be changed by moving the arms of instrument. Device is composed of base with chinrest and forehead-rest and of two L-shaped movable arms. Every arm contains system of lenses, mirror, space for placing of therapeutic images and light sources. Oculars are equipped with lens (+6D), which should eliminate accommodation. Arms of instrument also include mirrors, which should straighten eyes' fixation axes. So the rays, which go from picture to patient's eye, seem to come from infinity. This is the way, how eliminate patient's proximity reactions. Examiner can move with instrument's arms in horizontal and vertical positions. The position of picture is read from the scales in prismatic diopters or in degrees of arc. At fist arms should be properly adjusted to patient's pupilar distance. Troposcope could be used for:

- Diagnosis of degrees of SBV
- Elimination of eye suppression
- Improve of fusion and stereo vision
- Treatment of ARC and eccentric fixation

Special images are used for diagnostic and treatment of SBV in troposcope. These pictures we can distinguish from each other with special color. Two different pictures (e.g. bird and cage) are used for diagnose and training of superposition. We also measure subjective and objective angle of strabismus with these pictures. Patient should cover one picture with another. Pictures for fusion examination are different. They look nearly same, but differ with special small control mark. For example rabbit with hat on one picture and rabbit with carrot in second picture. These control marks show us possible eye suppression. Pictures in size of 3.8 cm are projected to retina in size of 1 degree of arc. We use different size of pictures for examination different types of fusion.

- *Fusion I (peripheral)* 10 degrees of arc (size 10x3.8 mm)
- *Fusion II (macular)* 3 degrees of arc (3x3.8 mm)
- *Fusion III (foveolar)* 1 degree of arc (1x3.8 mm)

The third type of picture is used for diagnostic of stereo vision. These pictures consist of same elements, which are projected on corresponding and slightly disparate parts of retina. We can use two types of stereo pictures:

- Picture's small details are shifted to each other
- Black part of one picture is covered by white part of the second picture, which make so called stereoscopic shine

4.1.1. Training on troposcope

Patient should sit comfortable behind the instrument. Examiner should correctly set patient's pupilar distance and all other scales should be set on zero. In case of strabismus we set the arms of instrument in objective angle of strabismus. With troposcope we can make a lot of exercises and many types of therapy, i.e. removing of eye suppression, training of superposition, fusion and its power and also training of stereo vision. During therapy of suppression arms of troposcope are set in objective angle of deviation and pictures for superposition are used. In principle we stimulate deviated eye with light of higher intensity and

sometimes we should oscillate with picture. Child should see both pictures in the same time as a result of this training. When suppression is not developed yet, we train the superposition. Arms of troposcope are set in objective angle with using of pictures for peripheral superposition. Child is trying to cover the picture if leading eye with picture of deviated eye, which is controlled by examiner. This method is called “Hunt on troposcope”. For training of fusion we use pictures for fusion I – the biggest pictures. The most important are control details of pictures for fusion. If some control mark of fusion picture disappears, we should oscillate with that picture. After that we try to make fusion stronger and stabile with changing of size of picture. At last we use pictures for foveolar fusion. We can also make fusion stronger. We set arms of troposcope in subjective angle. Then we move with arms to the limit position to the right and left, where is fusion possible. Fusion width we train with pictures for macular fusion. Tubes are set in subjective angle of strabismus and examiner tries to move pictures in convergence and divergence. Patient is trying to keep pictures fused as much as possible. The exercise is performed against direction of deviation. Stereopsis is trained by pictures for stereo vision. With troposcope is also possible to change ARC to normal retinal correspondence. This is possible usually in patients before 8 years of age. In principal we use the difference between the sensation of real space and space seen with instrument. We should stimulate the macula of deviated eye. We use pictures for superposition. At first we set arms in position, which corresponds with usual position of eyes. In case of unilateral strabismus we set arm before deviated eye to zero degree of arc position and the second in objective angle of strabismus. Then we fixed this position and we move with arms 3 degrees of arm in sides. If we can evoke superposition, we should provide “hunt on troposcope”. During next part of training we change the pictures and arms in inverse position. Usually ARC will manifest again and we should repeat the training again.

Figure 1 – Synoptophor [3]

4.2. Cheiroscope

This instrument is the second most used for orthoptics. With this instrument we try to overcome and to train superposition. Cheiroscope allows dissociation thanks to special mirror. Device is composed of horizontal working desktop and vertical place for pattern pictures. Patient can watch with one eye pattern picture and desktop with other eye (both through plus 8 diopters lenses). Oculars of instrument should be set in patient pupilar distance. Pattern space and desktop are divided with mirror in 45 degrees of arc angle. Patient watches the picture and tries to trace the picture. This training requires successful cooperation of both eyes. Examiner can control correctness of eyes cooperation with 3 ways:

- Watching eye with mirror
- Comparison painted pictures with pattern
- Control oculars of cheiroscope

In case, that child draws picture by memory, fixation is alternating. The drawn picture is bigger or smaller than pattern. Typical is shift of picture in direction of deviation. With youngest children is recommended to use soft and transparent paper for drawing. We can also use “hunt of cheiroscope”. Examiner move with pattern picture (e.g. butterfly) and patient hunt it with net on desktop.

Figure 2a – Drawing on cheiroscope [3]
Figure 2b – Hunt of cheiroscope [3]

4.3. Mirror stereoscope

This instrument is usually used for breaking suppression, training of superposition and fusion. Instrument has two main parts like cheiroscope, which are divided by mechanical septum covered by mirror. The septum can be set in right and left position. Mirror dissociation brings real sensation of space (not instrumental). Patient watches with one eye pattern and drawing part of board with other eye. During exercise patient can draw pattern picture or try to catch the butterfly by "hunt on stereoscope". Board can be set in two main directions:

- Horizontal (I) – in 180 degrees of arc angle
- Vertical (II) – in 135 degrees of arc angle

These positions and results of training can be controlled by orthoptist with scale on board.

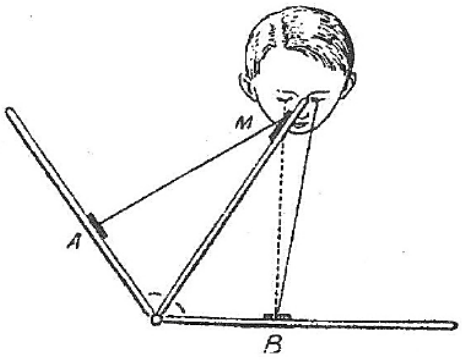

Figure 3 – Mirror stereoscope [3]

4.4. Brewster – Holmes stereoscope

This instrument allows training of fusion, its width and stereo vision. It is composed of horizontal lath with carriers of pictures and with two de-centered lenses (5 diopters and temporal basis with prismatic effect). In the middle of instrument there is mechanical septum. Distance of picture is invariable. We usually use pictures for fusion or stereo vision. After the placing the fusion pictures in the carriers we try to find the location on lath, where is possible fusion. Fusion of pictures is also controlled by special marks. We can train width of fusion with moving of picture to divergence (negative fusion) and convergence (positive fusion). For stereoscopy training we use special stereoscopy pictures with control marks.

Figure 4 – Brewster-Holmes stereoscope [3]

4.5. Vergence stereoscope

This instrument is used in the same way like Brewster-Holmes stereoscope (fusion, fusion width and stereopsis). The difference is in possibility of changing distance between pictures.

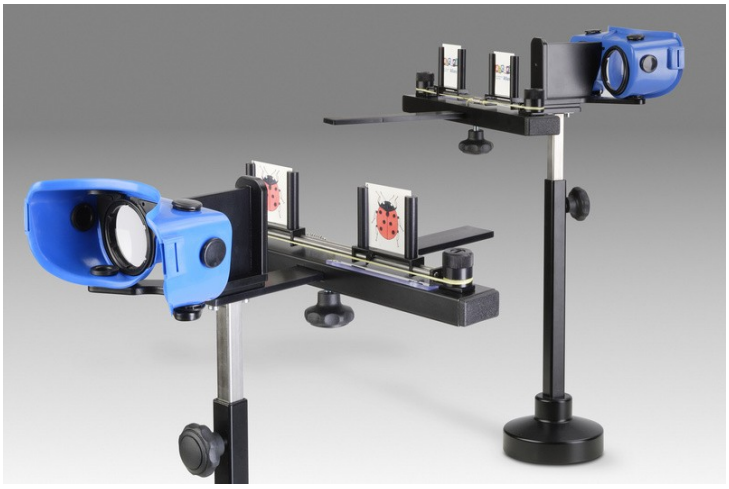

Figure 5 – Vergence stereoscope [http://www.dioptra.cz/opticke-adaptery-441/vergencni-stereoskop---vs-01.html]

4.6. Remy's separator

This mechanical instrument is used for relaxation of accommodation and convergence and for training their relationship. Partial dissociation in real space is reached with 30 cm long lath, which is placed to nose root. On the other side of this lath is transparent plastic film, which enables to see to the distance. Patient by watching the distance should connect transparent pictures placed in carrier near transparent plastic film.

Figure 6 – Remy's separator [3]

4.7. Remy's diplocope

This instrument is based on dissociation of real space. It is used for training of relationship between accommodation and convergence. Instrument is composed of metal lath with nose-rest, removable fixation stick, movable curtain with 4 apertures with 7 mm diameter (adjustable according to pupilar distance) and carriers for patterns. Curtain and fixation stick is movable. Distance between curtain and eyes is 250 mm. Apertures are placed in shape of "chair" (two vertically and two horizontally). Patterns are usually made of 3 letters, e.g. DOG, DAY etc. Patient can see them through the two apertures in the middle of curtain (horizontally). Every eye can see only two letters. This principal image is called diplogram.

- Parallel position of eye – patient see with one eye DO, with second eye OG – together DOG
- With esotropia patient see – OGDO
- With exotropia patient see – DOOG

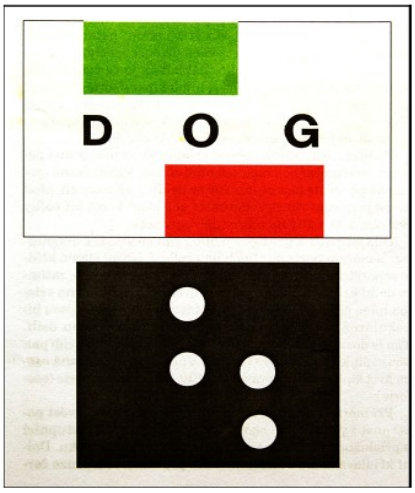

Figure 7 a – Remy's diploscope – curtain [3]
Figure 7 b – Remy's diploscope [3]

5. Diploptics training

Diploptics training was for the first time described by Avetisov in 1978. It is used for training of fusion. Instrument use real space dissociation with red filter. At first we initiate diplopia and after that we use red filter. Pictures could be than see still doubled or could be fused. We provide the treatment in dark room with one source of light, which could be placed from 1 to 6 meters. Patient should fix this point, examiner use red filter. Patient should notice his diplopia and should hold it despite weakening of light intensity and despite of presence of red filter. Due to this effect patient is trying to connect pictures with motor fusion. Children learn this way how to control position of both eyes. We can also use prisms with power matching to deviation. During the training we weaken power of prisms.

6. Reading with image divider

With this method is possible to fix fusion and train SBV. It is based on partial dissociation of image in real space. In principle we insert slit with various width in front of reading text. Person with normal SBV has no problem with reading. Eyes built the visual sense together. If there is some defect in SBV, some part of text could disappear. Part of image divider of instrument is also head-rest. If the slit is near to text, reading is harder.

Figure 8 – Image devider [3]

7. Motility training

Following exercises are not exactly orthoptics, but are complement. This training is performed without dissociation, but can positively influence function of musculus rectus externus. During this training we try to train motility of each eye (duction) and mutual cooperation between eyes (versions). If we train duction, we must use occlusion for other eye. During this exercise patient should not move with the head, but only with eye. Training could be performed in home conditions. Young children must be trained by their parents and older children by themselves. Training is based on moving of fixation target, which moves from vision direction to position of maximal action of muscle. For maximal effect of exercise patient should provide exercise several times a day, every time for few minutes.

8. Muscle trainer

In orthoptics outpatient office we can meet also muscle trainer. This instrument is usually used for patients with paralyses of any ocular muscle or as rehabilitation after surgical intervention. This device is composed of rotating arm. At the end of arm is placed “billboard”. Patient must fix his head on chinrest and watch the billboard monocularly, respective binocularly, which moves in different positions. Modern types of this instrument enable to move with arm in different directions and adjust speed of movable arm.

9. Training of convergence

Second complementary exercise to classic orthoptics is training of convergence. The biggest advantage of this exercise is possibility to do home training. Parent holds some small object in hand and child is trying to fixate this object at 1 meter distance. Parent moves with object closer to child, until it is seen doubled. Important thing is children’s head immobilization, because moving is allowed only for eyes. We try to find symmetrical convergence. In orthoptics outpatient office is used special device called convergence trainer (convergence-meter). There is movable light on the lath watched by patient. Lath works also as a scale. Patient moves with the light source closer to eyes. With this device we can measure near point of convergence (NPC). NPC is the point near the eyes when objects start to be seen doubled. This exercise is very useful for patient with divergent type of strabismus or after eye-muscle surgery (e.g. retro-position of musculus rectus internus).

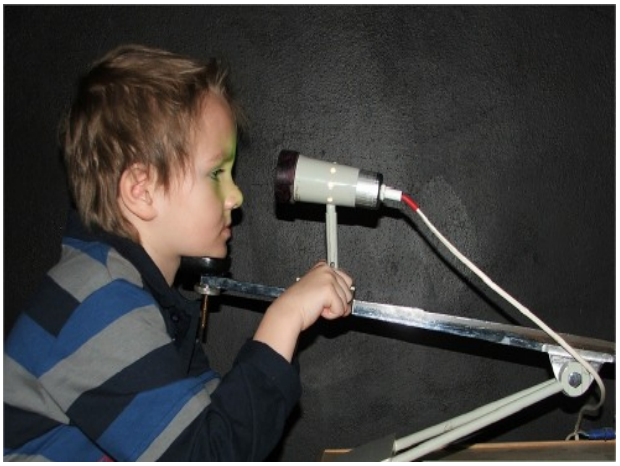

Figure 9 – Convergence trainer [3]

10. Orthoptics in Czech Republic

In the Czech Republic (CZE) we have few types of orthoptics workplaces. First types are outpatient offices in eye clinics of many hospitals in CZE. Every bigger hospital has own eye clinic with orthoptics outpatient office. For example town hospital in Pardubice (CZE) has outpatient orthoptics office. Faculty hospitals have orthoptics centers or more outpatient offices. For example Prague has 3 faculty hospitals with orthoptics centers. In Brno there is one faculty hospital with lot of outpatient offices. Other types of orthoptics workplaces are private orthoptics centers usually leaded by medicine doctor or orthoptist with maser or bachelor degree of orthoptics education, sometimes with diploma from post-graduation course. These two types of orthoptics workplaces are arranged as outpatient offices. Parents come here with their children once or twice a week. Other types of orthoptics workplace are for pre-school or school children with strabismus. These orthoptics places are really efficient for eye-therapy, because children have special orthoptics program. Children need not to do so many exercises at home. Last, special, type of orthoptics workplace is eye-sanatorium in Dvur Kralove nad Labem. Children stay here for 6 weeks. Their day schedule contains school lessons, playing games and entertainment with schoolmates. Three times per day children must undergo orthoptics training. This sanatorium works almost during whole year. This type of orthoptics training is most effective because of its intensity. Sometimes the problem is that children must stay here alone without their parents. But parents can visit their children.

10.1. Study of orthoptics in CZE

Study of orthoptics passed through o lot of changes during last 10 years. Before 2005 was legal in CZE to gain orthoptics diploma via distance studies at Institute for after-graduation education of health care staff. Today new orthoptics licence is connected only with a bachelor or master degree in orthoptics. Studying of orthoptics in CZE is today possible only in Olomouc (Palackeho University, Faculty of Science), but next year will be possible to study orthoptics also in Brno (Masaryk University, Medical Faculty).

11. Conclusion

Orthoptics training is very important discipline of ophthalmology. Now we have a lot of knowledge about the eye evolution and a lot of opportunities to diagnose vision disorders (exactly and sooner) and save or improve children's binocular vision and get better quality of their lives. Orthoptics training must be leaded with orthoptist with qualification and can be performed in outpatient offices, in hospitals or in home. Patients are usually school or pre-school children. This is the reason why orthoptist must be also emphatic, not only specialist. Success of orthoptics training depends also on motivation and good cooperation between the orthoptist and children. Orthoptics treatment in CZE has high position in word orthoptics. Every orthoptist in CZE must be member of Orthoptist association. Education of our specialist in orthoptics is still developing and we try to improve it as much as is possible.

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13. List of figures