MANAGEMENT OF PATIENTS WITH OPEN BITE MALOCCLUSION IN THE RETENTION PHASE

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Abstract

Introduction: New retainers constructions taking into account the length of orthodontic treatment and the phase of retention in patients with open bite malocclusion were developed. **Materials and methods**: 22 patients who finished an active period of orthodontic treatment received the suggested retention appliances, made of the EssixC+ polypropylene to prevent any relapse. The stability of results was assessed 12 months after with electromyography and occlusal analysis. The mechanism of action of the orthodontic appliance was evaluated through mechanical-mathematical simulation. **Results and discussion:** Mechanical mathematical simulation allowed to calculate the value and angle of application of the orthodontic effort necessary to move the mandible into the right position. **Conclusions:** The newly developed models of orthodontic appliances allowed to increase the efficacy of the retention phase due to the convenience of their use, while also aiding further remodeling of the functional state of the dentognatic apparatus.

Keywords: *open bite malocclusion, retention, orthodontic appliance.*

1. INTRODUCTION

Open bite malocclusion is one of the most complex dentognathic anomalies, accompanied by a high risk of uncertain outcomes and relapses [1]. The retention phase is a very important stage of the orthodontic treatment, allowing to retain the achieved results.

Despite the positive results of the orthodontic treatment in most patients with open bite malocclusion, it is impossible to evaluate the true success because, in the very first years after the treatment, relapse of this dentognathic anomaly may occur [2].

Stability of the non-surgical treatment options of open bite malocclusion along 12 months is 75% [3]. Evaluating the treatment results two years after the active phase, Cozza *et al.* discovered relapse in 15% of cases [4], and Huang G. J. *et al.* - in 18.4% of cases [5].

S. J. Littlewood and D. T. Millet observed the development of relapse in 18.9% of cases in adults and in 36.8% of cases in children [6], while S. Z. Kaan and M. Madlena established the relapse of the occlusion anomaly in 90% of cases [7].

D. Remmers *et al.*, who noticed relapse of the anomaly in 27% of cases 5 years after a successful treatment, state that the treatment with dental extraction is not related to the stability of the achieved outcomes [8]. G. Jonson *et al.*, however, noted a larger fraction of stable outcomes in groups with dental extraction, rather than without, which accounts for 25.8 % and 38.1%, respectively [9].

At present, there are a lot of different removable and bonded retainers: Hawley removable appliance, elastic retainers, bonded wired retainers, etc. But, even with fixed retainers, control examinations discovered that 16.6% of the patients had relapse of the open bite malocclusion [10].

Stability of treatment outcomes depends on a complete readjustment of the soft tissues [11]. Conducted functional research showed that full normalization of functional activity of mimic and masticatory muscles does not occur after orthodontic treatment, which could be the cause of relapse [12,13].

Taking into account a high fraction of relapses, there is a need for a long-term retention phase after the treatment [9]. Development of new retainers or modification of the existing constructions, which could help achieve a myodynamic balance and conserve the treatment results, remains a pressing problem.

Construction of orthodontic appliances and the ways they are used are devised based on mechanical-mathematical modelling of the treatment processes [14,15]. The eventual result of the modelling is a conceptual model, which represents the qualitative and quantitative features of the researched object [16].

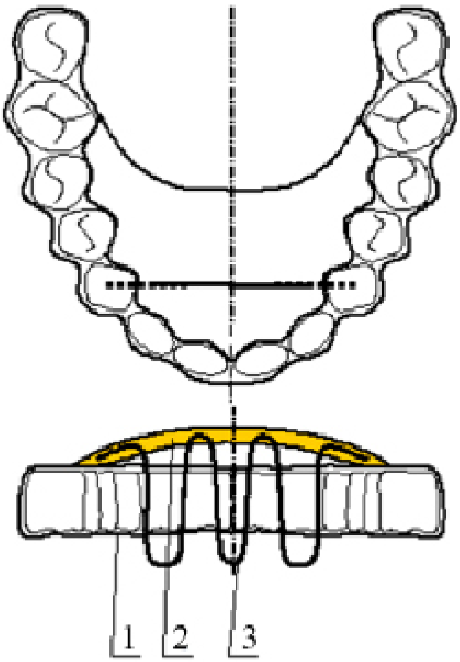
The goal of our research is to develop methods to stabilize the achieved outcomes of the orthodontic treatment in patients. Due to the length of the orthodontic treatment, the huge construction of the medical orthodontic appliances, the need in more aesthetic, light and simple to use models of retainers has risen.

2. MATERIALS AND METHODS

In the research phase, which lasted 12 months after the end of the active phase of treatment, 22 patients aged 15 or younger with vertical (12 people) and horizontal (10 people) types of facial skeleton growth were included. All were clinically examined for evaluation of facial images, plaster models of the jaws, as well as for exploration of the lateral cephalograms of the head with a notion of the type of facial skeleton growth, and functional condition of the muscles of the dentognathic system. Evaluation of results was done 12 months after the retention phase using clinical, as well as laboratory research methods (electromyography and occlusal analysis).

We devised a retainer for an upper jaw (maxilla) [17] to conserve the results of the treatment of patients with dentoalveolar form of an open bite malocclusion, as shown in Figure 1b.

The suggested retainer, made from thermoplastic material, is an alternative to a retainer plate: it needs more space in the oral cavity, covers the palate, has clamps and a vestibular arch. The retainer, made of EssixC + polypropylene, is extraordinarily firm, transparent, inexpensive, does not complicate the speech and is produced quickly. The appliance covers the dental arch of the upper jaw and the anterior part of the palate and, due to the firmness of the construction, does not let the teeth of the upper tooth row to mix into the position they were before the start of the orthodontic treatment. A protective grate is installed at the palate, between the canines, for the tongue, which changes tongue location in the resting state, as well as during talking and swallowing, and does not allow the patient to suck the tongue, press on the teeth and on the alveolar process, and deform the tooth row.



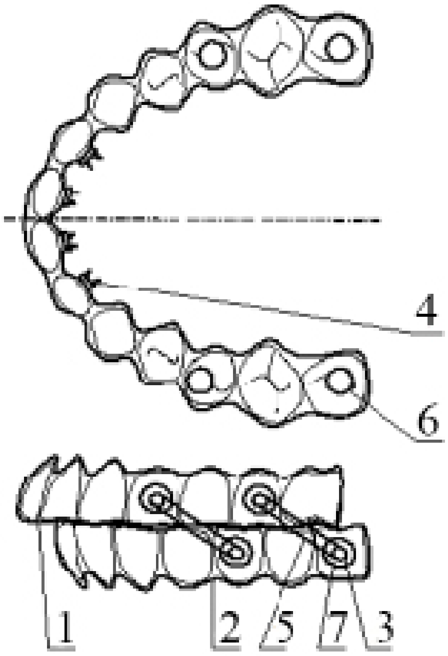
(a)

(b)

Fig. 1. Diagram (a) and photo (b) of the retainer for the upper jaw (maxilla): 1 – occlusal splint (bite splint); 2 – palate plate; 3 – wave-like wire screen

To preserve the results of the treatment of open bite malocclusion in patients with the vertical type of growth with decreased function of masticatory and mimic muscles of the maxillofacial area, we developed orthodontic retention (Fig. 2) [18].

The retainer consists of the upper and lower occlusal splints, made of thermoplastic EssixC + polypropylene lamina 1.0 mm thick by the “Ortho Technology”, which has the tongue spikes “Tongue Tamers” (Ortho Technology) welded in the projection of incisors, to prevent sucking of the tongue and any effect of pressure by the tongue onto teeth, in order to normalize its function.



(a)

(b)

(c)

Fig. 2. Diagram (a) and photo (b,c) of the retainer to preserve the results of the treatment of open bite malocclusion: 1, 2 – occlusal splint; 3 –vestibular buttons; 4 – lingual buttons; elastic rods; 6, 7 – apertures

The retainer fully covers the dental arches of the upper and lower jaws. On the dental surfaces, splint’s thickness was decreased as much as possible through the perforations in the appliance at the masticatory surfaces of the lateral teeth in the places of their first contact. On the vestibular surface of the splints in the area of the lateral teeth, the apertures were devised to fix the orthodontic buttons to apply traction between jaws, which included the orthodontic effort. Application of this effort fixes the location of the groove-to-cusp contact in patients and prevents undesirable extrusion of the molars.

To provide an effective treatment of the open bite occlusion it is necessary to correctly determine the magnitude, direction and application site of the orthodontic effort vector, which is achieved by methods of mechanical – mathematical modelling.

Mechanical – mathematical modelling

The orthodontic effort exerted by the elastic rods stretched between the vestibular buttons of the upper (maxilla) and lower (mandible) jaw moves the lower jaw upwards and forward by changing the form and size of the separate links of the dentognathic system and pushes the molars, thus preventing their extrusion.

Figure 3 plots patient's mandible with an occlusion splint of an orthodontic appliance under orthodontic effort P. in point A. through the meniscus of the temporomandibular joint of the mandible connected with the maxilla and held by the normal force R_A. The normal force R_A can be broken up into projections R_{Ax}, and R_{Ay}, which act, respectively, along the x and y axes [19]:

$R_{Ax} = R_A \cos \beta$, (1.1)

$R_{Ay} = R_A \sin \beta$, (1.2)

where β is the angle between the R_A vector and x axis. The absolute value of the normal force R_A vector and the slope of the R_A vector are calculated using the following formulas:

$R_A = (R_{Ax}^2 + R_{Ay}^2)^{0,5}$, (1.3)

$\beta = \text{arctg}\,(R_{Ay}/R_{Ax})$. (1.4)

In point B, the normal force R_B prevents extrusion of the molars by acting upon the lower jaw by the upper jaw. The orthodontic effort P acts upon point C at the a angle. The mandible is in a state of static mechanical equilibrium, so that forces , which act along the x and y axes and the momenta of these forces related to 0 can be described with the following equations [19]:

$\sum F_x = 0,$ (1,5)

$\sum F_y = 0,$ (1,6)

$\sum (F_{xi} y_i + F_{yi} x_i) = 0,$ (1,7)

where x_i, y_i are the coordinates of the applied efforts F_{xi}.

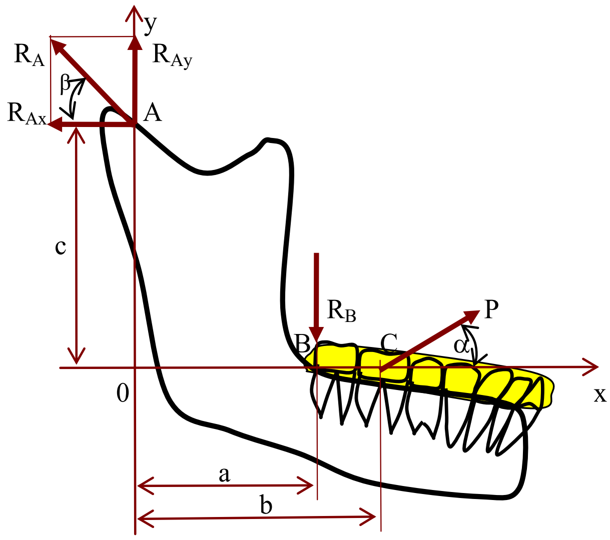


Fig. 3. The mandible with an occlusal splint of the orthodontic appliance

The system of equations (1.5) - (1.7) for the mandible can be represented as:

$R_{Ax} + P\cos a = 0$; (1.8)

$R_{Ay} - R_B + P\sin a = 0$; (1.9)

$R_{Ax} c + R_B a - P\sin a b = 0$, (1.10)

where a, b, c – are the parameters of the mandible.

Solving this system of equations (1.8) – (1.10) provides the following values for the normal forces:

$R_{Ax} = - P\cos a$, (1.11)

$R_{Ay} = P[c \cos a + (b - a) \sin a]/a$, (1.12)

$R_B = P(c \cos a + b \sin a)/a$ (1.13)

Table 1.1 lists the values of the normal forces R_{Ax}, R_{Ay}, R_A, R_B, and the tilt angle β calculated with formulas (1.3), (1.4), (1.11), (1.12), (1.13), depending on the value of a inclination of the orthodontic effort P. In our calculations we used the following parameters of the mandible: a = 56 mm, b = 77 mm, c = 75 mm for the orthodontic effort of P = 1 N.

Table 1. Normal forces of the mandible

a, grad.	R_{Ax}, N	R_{Ay}, N	R_A, N	R_B, N	β, grad.
15	0,97	1,40	1,70	1,65	55,3
30	0,87	1,35	1,61	1,85	57,2
45	0,71	1,22	1,41	1,92	59,8
60	0,50	0,99	1,11	1,86	63,2
75	0,26	0,71	0,76	1,68	69,9
90	0,0	0,38	0,38	1,38	90,0

Formulas (1.11) – (1.13) show that the normal forces R_{Ax}, R_{Ay}, R_A, R_B depend on the slope of the orthodontic effort a. The graphs plotted in Figure 4 show the relation between the normal forces R_A, R_B and the slope a. As observed, when a = 15 grad. the values of the normal forces R_A, R_B, which are directed at remodeling of, respectively, the temporomandibular joint and prevention of extrusion of the molars, have an approximately equal value.

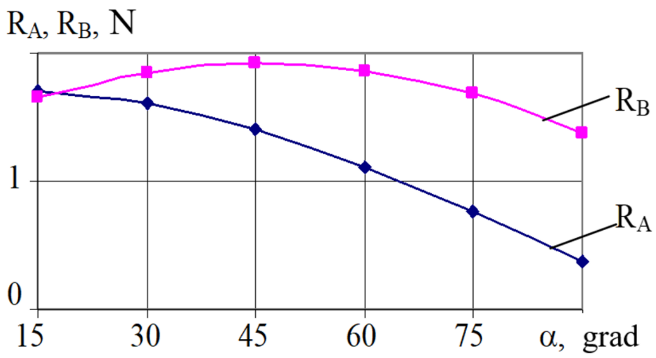


Fig. 4. Relation between the normal forces R_A, R_B and the a angle

As the a angle of the orthodontic force increases, the normal force of the mandible R_A gradually decreases almost to zero, and the effort R_B in the interval of 15° to 90° reaches its maximum. The a angle at which the value of the effort R_B reaches its maximum is calculated. In order to do this, the derivative of the effort R_B with respect to the a angle is determined and equated to zero:

$$R¢_B = P(- c \sin a + b \cos a)/a = 0. \quad (1.14)$$

Solving the equation (1.14) with respect to a results in:

$$a = \mathrm{arctg}\,(b/c) \quad (1.15)$$

By substituting the values of b and c in equation (1.15) it is found that the maximum effort $R_{A,}$ which holds back the extrusion of the molars for the given jaw's parameters: a, b and c equals a = 47 °.

The orthodontic effort can be applied to the mandible at different angles. The values of the normal forces do not only depend on the value of the orthodontic effort, but on the angle at which it is applied, as well. The mechanical mathematical modelling of the dentognatic apparatus – orthodontic appliance system under stress allows to calculate the value and angle of application of the orthodontic effort, which creates the normal forces, directed at the skeletal and dentoalveolar reconstruction of the dentognatic system.

3. RESULTS AND DISCUSSION

After an active period of orthodontic treatment, the patients were prescribed a mandatory retention phase, which is necessary not only to retain teeth location, sizes of the dental arches and interocclusal correlations, but also to let the muscles adapt and reach the muscular balance of the maxillofacial area.

22 patients, who finished the active period of orthodontic treatment and had close interocclusal contacts, evidenced by data from occlusal analysis performed by T-scan device and being in the primary period of permanent occlusion, were offered the designed constructions of the retention appliances to prevent relapse.

Taking into account that some patients had an infantile type of swallowing, even with the correct occlusal alignment we used the designed retainer appliance made of thermoplastic material with a protective grate for the tongue installed. (Fig. 5) [17].

a

b

Fig 5 a – retainer in the mouth cavity; b – anterior position of the tongue

This allowed to remove the tongue between the dental arches and adapt the tongue position to the new interocclusal alignment.

The change of tongue's position when swallowing aided remodelling of the function with activation of the circular muscle of the mouth and, as a consequence, increase in lip tone occurred. The orthodontic appliance is indicated in patients with a dentoalveolar form of open bite malocclusion, horizontal type of facial skeleton growth, partial normalization of the masticatory muscles function after an active period of orthodontic treatment. Such an application was recommended to 10 patients throughout 12 months. As the clinical observations showed, we had positive results in remodelling of the masticatory and mimic muscles in 9 patients. One patient was observed to have a relapse in the form of a minor 1 mm vertical gap, caused by refusal to regularly use the appliance.

12 patients with vertical type of facial skeleton growth with decreased function of the masticatory and mimic muscles of the maxillofacial area were designed the orthodontic retention appliance (Fig. 6) [18].

To preserve the stability of the groove-to-cusp contacts in patients with a vertical type of growth, together with the thermoplastic splints for the upper and lower jaws, we applied intraoral vertical intermaxillary rods as an adequate alternative to extraoral rods to aid fixation of the mandible in vertical direction. The effective traction vector passed from the first permanent molar of the maxilla to the second permanent molar of the mandible, or from the first upper pre-molar to the second lower one. Elastic rods were fixed directly to the buttons, located on the vestibular surface of the teeth, being recommended to be applied before sleep, when the activity of the masticatory muscles decreased, to ensure a correct interocclusal alignment and to prevent the lateral teeth from extrusion.

The mechanical mathematical modelling of the orthodontic appliance conducted to retain the results of treatment of the open bite malocclusion, equipped with intermaxillar rods, allowed to calculate the value and angle of application of the orthodontic effort for moving the mandible in the right position. If the main goal of the therapy of open bite malocclusion is prevention of undesirable extrusion of the molars, then the orthodontic effort has to be applied at an angle close to 45° with respect to the axis of occlusion [20].

a

b

c

Fig. 6. Retention appliance: a, b – in the oral cavity; c, d – intermaxillar rods

The first contact of the tongue with the sharp lingual buttons causes painful sensations, pushing the tongue to take the right position when talking, swallowing, chewing, in other words to adapt to its right position. The retaining complex made of a transparent polypropylene film is indicated in patients who fear fixing the lingual buttons directly in the oral cavity, explained by their possible detachment. Fixation of the lingual buttons on the appliance is stronger than on the teeth surface, and use of intraoral rods is more aesthetically pleasing compared to the extraoral ones.

The retention appliance was used in 12 patients with the vertical type of facial skeleton growth. Based on data of electromyography, performed 12 months after the start of the retention phase, 10 patients were proved to achieve a direct effect of the system on the muscular activity. 2 patients were diagnosed with relapse in the form of vertical interincisor gap of 2 mm, explained by an irregular use of the retainer. 12 months after the end of active period of orthodontic treatment, relapse was observed in 2 subjects (16.6%), which is explained by the irregular use of the retainer, as well as by continuing vertical growth of facial skeleton.

4. CONCLUSIONS

The retention phase can last a few years, its length depending upon many factors: length of the treatment, patient's age, direction of facial growth, recovery of the myodynamic balance, masticatory, mimic muscles and the tongue. When choosing the model of the retainer, one has to take into account the growing tendency of the facial skeleton, because the type of rotation of the mandible could cause a relapse at skeletal level, especially in males in the active growth phase.

Suggested models of the retention appliance, made from polypropylene EssixC+, are extraordinarily firm, transparent, inexpensive, do not complicate speech and are produced quickly. The use of the suggested appliances allowed to reliably conserve the results of the orthodontic treatment in patients with open bite malocclusion and aided in further remodelling of the functional state of the dentognatic apparatus in patients with horizontal and vertical types of facial skeleton growth with decreased function of the masticatory and mimic muscles of the maxillofacial area and tongue after a period of active therapy.

To amplify the intrusion effect and the occlusal contacts in the lateral areas, intraoral vertical elastic rods were used, wieved as an alternative to extraoral rods.

Mechanical mathematical modelling of the orthodontic appliance, equipped with intermaxillar rods, showed that the orthodontic effort depends not only on the magnitude of traction of the intermaxillar rods, but also on the angle of its application with respect to the axis of occlusion.

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