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Treatment of sagittal bite anomalies: Effect of different orthodontic devices on the state of temporomandibular joint

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Summary. This review reflects the results obtained with different orthodontic devices used for treatment on the state of temporomandibular joint.

Key words: muscles, temporomandibular joint (TMJ), functional treatment.

The changes taking place in the temporomandibular joint (TMJ), muscle complex, and occlusive contacts caused by functional treatment approaches are of the greatest interest for research workers and are discussed long ago in scientific literature. The effect of functional devices being intended for enhanced growth of non-sufficiently developed jaw, the most important problem concerns the treatment efficacy; therefore, the main specialists' attraction is paid to the efficacy of treatment approaches; the problem is if they are really effective and if they really regulate the jaw growth in the direction necessary in concrete clinical situations. Besides, it is also important to understand if the use of such approaches does not cause some undesirable side effects. Recently, great attention is paid to study of non-replaceable (non-removable) functional devices because of their intensive elaboration; a lot of new devices have been recently presented on the orthodontic production market including also such modified variants of Herbst device as Twin Block and Forsus. They are rather well adapted for patients' need and are now widely used. However, the up-to-date literature available deals with investigations aiming to understand the effect of replaceable functional devices intended for sagittal anomalies treatment on maxillofacial structures; these devices include Frenkel apparatus, bionators, activators, and twin-blocks.

A.Gupta et al. realized a series of investigations concerning the influence of lower jaw protraction on the load distribution in the TMJ using a 3D-model having been developed on the basis of magnetic resonance tomograms of an aged 12 boy [1, 2]. This model simulated the sagittal displacement of lower jaw by 5 mm and also the bite opening by 2, 4, and 6 mm. The authors describe that the load, i.e. tissue extension, was localized on the posterior upper surface of joint, the tissue compression being occurred on its anterior and upper anterior surfaces. In addition, the tissue extension was also found in the posterior area of articular fossa adjacent to the site of connective tissue attachment to the joint. The increase of the constructive occlusion height was accompanied by increased load for the TMJ of the same localization. According to the authors' opinion, the observed load distribution in TMJ in the case of lower jaw protraction and bite opening may be due to the condyle growth occurring in posterio-anterior direction. The load distribution in joint fossa correlates also with increased cell activity found in its posterior area. The investigators propose the increase of bite height may be favorable for functional device efficacy.

S. Baltromejus et al. compared so-called effective TMJ growth and the chin position during the treatment using activator and Herbst device [3]. Effective TMJ growth is a result of condyle and joint fossa rebuilding as well as of the condyle position changes within its fossa. The authors underline that the joint remodeling in these two patient groups has been carried out in two absolutely different directions, the changes being vertical and somewhat directed to the front in the group with activator contrary to changes directed mostly backwards in the group treated by the Herbst device. The changes of the chin position are significantly more pronounced in the patient group with the Herbst device. Anterior rotation of the lower jaw was seen in patient group with activator, insignificant backwards rotation being observed in persons treated with Herbst device. The authors underline the positive changes to be seen in both patient groups; however, in patients having used the Herbst device such results were obtained more quickly, the sagittal effects being better.

Using the Herbst device, S. Ruf and H. Pancherz observed substantial rebuild of both condyle and articular fossa [4]. In this case the effective condyle growth was almost by 5 times higher comparing to “ideal Bolton standards”. The authors observed the results of rebuilding of condyle and articular fossa on magnet resonance images taken in 6-12 weeks after the treatment beginning, the condyle rebuilding having been occurred more early than the fossa rebuilding.

C. Serbesis-Tsarudis and H. Pancherz also studied successful TMJ growth and changes of the chin position using the Herbst device and compared them with the same parameters obtained in class II patients having used intermandibular tractions by the aid of bracket-system [5]. No orthodontic effect was found following intermandibular elastics use, the Herbst device having permitted to obtain soon after the necessary changes. However, it is probable that the use of elastics for the treatment of class II anomalies may influence on the TMJ structures.

E.G. Katsavrias and J.C. Voudouris investigated the changes of articular fossa following the use of activator to treat class II skeletal cases [6]. The authors found no significant changes of articular fossa as a treatment result.

N. Wadhawan et al. note the use of twin-block or bionator for class II, subclass 1 cases treatment and the treatment completion with non-removable devices leads to the onward displacement of condyle and articular fossa complex [7]. The correlation of joint structures was changed during the treatment: after the treatment beginning the onward condyle displacement and disk retrusion were seen; however, following the treatment completion the TMJ structures correlation was restored becoming the same as before treatment.

Adaptation of TMJ structures following functional therapy was also described by other researchers. For example, G. Kinzinger et al. saw the restoration of physiological TMJ structures correlation after functional therapy with FMA devices (Functional Mandibular Advancers) [8]. The same results were observed by J. Cobo et al. [9] who had used different types of orthodontic functional devices. Similar data were obtained also by G. Kinzinger et al. having studied the effect of non-removable functional devices on the TMJ structures correlation [10, 11]. Having used the Herbst device, S. Ruf and H. Pancherz stated physiological TMJ structures correlation in the end of treatment in spite of pronounced effective TMJ growth [12]. The same results were reported by K. Popowich et al. having carried out a review of special publications concerning the effect of Herbst device on the TMJ [13]. K. Hansen et al. observed 7.5 years old patients having been treated using the Herbst device, no side negative effects of this device on the TMJ being found [14].

However, Z.M. Arat et al. showed the onward displacement of the condyle in persons with anomalies class II, subclass 1 using Andresen activator [15]. S. Arici et al. observed mostly more backward candyle position after the treatment by Forsus device [16].

K.L. Carlton and R.S. Nanda carried out a systematic analysis of the TMJ changes having occurred following orthodontic treatment of class II, subclass 1 anomalies [17]. After the treatment completion these authors found no significant changes of TMJ structures correlation as well as no correlations with such parameters, as patients' age, sex, skeletal and dento-alveolar parameters, signs (markers) or symptoms of the TMJ damages, use of head traction, types of intermandibular elastics, treatment accompanied or not accompanied by teeth extraction.

A.A. Gianelly et al. estimated the condyle positions in class II patients whose treatment using non-replaceable devices had been accompanied by their first premolar extraction; no changes of condyles and articular fossae correlation was demonstrated [18]. No correlations were found between condyle positions and orthodontic treatment type, bite depth, inter-incisor angle, and upper incisors inclination.

Using distraction to extend lower jaw length and/or to broaden its anterior area in severe skeletal class II cases, Y. Azumi et al. stated condyles displacement in atricular fossae upwards and backwards; it should be noted that in 20 % of cases condyle resorption was observed [19].

INFLUENCE ON THE MUSCLE COMPLEX

In available literature there are a lot of publications concerning head and neck muscles functioning during sagittal anomalies treatment with functional approaches.

T.D. Freeland investigated the activity of facial and masticatory muscles in patients with Frenkel functional regulative device [20]. The author notes the activity of suprahyoid group muscles as well as upper lip ones to be significantly lower in this group comparing to the control group patients with class I occlusions. In class III patients, the activity of facial and masticatory muscles was higher comparing to the control group.

R. Miralles et al. underline the use of activator for class II patients leads to significantly higher electromyographic activity of masticatory and anterior temporal muscle comparing to treatment without activator [21]. It is important to note this effect becoming less pronounced when patients grow old, so the authors propose the therapeutic use of activator for patients in early years.

C. Yamin-Lacouture et al. studied electromyographic activity of masticatory and digastric muscles as well as of low and upper heads of lateral pterygoid muscle in primates with constantly implanted electrodes [22]. Their experiments are based on the hypothesis assuming that the use of functional devices increases the activity of both lower and upper heads of lateral pterygoid muscle; in turn, this activity increase stimulates the condyle growth. The authors used Herbst device, Frenkel regulator, and Clark twin-block. Their experiments showed the use of these devices, both at once and after prolonged time, led to the decrease of mentioned muscles activity during rest and swallowing, although significant skeletal changes had been observed. As a result, the hypothesis proposed was not confirmed.

J. Ahlgren mentions the activator use during the day time leads to increased activity of protractor muscles and to inhibition of retractor ones; in night, however, no changes of their activity is seen, only the passive tissue stretching having place [23].

C. Carels and D. van Steenberghe carried out the study of masticatory muscle electromyographic activity in children with class II, subclass 1 bite pathologies during treatment by the bionator; the researchers found specific patterns of muscle activity inherent to successful clinical results [24]. The authors thought some further investigations in this direction might have been useful for the development of functional therapy. However, we have found no similar publications following this study having been carried out in 1986.

An interesting series of muscle state studies was realized by German scientists, the expression of myosin and myostatin heavy chains was estimated on the base of their mRNAs expression levels being the marker of muscle state. The evident novelty of such approach consists in direct evaluation of the muscle state taking into account the contractor protein expression with no possible influence of foreign factors on electromyography data. It should be, however, taken into consideration this approach to need muscle tissue materials (taken by biopsy). T. Gedrange et al. studied the mRNA expression and synthesis of heavy chains of myosin in masticatory muscles of patients with distal and mesial occlusions [25]. According to their data, the anterior part of masticatory muscle of patients with distal occlusion contains higher levels of mRNA coding the proteins mentioned above comparing to patients with mesial occlusion. According to the authors' opinion, such different contractor protein expression may be due to increased muscle load. The authors think the level difference of expressed mRNA coding the contactor protein may be due to increased muscle load because of unfavorable contraction vector. No differences concerning the myosin distribution in the muscle were found.

A series of investigations was later realized to study the muscle state before and after orthognathic surgical treatment of sagittal skeletal occlusion anomalies. N. Maricic et al. studied the masticatory muscle adaptation following orthognathic surgery aiming to estimate the recurrence probability caused by the loss of muscle adaptation [26]. The authors note the restoration of mRNA expression coding heavy chains of myosin and myostatin occurs in six months after orthognathic surgical intervention in cases of both distal and mesial jaw correlation. K. Oukhai et al. investigated diagnostic and prognostic value concerning determination of embryonic myosin modifications content in masticatory muscle; they think these proteins may be important for muscle adaptation [27]. W. Harzer et al. emphasize the treatment to cause the displacement from the myosin type I content (from 46 % before to 37 % after treatment) to the myosin type IIa (its share increased from 29 % before treatment up to 42 % following the treatment) in the masticatory muscle, these changes being correlated with increased quantity of teeth found in occlusion [28]. The authors state the correlation between the displacement of myosin isoforms and increase of occlusive contacts number indicate the increased force of the masticatory muscle stabilizing the treatment results.

T. Gedrange et al. note the restoration of mRNA levels coding high myosin chains in masticatory muscle after orthognathic surgical procedure occurs more quickly in patients with distal occlusions comparing to persons with mesial ones

[29]. The authors underline the post-surgical patients must carry out exercises for their mimic and masticatory muscles to increase the stability of results obtained and to prevent recurrences. Only 35 mg of muscle tissue are needed to determine the mRNA levels in masticatory muscles.

It is necessary to indicate these results to be also interesting from the point of view of non-removable functional devices use; in such cases the "bite jumping" is rather swift and needs also muscle complex adaptation.

S. Hiyama at al. note that in spite of evident improvement of muscular function following orthodontic treatment it is necessary to define more precisely interactions between causes and results for electromyographic data and occlusive contacts acquired due to the treatment [30].

A. Erdem et al. studied the changes of soft tissues profile and of electromyographic activity during the treatment of anomalies class II, subclass 1 with activator [31]. According to the results obtained, the treatment was accompanied by improvement of soft tissue profile and increased electromyographic activity of masticatory, temporal, and orbicular mouth muscles.

In accordance with data of S. Kiliaridis et al., after the treatment of children with dental anomalies class II and skeletal class using twin-blocks, a moderate atrophy of the masticatory muscle was observed [32]. The initial muscle state may be associated with low incisors proclination, position of first upper molars and A-point. The children with more thin masticatory muscle before treatment demonstrated more pronounced low incisors proclination, distalization of upper molars and backward displacement of the A-point.

Having used the device Forsus, S. Sood et al. found the significant decrease of temporal and masticatory muscles activity after a month of treatment; their activity was then gradually restored [33]. Electromyographic parameters restored their initial levels in 6 months after the treatment beginning. In another similar study S. Sood et al. obtained coincident data [34].

It should be noted the data of different investigations dealing with the problem of muscle complex functioning when functional treatment is used are generally not contradictory. In some studies the authors underline the improvement of muscle function caused by the treatment, in other ones – muscle complex adaptation to new lower jaw position and to changed occlusive contacts. In general, the data obtained reflect the satisfactory efficacy of functional treatment of class II pathologies.

As to malocclusions class III, there are scanty data concerning the functional approaches for their treatment. The studies concerning pathologies class III concern mostly the recurrence prevention following orthognatic surgical intervention.

D.R. de Souza et al. studied the electric activity of orbicular mouth muscle and of chin muscle in patients with occlusions class II, subclass 1; such patients treatment was accompanied by first premolar extraction. The authors found no significant changes of electric activity of muscles mentioned during rest and swallowing in spite of significant changes of dental arches perimeters [35]. However, the indices in patient group with anomalies mentioned were significantly different from those found in the control group, i.e. in patients with class I occlusion. The authors think the absence of adaptation of muscular complex to the changed teeth position caused by the treatment may influence on the stability results leading to recurrence development. This is the only study found during our search having been carried out in database systems Pubmed, Cochrane Database Google Scholar and concerning exactly muscular activity in the course of treatment using non-removable devices.

INFLUENCE ON OCCLUSIVE CONTACTS

It should be noted the problem of occlusive changed due to orthodontic treatment of sagittal anomalies is mostly discussed concerning comparison of its different approaches, long-term stability of treatment results or contribution of dento-alveolar changes to the general result. The normalization of molar and canine correlations as well as of sagittal and vertical overbite, i.e. exactly of the achievement of dento-alveolar changes desired are almost not discussed. A number of studies available investigate mostly the effect of functional approaches to sagittal anomalies treatment and of possible recurrences after the results have been obtained.

C. Mauck and J. Trankmann studied the efficacy of early orthodontic treatment for patients with different types of occlusion anomalies. The mean patients' age in their sample was 4.4 years, the mean age of the same patients during the second examination being 15.4 years [36]. The authors indicate there were no recurrences in all patients having obtained successful treatment during milk occlusion, the formation of permanent occlusion occurred correctly. The authors think the achievement of the occlusion class I for the milk occlusion guarantees the correct mandibulo-facial growth. This fact is to be taken into consideration because sagittal malocclusions are found to be not self-recovered in the course of patients' growing old. For example, the data of T. Baccetti et al. show the signs of occlusion class II are usually kept during bite changes and may be enhanced during permanent bite formation because of unfavorable mandibulo-facial growth [37].

In spite of evident positive effect of orthodontic treatment on teeth correlation, the correct functional occlusion does not always develop after such treatment completion. For example, Y. Deng and M.K. Fu investigated the changes of occlusive contacts in position of intercuspation before and after orthodontic treatment of sagittal anomalies [38, 39]. After orthodontic treatment the mean contact quantity on front teeth decreased as well as the mean contact area. The authors observed increased contact quantity for lateral teeth. Generally saying, the authors think that the orthodontic treatment has positive effects on the load distribution during chewing in patients of the sample studied. However, having studied the distribution of functional contacts after treatment using a lingual bracket-system, J. Cohen-Levy and N. Cohen note that even if the aim is achieved, occlusion forces may be distributed in non-regular manner; in such cases the asymmetry and potential recurrence danger are present caused by the absence of functional equilibrium [40]. J.R. Clark and R.D. Evans inform that after orthodontic treatment using non-removable devices balancing contacts are observed on one of parts [41].

Rather considerable number of studies deal exactly with comparison of different approaches for sagittal anomalies belonging mostly to the class II. B. Nelson et al. compared skeletal and dento-alveolar effects of two treatment approaches for class II anomalies – Begg techniques using elastics and Herbst device [42]. According to their results, the use of the Herbst device leads to significant skeletal result (51 %), such result being reached only for 4 % of patient group treated using the Begg techniques. Among dento-alveolar changes predominant in this group vertical changes were the most pronounced, in particular increased height of a face low third and increased NSL/ML angle.

G. Kinzinger et al. compared the effects of class II anomalies correction using non-removable functional devices, camouflage accompanied by extraction of first premolars of the upper jaw, and orthosurgical intervention [43]. The data concerning dento-alveolar effects show the incisors positions were rather different in three groups studied. The incisors kept their correct position in patient group after orthosurgical treatment. In patients having been treated by functional orthodontic devices the retrusion of upper incisors and proclination of lower ones were found. In patient group with extractions retrusion of both lower and upper incisors had place accompanied by the increase of nasolabial angle. The authors emphasize this fact to be important and should be taken into consideration for the planning the patient treatment.

Having reviewed special literature, J.E. Harrison et al. found no statistically significant differences in sagittal overbites after treatment using functional devices and early treatment using head traction [44]. The type of functional device having been used for class II anomalies correction did not also influence on sagittal overbites obtained. At the same time the authors indicate that, according to the data available, early treatment of sagittal anomalies is not more successful than their treatment in adolescents.

According to the data of S.D. Keeling et al., the use of both bionator and head traction for treatment of patients class II, their mean age being 9.6 years, led to the correction of molar correlation, decrease of the sagittal split, neutralization of apical basis discrepancy and caused at the same time the teeth distalization [45].

R.R. de Almeida-Pedrin et al. found no significant differences between teeth position after correction of the class II anomalies using pendulum device, neck traction, and treatment including the extraction of two premolars of the upper jaw [46]. However, the authors underline the treatment results had been obtained more quickly in patient group with premolar extraction.

J.R. Wortham et al. compare dento-alveolar results when class II occlusion anomalies were treated using two-phase (bionator and non-removable devices) approaches and one-phase (non-removable devices) ones [47]. The authors insist that no differences between two groups of patients has been found after treatment.

N. Bock and S. Ruf studied the stability of occlusive contacts after treatment of adolescents and adults with class II occlusions using the Herbst device [48]. According to their data, the correlation stability of molars, canines, and vertical overbite were the following: in early adolescent age – 95.0, 100.0, and 70.0 %, respectively; in late adolescent age – 92.9, 74.1, and 85.7 %, respectively; in adults – 61.5, 80.8, and 69,2 %, respectively. Therefore, the results of treatment kept rather stable during 27 months beginning from the moment when the device had been took off. The most stable treatment results were seen in the adolescent group.

Having studied the long-term stability following the treatment with activator and head traction of the class II patients, M. Lerstol et al. state that all patients of the sample studied, their mean age being 11.9, achieved the class I state according the Angle classification, their bite depth and sagittal split having significantly decreased [49]. The interincisor angle increased due to significant retroclination of upper and lower incisors. The authors did not see substantial recurrences in patients after 12–15 years of retention period, the mean age of patients having reached 28.6 years.

Some researchers think the long-term results stability to depend not only on the treatment approach chosen, but also on some other pre-conditions. E. Kondo states the achievement of the successful stable result after treatment of class II, subclass 2 cases is possible if at the end of treatment there are the following characteristics of the dento-mandibular system [50]: molar axes are perpendicular to the occlusion area; the lower incisor axis is almost perpendicular to the lower jaw area; occlusion hypercorrection in the anterior part of dentition guarantees the contact of incisors cutting edges. During the retention period the author noted vestibular inclination of incisors accompanied by correct vertical overbite as well as by correct pro- and retrusive ways for lower jaw traction.

Besides obtaining new occlusive contacts during active treatment period, the problem of final teeth displacement during the retention period is not yet completely solved. Y. Razdolsky et al. state the final placement of occlusive contacts occurs during first three months of occlusion period [51]. It concerns, first of all, occlusion placement in the vestibulo-oral direction. D.S. Durbin and C. Sadowsky publish almost similar data: according to their information, the contact quantity in their mixed sample including patients with sagittal anomalies increased by 14 % during first three months of retention [52].

CONCLUSIONS

Generally saying, it should be noted the dento-alveolar changes do not belong to problems being of paramount interest for researchers discussing the effects of sagittal anomalies treatment. Because of possibilities of modern orthodontic approaches, the achievement of necessary correlation may be obtained without difficulty, therefore the studies being carried out concern mostly of optimal results search, i.e. of long-term stable results.

References

1. Gupta A., Kohli V.S., Hazarey P.V., Kharbanda O.P., Gunjal A. Stress distribution in the temporomandibular joint after mandibular protraction: a 3-dimensional finite element method study. Part 1. Am J Orthod Dentofacial Orthop. 2009 Jun; 135 (6): 737–48.

2. Gupta A., Hazarey P.V., Kharbanda O.P., Kohli V.S., Gunjal A. Stress distribution in the temporomandibular joint after mandibular protraction: a 3-dimensional finite element study. Part 2. Am J Orthod Dentofacial Orthop. 2009 Jun; 135 (6): 749–56.

3. Baltromejus S., Ruf S., Pancherz H. Effective temporomandibular joint growth and chin position changes: Activator versus Herbst treatment. A cephalometric roentgenographic study. Eur J Orthod. 2002. Dec; 24 (6): 627–37.

4. Ruf S., Pancherz H. Temporomandibular joint growth adaptation in Herbst treatment: a prospective magnetic resonance imaging and cephalometric roentgenographic study. Eur J Orthod. 1998. Aug; 20 (4): 375–88.

5. Serbesis-Tsarudis C., Pancherz H. «Effective» T.M.J. and chin position changes in Class II treatment. Angle Orthod. 2008. Sep; 78 (5): 813–8.

6. Katsavrias E.G., Voudouris J.C. The treatment effect of mandibular protrusive appliances on the glenoid fossa for Class II correction. Angle Orthod. 2004. Feb; 74 (1): 79–85.

7. Wadhawan N., Kumar S., Kharbanda O.P., Duggal R., Sharma R. Temporomandibular joint adaptations following two-phase therapy: an MRI study. Orthod Craniofac Res. 2008. Nov; 11 (4): 235–50.

8. Kinzinger G., Gülden N., Roth A., Diedrich P. Disc-condyle Relationships during Class II Treatment with the Functional Mandibular Advancer (FMA). J Orofac Orthop. 2006. Sep; 67 (5): 356–75.

9. Cobo J., Argüelles J., Vijande M., Costales M., Fernández Y. Transcranial oblique lateral radiography to verify the position

of the mandibular condyles with the use of functional appliances. Eur J Orthod. 1993. Oct; 15 (5): 387–91.
10. Kinzinger G.S., Roth A., Gülden N., Bücker A., Diedrich P.R. Effects of orthodontic treatment with fixed functional orthopaedic appliances on the condyle-fossa relationship in the temporomandibular joint: a magnetic resonance imaging study (Part I). Dentomaxillofac Radiol. 2006. Sep; 35 (5): 339–46.
11. Kinzinger G.S., Roth A, Gülden N, Bücker A, Diedrich PR. Effects of orthodontic treatment with fixed functional orthopaedic appliances on the disc-condyle relationship in the temporomandibular joint: a magnetic resonance imaging study (Part II). Dentomaxillofac Radiol. 2006 Sep; 35 (5): 347–56.
12. Ruf S., Pancherz H. Temporomandibular joint remodeling in adolescents and young adults during Herbst treatment: A prospective longitudinal magnetic resonance imaging and cephalometric radiographic investigation. Am J Orthod Dentofacial Orthop. 1999. Jun; 115 (6): 607–18.
13. Popowich K., Nebbe B., Major P.W. Effect of Herbst treatment on temporomandibular joint morphology: a systematic literature review. Am J Orthod Dentofacial Orthop. 2003. Apr; 123 (4): 388–94.
14. Hansen K., Pancherz H., Petersson A. Long-term effects of the Herbst appliance on the craniomandibular system with special reference to the TMJ. Eur J Orthod. 1990 .Aug;.12 (3): 244–53.
15. Arat Z.M., Gökalp H., Erdem D., Erden I. Changes in the TMJ disc-condyle-fossa relationship following functional treatment of skeletal Class II Division 1 malocclusion: a magnetic resonance imaging study. Am J Orthod Dentofacial Orthop. 2001. Mar; 119 (3): 316–9.
16. Arici S., Akan H., Yakubov K., Arici N. Effects of fixed functional appliance treatment on the temporomandibular joint. Am J Orthod Dentofacial Orthop. 2008. Jun; 133 (6): 809–14.
17. Carlton K.L., Nanda R.S. Prospective study of posttreatment changes in the temporomandibular joint. Am J Orthod Dentofacial Orthop. 2002. Nov; 122 (5):486–90.
18. Коренев А.Г., Никитина Н.С., Райская М.В. Эпидимиологическая характеристика зубочелюстных аномалий у детей и подростков в возрасте от 3 до 18 лет, проживающих в крупном городе или сельской местности // Стоматол. журн. – 2005. – № 1. – С. 9–11.
19. Azumi Y., Sugawara J., Takahashi I., Mitani H., Nagasaka H., Kawamura H. Positional and morphologic changes of the mandibular condyle after mandibular distraction osteogenesis in skeletal class II patients. World J Orthod. 2004. Spring; 5 (1): 32–9.
20. Freeland T.D. Muscle function during treatment with the functional regulator. Angle Orthod. 1979. Oct; 49 (4): 247–58.
21. Miralles R., Berger B., Bull R., Manns A., Carvajal R. Influence of the activator on electromyographic activity of mandibular elevator muscles. Am J Orthod Dentofacial Orthop. 1988. Aug; 94 (2): 97–103.
22. Yamin-Lacouture C., Woodside D.G., Sectakof P.A., Sessle B.J. The action of three types of functional appliances on the activity of the masticatory muscles. Am J Orthod Dentofacial Orthop. 1997. Nov; 112 (5): 560–72.
23. Ahlgren J. Early and late electromyographic response to treatment with activators. Am J Orthod. 1978. Jul; 74 (1): 88–93.
24. Carels C., van Steenberghe D. Changes in neuromuscular reflexes in the masseter muscles during functional jaw orthopedic treatment in children. Am J Orthod Dentofacial Orthop. 1986. Nov; 90 (5): 410–9.
25. Gedrange T., Büttner C., Schneider M., Oppitz R., Harzer W. Myosin heavy chain protein and gene expression in the masseter muscle of adult patients with distal or mesial malocclusion. J Appl Genet. 2005; 46 (2): 227–36.
26. Maricic N., Stieler E., Gedrange T., Schneider M., Tausche E., Harzer W. MGF- and myostatin-mRNA regulation in masseter muscle after orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008. Oct; 106 (4): 487–92.
27. Oukhai K., Maricic N., Schneider M., Harzer W., Tausche E. Developmental myosin heavy chain mRNA in masseter after orthognathic surgery: a preliminary study. J Craniomaxillofac Surg. 2011. Sep; 39 (6): 401–6.
28. Harzer W., Worm M., Gedrange T., Schneider M., Wolf P. Myosin heavy chain mRNA isoforms in masseter muscle before and after orthognathic surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007. Oct; 104 (4): 486–90.
29. Gedrange T., Büttner C., Schneider M., Lauer G., Mai R., Oppitz R., Harzer W. Change of mRNA amount of myosin heavy chain in masseter muscle after orthognathic surgery of patients with malocclusion. J Craniomaxillofac Surg. 2006. Sep; 34. Suppl 2: 110–5.
30. Hiyama S., Asakawa S., Ono T., Mochida-Matsubara M., Ohyama K. Evaluation of stomatognathic function in orthodontic treatment.World J Orthod. 2005. Winter; 6 (4): 343–54.

31. Erdem A., Kilic N., Eröz B. Changes in soft tissue profile and electromyographic activity after activator treatment. Aust Orthod J. 2009. Nov; 25 (2): 116–22.
32. Kiliaridis S., Mills C.M., Antonarakis G.S. Masseter muscle thickness as a predictive variable in treatment outcome of the twin-block appliance and masseteric thickness changes during treatment. Orthod Craniofac Res. 2010. Nov; 13 (4): 203–13.
33. Sood S., Kharbanda O.P., Duggal R., Sood M., Gulati S. Muscle response during treatment of Class II Division 1 malocclusion with Forsus Fatigue Resistant Device. J Clin Pediatr Dent. 2011. Spring; 35 (3): 331–8.
34. Sood S., Kharbanda O.P., Duggal R., Sood M., Gulati S. Neuromuscular adaptations with flexible fixed functional appliance – a 2-year follow-up study. J Orofac Orthop. 2011. Nov; 72 (6): 434–45.
35. De Souza D.R., Semeghini T.A., Kroll L.B., Berzin F. Oral myofunctional and electromyographic evaluation of the orbicularis oris and mentalis muscles in patients with class II/1 malocclusion submitted to first premolar extraction. J Appl Oral Sci. 2008. May-Jun; 16 (3): 226–31.
36. Mauck C., Tränkmann J. Influence of orthodontic treatment in the primary dentition upon development of the dentition and craniofacial growth. J Orofac Orthop. 1998; 59(4): 229–36.
37. Baccetti T., Franchi L., McNamara J.A. Jr., Tollaro I. Early dentofacial features of Class II malocclusion: a longitudinal study from the deciduous through the mixed dentition. Am J Orthod Dentofacial Orthop. 1997. May; 111 (5): 502–9.
38. Алимова М.Я. Современные возможности ортодонтического лечения с помощью несъемной аппаратуры // Ортодент-Инфо. – 2001. – № 1. – С. 2–3.
39. Алимова М.Я. Общие аспекты профилактического и лечебного протезирования при преждевременной потере молочных моляров // Актуальные проблемы медицины. – Воронеж, 1998. – С. 213–214.
40. Cohen-Levy J., Cohen N. Computerized analysis of occlusal contacts after lingual orthodontic treatment in adults. Int Orthod. 2011. Dec; 9 (4): 410–31.
41. Clark J.R., Evans R.D. Functional occlusal relationships in a group of post-orthodontic patients: preliminary findings. Eur J Orthod. 1998. Apr; 20 (2): 103–10.
42. Nelson B., Hansen K., Hägg U. Class II correction in patients treated with class II elastics and with fixed functional appliances: a comparative study. Am J Orthod Dentofacial Orthop. 2000. Aug; 118 (2): 142–9.
43. Kinzinger G., Frye L., Diedrich P. Class II treatment in adults: comparing camouflage orthodontics, dentofacial orthopedics and orthognathic surgery – a cephalometric study to evaluate various therapeutic effects. J Orofac Orthop. 2009. Jan; 70 (1): 63–91.
44. Harrison J.E., O'Brien K.D., Worthington H.V. Orthodontic treatment for prominent upper front teeth in children. Cochrane Database Syst Rev. 2007. Jul 18; (3): CD003452.
45. Keeling S.D., Wheeler T.T., King G.J., Garvan C.W., Cohen D.A., Cabassa S., McGorray S.P., Taylor M.G. Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear. Am J Orthod Dentofacial Orthop. 1998. Jan; 113 (1): 40–50.
46. De Almeida-Pedrin R.R., Henriques J.F., de Almeida R.R., de Almeida M.R., McNamara J.A. Jr. Effects of the pendulum appliance, cervical headgear, and 2 premolar extractions followed by fixed appliances in patients with Class II malocclusion. Am J Orthod Dentofacial Orthop. 2009. Dec; 136 (6): 833–42.
47. Wortham JR, Dolce C, McGorray SP, Le H, King GJ, Wheeler TT. Comparison of arch dimension changes in 1-phase vs 2-phase treatment of Class II malocclusion. Am J Orthod Dentofacial Orthop. 2009. Jul; 136 (1): 65–74.
48. Bock N, Ruf S. Post-treatment occlusal changes in Class II division 2 subjects treated with the Herbst appliance. Eur J Orthod. 2008. Dec; 30 (6): 606–13.
49. Lerstøl M, Torget O, Vandevska-Radunovic V. Long-term stability of dentoalveolar and skeletal changes after activator-headgear treatment. Eur J Orthod. 2010. Feb; 32 (1): 28–35.
50. Kondo E. Occlusal stability in Class II, Division 1, deep bite cases followed up for many years after orthodontic treatment. Am J Orthod Dentofacial Orthop. 1998. Dec; 114 (6): 611–30.
51. Razdolsky Y, Sadowsky C, BeGole EA. Occlusal contacts following orthodontic treatment: a follow-up study. Angle Orthod. 1989. Fall; 59 (3): 181–5; discussion 186.
52. Durbin D.S, Sadowsky C. Changes in tooth contacts following orthodontic treatment. Am J Orthod Dentofacial Orthop. 1986. Nov; 90 (5): 375–82.

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