ORTHODONTIC SECTION

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MECHANICAL AND MATHEMATICAL
MODELING OF THE PROCESS
OF TREATMENT OF DENTITION DEFECTS
OF THE FRONTAL AREA IN CHILDREN
AND ADOLESCENTS

ABSTRACT

Topicality of research. Treatment of dentition defects of the frontal area in children and adolescents involves the usage of special devices, that is prosthesis appliances, that have specific design features. Such devices create orthodontic forces. As the force is a vector characteristic, it means that it is necessary to determine the magnitude, direction and the point of the force application to provide treatment.

The purpose of research. Was improvement of the methods of treatment of dentition defects, in particular, the frontal area in children and adolescents based on the process of mechanical and mathematical modeling using a non-removable orthodontic prosthesis appliance on the upper jaw.

Materials and methods. The subject of the research was a system consisting of a dento-maxillaire complex of a patient and an orthodontic device for treatment of dentition defects of the frontal area in children and adolescents on the upper jaw during orthodontic treatment. The research was carried out by the method of theoretical mechanics and mechanics of a deformable solid.

Results. The point of application and direction of the orthodontic force significantly influences teeth movement. Depending on how the orthodontic force is applied, it can produce a translation movement of a tooth or translation-rotational one.

The type of teeth movement depends on the relative position of the orthodontic force vector and the resistance forces that are applied from the jaws’ bone tissue. Resistance forces are applied to the tooth root surface and their action can be replaced by an equal force that passes through the center of the resistance of the tooth. The center of the resistance is the point through which the resultant forces that prevents teeth from movement. The center of tooth resistance is in the middle part of the tooth root. Here is the case when the orthodontic force vector is applied in the direction parallel to the occlusal plane and passes through the center of the resistance of the tooth root. The action of orthodontic force causes the appearance of normal stresses, which are evenly distributed at the point that passes through the axis of the tooth. Since the vectors of the resultant resistance force and orthodontic force coincide in the direction, the tooth moves translationally and parallel to the occlusal plane in the direction of the orthodontic force.

When the orthodontic force vector passes through the center of the resistance of the tooth root at some angle to the occlusal plane, it causes the appearance of not only normal but also tangential stresses. The tooth will move translationally (bodily) in the direction of the orthodontic force.

The case of orthodontic force, the vector of which passes between the apex of the tooth root and the center of the resistance of the tooth causes the appearance of evenly distributed tangential and unevenly distributed normal stresses in the axial section of the tooth. The vectors of the resultant resistance force and the orthodontic force do not coincide in the direction, which leads to translational and rotational movement of the tooth. The tooth in this case rotates clockwise. If the vector of orthodontic force passes between the crown of the tooth and the center of the resistance of the tooth root, the action of the orthodontic force will cause the appearance in the axial section of evenly distributed tangential and unevenly distributed normal stresses. But the tangential stresses in this case will act in the opposite direction, restraining the vertical movement of the tooth. The tooth rotates in this case counterclockwise.

Conclusions. The point of application and direction of the orthodontic force significantly influences the teeth movement. Depending on how the orthodontic force is applied, the tooth movement can be translational, or translational-rotational.

If the orthodontic force vector is applied in the direction parallel to the occlusal plane and passes through the center of the resistance of the root, the tooth moves translationally and parallel to the occlusal plane. When the action of orthodontic force, the vector of which passes between the apex of the root and the center of the resistance of the tooth, it leads to translational and rotational movement of the tooth clockwise. If the orthodontic force vector passes between the crown of the tooth and the center of the resistance of the tooth, in this case, the tooth rotates counterclockwise. If the orthodontic force is not directed through the center of the resistance, the orthodontic force will cause in addition to the translational movement in the direction of the orthodontic force, also its rotation around the axis of the tooth.

The work is a fragment of a topic of the academic research works “Differentiated approach in the choice of treatment of dentition defects of the frontal area in children and adolescents” (state registration number (0116U008918))

Key words: defects in the dentition rows, the place of application of force, the direction of action of orthodontic force.
Дія ортодонтичного зусилля викликає вони нормально розподілені дотичних і нерівномірно розподілені нормальних напружень. Вектори резистентності і ортодонтичної сили не співпадають по напрямку, що призводить до поступально-аберторального переміщення зуба. Зуб у цьому випадку обертається в годинниковому напрямку. Якщо вектор ортодонтичного зусилля проходить між коронкою зуба та центром опору кореня зуба, то дія ортодонтичного зусилля викликає появу в основному петрени рівномірно розподілені дотичних і нерівномірно розподілені нормальні напружень. Але дотичні напружнення в цьому випадку будуть діяти в зворотному напрямку сприяючи вертикалі переміщення зуба. Зуб обертається в цьому випадку проти напряму руху годинникової стрілки.

**Main topic.** Прикладання та напрям дії ортодонтичного зусилля істотно впливають на поступове переміщення зубів. В залежності від того, як прикладається ортодонтичне зусилля, зуб може пересуватися поступально, або поступально-аберторально.

Якщо вектор ортодонтичного зусилля діє в напрямі центрального перетину зуба, то зуб переміщується в основному петрени нормально розподілені дотичних і нерівномірно розподілені нормальних напружень. Коли вектор ортодонтичного зусилля проходить через верхівку кореня зуба і центром опору кореня зуба, то вони нормально розподілені дотичних і нерівномірно розподілені нормальних напружень. Резистентності і ортодонтичної сили не співпадають по напрямку, що призводить до поступально-аберторального переміщення зуба. Зуб обертається в цьому випадку проти напряму руху годинникової стрілки.

Співпраця дія ортодонтичного зусилля, який проходить через центр опору кореня зуба, та роль дії ортодонтичного зусилля, який проходить через верхівку кореня зуба. У такому випадку зуби обертаються проти напряму руху годинникової стрілки. Якщо вектор ортодонтичного зусилля проходить між коронкою зуба та центром опору кореня зуба, то дія ортодонтичного зусилля викликає появу в основному петрени рівномірно розподілені дотичних і нерівномірно розподілені нормальні напружень. Але дотичні напружнення в цьому випадку будуть діяти в зворотному напрямку сприяючи вертикалі переміщення зуба.

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**Key words:** Defects of teeth, the course of orthodontic treatment.
Treatment of dentition defect of the frontal area in children and adolescents involves the usage of special devices, that is prosthesis appliances, that have specific design features [3, 4]. Such devices create orthodontic force. As the force is a vector characteristic, it means that it is necessary to determine the magnitude, direction and the point of force application to provide treatment [5].

**Purpose of research.** was improvement of the methods of treatment of dentition defects, in particular the frontal area in children and adolescents based on the process of mechanical and mathematical modeling using a non-removable orthodontic prosthesis appliance on the upper jaw in children and adolescents.

**Materials and methods.** The subject of the research was a system consisting of a dento-maxillaire complex of a patient and an orthodontic device for the treatment of dentition defects of the frontal area in children and adolescents on the upper jaw during orthodontic treatment. The research was carried out by the method of theoretical mechanics and mechanics of a deformable solid.

**Results.** The absence of some teeth and the incorrect position of others creates functional and aesthetic problems for patients. For treatment of dentition defects of the frontal area in children and adolescents, an orthodontic prosthesis appliance was designed, that is presented in Fig. 1, by means of which the normalization of the transverse sizes of the jaws was performed and dentition defect was compensated during the temporary and mixed periods of occlusion.

By unscrewing the orthodontic screw 2, an orthodontic force is created, which is applied through the rods 4 and teeth gap bands 3 on the teeth of a patient 7, thus expanding the upper jaw. Expansion of the upper jaw is achieved by lengthening the upper dentition and creating space for permanent teeth that are to erupt. The rods 5, which are fixed with one end in the parts of the base 1, support the artificial teeth 6, which perform the function of biting food, compensate for aesthetic defects and do not allow adjacent teeth to lean towards the missing teeth.

The point of application and direction of the orthodontic force significantly influences the teeth movement. Depending on how the orthodontic force is applied, the tooth movement can be translational, or translational-rotational Fig 2.

![Fig. 2. Tooth movement caused by the force in the direction of the cheek through the center of tooth resistance.](image)

1 – normal stresses \( \sigma_i \);  
2 – orthodontic force \( \Sigma \);  
3 – position of a tooth before movement;  
4 – centre of tooth root resistance;  
5 – position of a tooth after movement

The type of tooth movement depends on the relative position of the orthodontic force vector and the resistance forces that are applied from the jaws bone tissue. Resistance forces are applied to the tooth root surface and their action can be replaced by an equal force that passes through the center of the resistance of the tooth. The center of the resistance is the point through which the resultant passes that prevents teeth from movement. The center of tooth resistance is in the middle part of the tooth root.

Here is the case when the orthodontic force vector is applied in the direction parallel to the occlusal plane and passes through the center of the resistance of the tooth root. The action of orthodontic force causes the appearance of normal stresses, which are evenly distributed at the point that passes through the axis of the tooth. Since the vectors of the resultant resistance force and the orthodontic force coincide in the direction, the tooth moves translationally and parallel to the occlusal plane in the direction of the orthodontic force Fig 3.
Fig. 3. Tooth movement caused by the force, that deviates from the horizon and directed through the center of the resistance of the tooth:
1 – tangential stresses $\sigma_1$;
2 – normal stresses $\sigma_2$;
3 – orthodontic force $\Sigma$;
4 – position of a tooth before the movement;
5 – centre of tooth root resistance;
6 – position of a tooth after the movement.

When the orthodontic force vector passes through the center of the resistance of the tooth root at some angle to the occlusal plane, it causes the appearance of not only normal 2 but also tangential stresses 1. The tooth 4 will move translationally (bodily) in the direction of orthodontic force 3.

The case of orthodontic force, the vector of which passes between the apex of the tooth root and the center of resistance of the tooth that is shown in Fig. 4 causes the appearance of evenly distributed tangential 1 and unevenly distributed normal 2 stresses in the axial section of the tooth. The vectors of the resultant resistance force and orthodontic force do not coincide in direction, which leads to translational and rotational movement of the tooth from position 4 into position 6. The tooth in this case rotates clockwise.

Fig. 4. The tooth movement cause by the force, that is directed between the apex of the tooth root and the centre of tooth root resistance and is applied at some angle to the occlusal plane:
1 – tangential stresses $\sigma_1$;
2 – normal stresses $\sigma_2$;
3 – orthodontic force $\Sigma$;
4 – position of a tooth before the movement;
5 – centre of tooth root resistance;
6 – position of a tooth after the movement.

If the vector of the orthodontic force passes between the crown of the tooth and the center of the resistance of the tooth root, which is shown in Fig. 5, the action of the orthodontic force will cause the appearance of evenly distributed tangential 1 and unevenly distributed normal 2 stresses in the axial section. But the tangential stresses in this case will act in the opposite direction, restraining the vertical movement of the tooth. The movement of the tooth will be translational-rotational which will move the tooth from position 4 to position 6. In this case the tooth moves counterclockwise.

Fig. 5. Tooth movement caused by the force, that is applied at the angle with respect to the horizon and directed between the tooth crown and the center of the resistance of the tooth:
1 – tangential stresses $\sigma_1$;
2 – normal stresses $\sigma_2$;
3 – orthodontic force $\Sigma$;
4 – position of a tooth before the movement;
5 – centre of tooth root resistance;
6 – position of a tooth after the movement.

The cases considered above (Fig. 2-5) concerned the movement of the tooth in the plane passing through the tooth axis. The movement of the tooth in the plane perpendicular to its axis is shown in Fig. 6. The force 6 is applied to the tooth 5 directed through the center of the resistance of the tooth root 4. The orthodontic force 6 in the axial section of the tooth causes tangential 1 stresses and normal stresses 2. The tooth moves translationally from position 5 to position 3.

Fig. 6. The tooth movement in the plane perpendicular to its axis is caused by the force directed to the centre of the tooth root resistance:
1 – tangential stresses $\sigma_1$;
2 – normal stresses $\sigma_2$;
3 – orthodontic force $\Sigma$;
4 – position of a tooth before the movement;
5 – centre of tooth root resistance;
6 – position of a tooth after the movement.
If the orthodontic effort is not directed through the center of the resistance Fig. 7, the orthodontic force 6 will cause its rotation around the axis of the tooth in addition to the translational movement in the direction of the orthodontic force.

Fig. 7. The tooth movement in the occlusal plane caused by the force that does not coincide with the tooth axis:
1 – tangential stresses $\sigma_t$;
2 – normal stresses $\sigma_n$;
3 – orthodontic force $\Sigma$;
4 – position of a tooth before the movement;
5 – centre of tooth root resistance;
6 – position of a tooth after the movement.

Therefore, the point of application and the direction of the orthodontic force significantly influences the type of the tooth movement. If it is necessary to move the tooth translationally, then the orthodontic force should be applied to the tooth so that the vector passes through the center of the resistance of the tooth root, which is approximately halfway between the neck and the apex of the root.

If the tooth inclination is necessary parallel to the translational movement of the tooth, then the vector of the orthodontic force must pass through the axis of the tooth root above or below the center of the resistance. If it is necessary to simultaneously move translationally and rotate the tooth around its axis, it is necessary that the orthodontic force vector does not pass through the axis of the tooth.

**Discussion.** Today, it is especially important to conduct informative and educational work among children and their parents in order to early detect disorders of the dento-maxillare system in children, provide timely dental prosthetics to prevent persistent deformities of the dento-maxillofacial area.

In addition, a scientific and mechanical – mathematical substantiation of rational methods of replacement of dentition defects is planned in order to determine the most acceptable vector of the orthodontic force during treatment with a fixed orthodontic prosthesis appliance on the upper jaw.

**Conclusions.** The prosthesis appliance was made taking into account individual anatomical and medical features of patients on the basis of their diagnostic models. The clinical application of the proposed device provided an impact on the transverse sizes of the jaws, correction the position of incorrectly positioned teeth, free eruption of permanent teeth and meeting the physiological and aesthetic needs of patients.

The use of methods of mechanical and mathematical modeling allows to create a mathematical description of the processes that occur during treatment, and improve it. The point of application and direction of the orthodontic force significantly influences tooth movement. According to the way the orthodontic force is applied, it can produce a translation movement of a tooth or translation-rotational one.

If the orthodontic force vector acts in the direction parallel to the occlusal plane and passes through the center of the resistance of the root, the tooth moves translationally and parallel to the occlusal plane. When the action of the orthodontic force, the vector of which passes between the apex of the root and the center of the tooth resistance, it leads to translational and rotational movement of the tooth clockwise. If the orthodontic force vector passes between the crown of the tooth and the center of the resistance of the root of the tooth, in this case, the tooth rotates counterclockwise. If the orthodontic force is not directed through the center of the resistance, the orthodontic force will cause in addition to the translational movement in the direction of the orthodontic force, also its rotation around the axis of the tooth.

**Directions for future research.** Development and implementation in the medical practice of a non-removable orthodontic prosthesis appliance to replace dentition defects of the frontal area in children and adolescents.

**Conflict of interests.** Absent.

**REFERENCES**


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