ORTHODONTIC SECTION

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S.I. Doroshenko, M.D., S.M Savonik

Private Education Institution «Kyiv Medical University», Kyiv Ukraine

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. According to the way 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 pasese 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 influencs 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.*

С.І. Дорошенко, д. мед. н., С.М. Савонік

Приватний вищий навчальний заклад «Київський медичний університет», Київ Україна

МЕХАНІКО-МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ ПРОЦЕСУ ЛІКУВАННЯ ДЕФЕКТІВ ЗУБНИХ РЯДІВ ФРОНТАЛЬНОЇ ДІЛЯНКИ У ДІТЕЙ ТА ПІДЛІТКІВ

АНОТАЦІЯ

Актуальність дослідження. *Лікування дефектів зубних рядів фронтальної ділянки у дітей та підлітків передбачає використання спеціальних пристроїв, тобто апаратів – протезів, які мають певні конструктивні особливості. Такі пристрої створюють ортодонтичні зусилля. Оскільки зусилля є векторною величиною, то для проведення ортодонтичного лікування необхідно визначити величину, напрям та точку прикладання цих зусиль.*

Мета дослідження. *є удосконалення методик лікування дефектів зубних рядів, зокрема фронтальної ділянки у дітей та підлітків на основі процесу механіко-математичного моделювання за допомогою незнімного ортодонтичного апарата-протеза на верхню щелепу у дітей та підлітків.*

Матеріали та методи. *Предметом дослідження була система, яка складалася із зубощелепного комплексу пацієнта та ортодонтичного пристрою для лікування дефектів зубних рядів фронтальної ділянки у дітей та підлітків на верхню щелепу в процесі ортодонтичного лікування. Дослідження проводили методом теоретичної механіки та механіки деформівного твердого тіла.*

Результати. *Місце прикладання та напрям дії ортодонтичного зусилля істотно впливають на пересування зубів. В залежності від того, як прикладається ортодонтичне зусилля, зуб може пересуватися поступально, або поступально-обертально.*

Спосіб пересування зубів залежить від взаємного положення вектора ортодонтичної сили та сил опору, які діють з боку кісткової тканини щелеп. Сили опору діють на поверхню кореня зуба і їх дію можна замінити рівнодіючою силою, яка проходить через центр опору (резистентності) зуба. Центр резистентності – це точка, через яку проходить рівнодіюча сил, які протидіють переміщенню зуба. Центр опору зуба знаходиться в середній частині кореня зуба.

Розглянемо випадок, коли вектор ортодонтичного зусилля діє в напрямі паралельному оклюзійній площині і проходить через центр опору кореня зуба. Дія ортодонтичної сили викликає появу нормальних напружень, які рівномірно розподіляються на перетині, яке проходить через вісь зуба. Оскільки вектори результуючої сили опору і ортодонтичної сили співпадають по напряму, то зуб переміщується поступально та паралельно оклюзійній площині в напрямі дії ортодонтичного зусилля.

Коли вектор ортодонтичного зусилля проходить через центр резистентності кореня зуба під деяким кутом до оклюзійнійної площини, то це викликає появу не тільки нормальних, але й дотичних напружень. Зуб буде переміщуватися поступально (корпусно) в напрямі дії ортодонтичної сили.

Випадок дії ортодонтичного зусилля, вектор якого проходить між верхівкою кореня зуба та центром опору зуба викликає появу в осьовому перетині зуба рівномірно розподілених дотичних і нерівномірно розподілених нормальних напружень. Вектори результуючої сил резистентності і ортодонтичної сили не співпадають по напряму, що призводить до поступально-обертального переміщення зуба. Зуб в цьому випадку обертається в годинниковому напрямку. Якщо вектор ортодонтичного зусилля проходить між коронкою зуба та центром опору кореня зуба, то дія ортодонтичного зусилля викличе появу в осьовому перетині рівномірно розподілених дотичних і нерівномірно розподілених нормальних напружень. Але дотичні напруження в цьому випадку будуть діяти в зворотному напрямку стримуючи вертикальне переміщення зуба. Зуб обертається в цьому випадку проти напряму руху годинникової стрілки.

Висновки. *Місце прикладання та напрям дії ортодонтичного зусилля істотно впливають на пересування зубів. В залежності від того, як прикладається ортодонтичне зусилля, зуб може пересуватися поступально, або поступально-обертально.*

Якщо вектор ортодонтичного зусилля діє в напрямі паралельному оклюзійній площині і проходить через центр опору кореня, то зуб переміщується поступально та паралельно оклюзійній площині. Коли дія ортодонтичного зусилля, вектор якого проходить між верхівкою кореня та центром опору зуба це призводить до поступально-обертального переміщення зуба за годинниковою стрілкою. Якщо вектор ортодонтичного зусилля проходить між коронкою зуба та центром опору кореня зуба. У такому випадку зуб обертається проти напряму руху годинникової стрілки. Якщо ортодонтичне зусилля спрямовано не через центр резистентності, то ортодонтичне зусилля викличе крім поступального руху в напрямі дії ортодонтичного зусилля, ще й його поворот навколо осі зуба.

Робота є фрагментом теми науково-дослідної роботи «Диференційований підхід у виборі методу лікування дефектів зубних рядів фронтальної ділянки у дітей та підлітків» (номер державної реєстрації (0116U008918)).

Ключові слова: *дефекти зубних рядів, місце прикладання сили, напрям дії ортодонтичного зусилля.*

Topicality of research. Lack of teeth in childhood leads to interference of growth physiological processes, improper formation of the masticatory apparatus and the overload of the remaining teeth. This prevents the process of teeth eruption, uneven growth of the jaws, the formation of pathological forms of occlusion, dento-maxillaire deformities and the appearance of profound morphological and functional changes in the dento-maxillofacial complex. Treatment of such defects of the frontal dentition in children and adolescents during the change of temporary teeth should ensure proper formation of den-

tition, normal development of jaws, timely eruption, correct position of permanent teeth in the alveolar bone, normal tongue development, mastication and swallowing functions. In addition, such treatment should prevent secondary dental deformities in the form of shortening of the dental arch, the occurrence of dentoalveolar lengthening and displacement of the teeth around the defect [1, 2].

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.

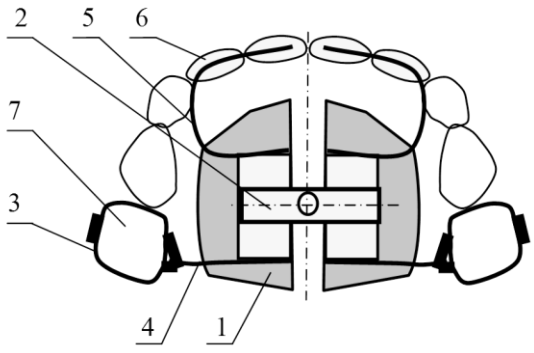

Fig. 1. The scheme of the prosthesis appliance for treatment of dentition defects in the frontal area in children and adolescents.

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 influencs the teeth movement. Depending on how the orthodontic force is applied, the tooth movement can be translational, or translational-rotational Fig 2.

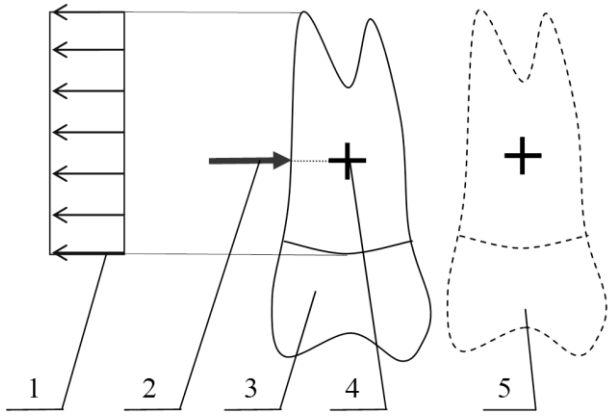

Fig. 2. Tooth movement caused by the force in the direction of the cheek through the center of tooth resistance.
1 – normal sresses $\sigma_н$;
2 – orthodontic force Σ;
3 – position of a tooth before movement;
4 – centre of tooth root resistance;
5 – position of a tooth after movement

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 pasese 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.

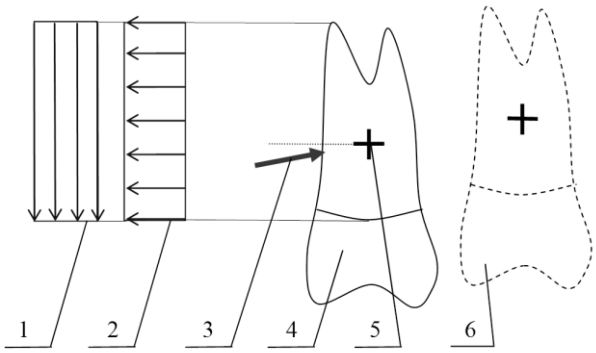

Fig. 3. Tooth movement caused by the force, that deviates from the horizon and directed through the center of the resistance of the tooth:
1 – tangential stresses $\sigma_д$;
2 – normal stresses $\sigma_н$;
3 – orthodontic force Σ;
4 – position of a tooth before the movement;
5 – centre of tooth root 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 the 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.

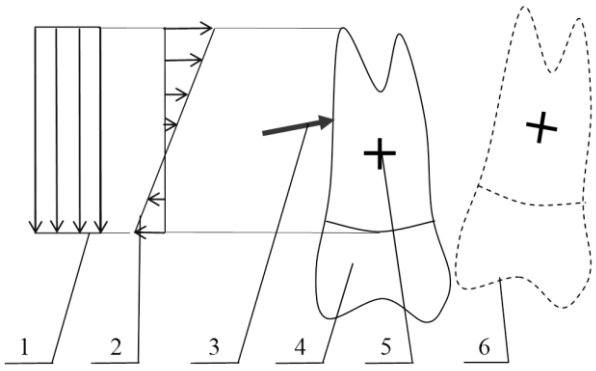

Fig. 4. The tooth movement cause by the force, that is directed between the apex of the tooth root and the centre of tooth root resistance and is applied at some angle to the occlusal plane:
1 – tangential stresses $\sigma_д$;
2 – normal stresses $\sigma_н$;
3 – orthodontic force Σ;
4 – position of a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

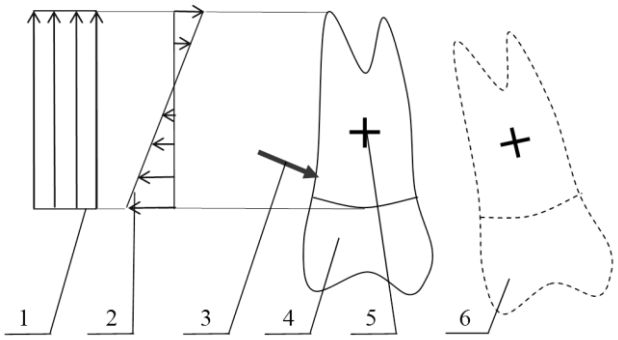

Fig. 5. Tooth movement caused by the force, that is aplied at the angle with respect to the horizon and directed between the tooth crown and the center of the resistance of the tooth:
1 – tangential stresses $\sigma_д$;
2 – normal stresses $\sigma_н$;
3 – orthodontic force Σ;
4 – position of a tooth 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.

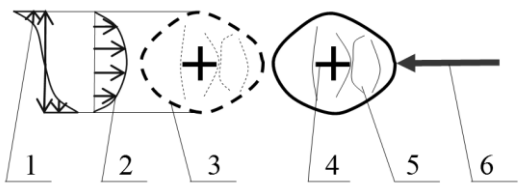

Fig. 6. The tooth movement in the plane perpendicular to its axis caused by the force directed to the centre of the tooth root resistance:
1 – tangential stresses $\sigma_д$;
2 – normal stresses $\sigma_н$;
3 – orthodontic force Σ;
4 – position of a tooth before the movement;
5 – centre of tooth root 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.

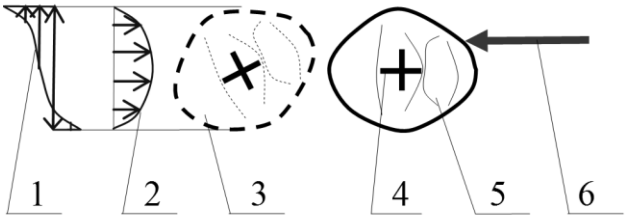

Fig. 7. The tooth movement in the occlusal plane caused by the force that does not coincide with the tooth axis:
1 – tangential stresses $\sigma_д$;
2 – normal stresses $\sigma_н$;
3 – orthodontic force Σ;
4 – position of a tooth before the movement;
5 – centre of tooth root resistance;
6 – position 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 its 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 traslationally 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-maxillaire 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.

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