

ORIGINAL ARTICLE

MODELING THE TELESCOPIC CONNECTION DEVICE OF RAINBOW MUSCLE PROTESES

DOI: 10.36740/WLek202004124

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ABSTRACT
The aim: Mathematical modeling and peculiarities of the proposed telescopic connection design.
Materials and methods: For the implementation of the mathematical model of telescopic joints of removable dentures, elements of the external and internal parts of such a design having the same nominal angles of cones, or identical nominal cones of these parts are considered.
Results: Dependence of retention force is determined from various parameters, equating it with equilibrium values of compressive dynamic force and the total force of friction. Connection is set between the separate geometricalparameters of elements of telescopic cone connection andoperating between them various internal and external efforts.At creation of different individual modifications of theseconnections, gives possibility, attracting the values ofcorresponding geometrical or po wer elements, that isrationed or accepted on results measuring or scanouts, toexpect other parameters that is determined in dependenceon preliminary appointed.
Conclusions: The given mathematical dependences can be represented as algorithms of calculation and realized by computer programs.

KEY WORDS: Mathematical model, telescopic connection

Wiad Lek. 2020;73(4):751-754

INTRODUCTION
The best conditions for restoring chewing efficacy, function and aesthetics of the tooth-jaw system, eliminating the deformation of the occlusal surface of the dentition and traumatic occlusion in patients with partial loss of teeth can be achieved by using removable dentures with a telescopic fixing system [1]. However, the presence of constant active friction between the elements of the proposed cylindrical and cone systems of telescopic latches, excessive twisting slip during the removal and installation of a partial removable prosthesis, over time reduces the fixing properties of the telescopic connection [2, 3]. Also, the presence of heterogeneous biological structures (hard and soft tissues), which are based on removable dentures, are not able to fully compensate for the potential diversity in transferring pressure on these tissues and contribute to maintaining their normal functional state. Telescopic tapered crowns and many double crowns do not allow elasticity of the mucous membrane [4, 5].

So, the problem of fixing removable prosthesis with a telescoping fixing system remains unresolved, primarily due to the disadvantages of the structures of the telescopic systems itself. This state of affairs prompted us to propose a new development of a telescopic connection design using the rheological properties of materials.

THE AIM
Mathematical modeling and peculiarities of the proposed telescopic connection design, which would provide the following functions:

• stable fixation and required level of grip of the outer element of the telescopic connection with the internal;
• protection of the reference tooth and mucous membrane of the prosthetic bed from traumatic injuries;
• Improvement of the functional values of removable dentures.

MATERIALS AND METHODS
For the implementation of the mathematical model of telescopic joints of removable dentures, elements of the external and internal parts of such a design having the same nominal angles of cones, or identical nominal cones of these parts are considered.

As the main elements of the model, which correspond to the specified features of work, the scheme is shown, shown in Fig. 1

The proposed telescopic connection for fixing removable dentures is implemented as follows. With the first installation of the prosthesis with a fixed crown 2 fixed in it, it is filled with the required amount of a smoother plastic material 3. This material then hardens and passes into the state of elastic (elastic-deforming) material. In this case, a reliable adhesion (adhesion of surfaces of heterogeneous solids) is provided on the inner surface of the crown 2 and the outer surface of the hardened elastic material 3 in contact with it, whereas between the outer surface of the inner crown 1 with the toroidal depression and the elastic formed by the cap-replica 3 such adhesion is absent.

After performing such actions and installing the outer crown filled with plastic (softened) material, a toroidal

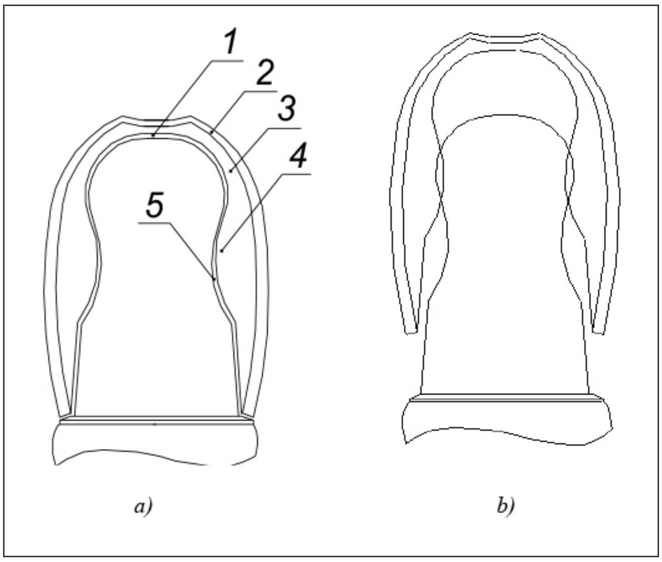

Figure 1. Scheme of the device of the telescopic connection: a) - the working position of the "lock"; b) - the position of elastic deformation.
1- An internal element (cap) with a toroidal depression;
2 - External element (crown), filled with elastic material;
3 - Elastic material (cap-replica);
4-Toroidal projection part of the outer crown made of elastic material;
5-Deepening of the toroidal shape on the inner cap;

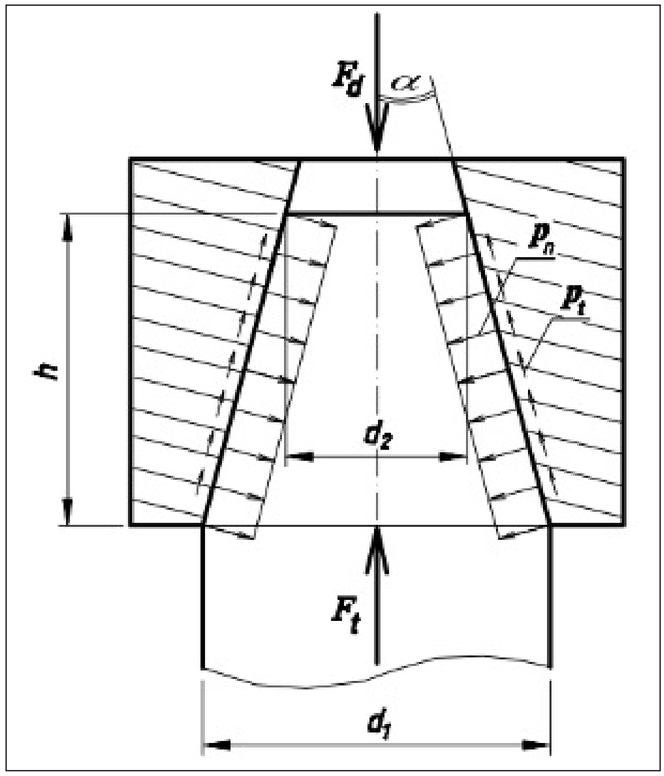

Figure 2. Scheme of conical connection

deepening of the inner crown forms a similar appearance in the shape of its surface, which, after solidifying and subsequent removal and installation, can fix the demountable prosthesis in the working position, working as a kind of "lock". This function performs this element after combining the surfaces of the recess 5 and the protrusion 4, which sets the working position of the crowns.

An elastic gasket 3 in the form of an outer crown 2 is created in such a way and can elastically deform with the action of the corresponding force (pressing or detachment), which allows the installation or removal of the denture, with its fixation in the working position.

In order to carry out the necessary functions of the connection of the outer crown 2, filled with elastic material 3, and the inner crown with a toroidal groove 1, the principle of the fixed conical connection is used. Fixation and stabilization of a removable prosthesis is provided with the landing of cones of crowns, which implies the provision after the assembly of their tensions.

For the mathematical modeling of devices for telescopic joints of removable dentures, the determination of the various parameters of their constituent elements and the various types of efforts that are in force among them – necessary for the creation of individual modifications of these devices for different patients, – the calculation scheme, shown in figure 2.

Here a projection of the axial section of a telescopic joint height h, which outlines the common contact area of the friction surfaces of the cones, is limited by two parallel planes with diameters d1 and d2, located in the upper and lower part of the contact zones.

In the illustrated scheme, the "lock" part of the joint that fixes the prosthesis in the working position is not conditionally shown, while it is considered that the figure shows the working state of the telescopic connection.

The reliability of fastening of the conical joint depends on the size of the taper, the purity of the connecting surfaces, as well as the physical and mechanical properties of the materials of the patrician system and the matrix. The system should accept maximum chewing loads, and slip in the connection is not permissible. The connection works as follows.

The calculation of the cone telescopic model of the connection is carried out in the assumption that, after creating the tension of the cones, which ensures the fixation and stabilization of the telescopic crowns, a pressure pn (Fig. 2) occurs uniformly on the conical surface of the contact evenly distributed over this surface.

Proceeding from the fact that the value of the frictional forces (according to the 1st Coulomb law) does not depend on the magnitude of the area of the rubbing surfaces, and is determined (according to the 2nd Coulomb law), depending on the normal component of the external force (the force of pressing the conic surfaces, rubbing), as well as the coefficient of friction, we accept the following. The value of the normal clamping force $\boldsymbol{n}_n$, which falls on the unit area of the contact surface, is determined by the dependence

$\boldsymbol{n}_n = \boldsymbol{p}_n \times \boldsymbol{\mu}$,

where: μ – the value of the coefficient of friction that is experimentally depending on the type of material of the rubbing surfaces, their roughness and the presence of lubrication between them.

The full value of the normal clamping force $\boldsymbol{N}_n$, which acts on the total contact area of conical surfaces S in the presence of friction forces p_t, which also fall on the unit area of the contact surface, is based on the formula

$N_n = n_n \times S = p_n \times \mu \times S$.

In these equations, the area of the common conical surface **S** can be calculated by an approximate formula as the common lateral surface of the contact of the two truncated cones and determined by the dependence

$S = \pi (r_1 + r_2) l$,

$\pi \approx 3{,}14$;

r_1 and r_2 – the radius of the corresponding diameters d_1 and d_2 (see picture 2); (l – forming the lateral surface of truncated cones, determined by height h and the angle of inclination of the lateral surfaces of the cones α, that is how $l = h / \cos\alpha$.

To estimate the projection of the total force of friction on the axis of a telescopic conic joint F_t, which provides one of the main functions of this connection, namely – balances the action of compressive dynamic force F_d, we accept equality $F_d = F_t$. At the same time, we believe that the total force of friction F_t is a paramount effort p_t, which act in the contact area of the conical surfaces **S**, taking into account the angle *α and the values of other geometric parameters of the schemes (see* figure 2).

Considering the balance of these efforts, we can determine the dependence of the retention force F_{ret} from various parameters, equating it with equilibrium values of compressive dynamic force F_d and the total force of friction F_t. That is:

$F_{ret} = F_d = F_t$.

Considering the resulting equality, after substitution of the force and geometric parameters, as well as the transformation and simplification of their expressions, we will find that after providing a fit with a tension (without gap) F_{ret} can be estimated by the formula

$F_{ret} = p_n \pi d_m h (\sin\alpha + \mu \cos\alpha)$,

There d_m – medium diameter defined as $d_m = (d_1 + d_2) / 2$.

The accuracy of the represented conic compounds, and hence their interchangeability, depends on the accuracy of the performance of certain geometric parameters, namely: the angle of the cone or the slope, the diameters of its outer and inner working parts, the lengths of these parts and the accuracy of the form (non-circularity and non-linearity of the forming ones).

DISCUSSION

In the basis of the device of the proposed technical solution the cone connection which is widely used in a variety of industries for cases where there is a need for numerical or periodic disassembly and assembly of devices with a good centering of the interconnected elements, as well as the need to ensure the stability and stability of these interconnections, is considered.

In order to improve and implement the necessary functions of telescopic joints in dentistry, a well-known non-rotating (rigid), easily cut-off conical joint is adopted. Fixation and stabilization of such a connection is provided by the landing of cones, which implies maintenance after the assembly of their tension.

As it is known from the mechanics of conical joints, the nature of their fit (mobile or immobile) is determined by the values of gaps or tensions [6].

Moving fit takes place when there is a gap between the connecting surfaces of the cones of the connection, which provides an opportunity, relative to the axial displacement of the assembled parts. This condition will take place until the installation and fixing of the cones of the connection to the working condition.

Landing with a tension is possible in the presence of an axial tightening force that occurs during mounting the connection. When creating such a force, the gap disappears (closes) first between the surfaces of the cones that are connected. Then, the surface of the contact of such cones creates a normal pressure distributed to this surface, which creates a tension and the presence of frictional forces on the contact surface.

Friction further refers to the phenomenon of resistance to the relative displacement of rubbing parts, which occurs between the two surfaces of the cones in the area of their contact and directed at the tangent to these surfaces.

Such friction contributes to the creation of the adhesion of the surfaces of the cones, while ensuring the stability and stability of their position after the assembly.

At the same time, the value of the friction forces, as it is known from the laws of the tribology, does not depend on the size of the surface area (Coulomb's 1st law), which is rubbing, but is determined (according to the 2nd Coulomb law) depending on the normal component of the external force (the force of pressing surfaces of the tapered crowns), as well as the coefficient of friction. The value of such a coefficient is determined experimentally, depending on the type of material of the rubble surfaces, their roughness and the presence of lubrication between them [7].

The presence of such an elastic cap provides sufficiently high damping properties of the telescopic connection. At the same time it is impossible to rigid work of the prosthesis, in the presence of which there is an increased wear of the connection, there is discomfort in patients and increased trauma to the supporting tooth and the mucous membrane of the prosthetic bed. As a consequence of this, there is a need for frequent repair of prosthetics.

Thus, the design of the telescopic connection, due to the presence of an elastic gasket, has a rather soft elasticity. In the process of use, such a connection provides synchronous movement of removable dentures in the areas of supporting teeth and mucous membrane of the prosthetic bed. Such a feature of including in the work of the device telescopic connection removable dentures with an elastic liner helps to protect the reference tooth and mucous membrane of the prosthetic bed from traumatic damage.

In contrast to the fairly common in the prosthetics of the hard tapered telescopic compound, the design considerably improves the properties of this model.

Under these conditions, the axial movement of the outer crown, together with the elastic material on the surface of the inner crown, is possible. A similar fixation occurs in the process of further use of the prosthesis with the axial movements of the outer crown. When moving the prosthesis with a crown after its installation in the opposite direction after applying a pulling force to it, it can take its removal.

The nature of the connection (mobile or non-moving) of the outer crown cone relative to the fixed inner cone is determined by the values of gaps or tensions.

In this case, a mobile landing will take place until the end of the installation and fixation of the denture in working condition.

The stability and stabilization of such a prosthesis in the presence of friction forces on the contact surface of the cones, which arise in the presence of an axial moment-acting compressive dynamic force from the effect of the denture during its installation. Such force at first installing the prosthesis eliminates the gap between the surfaces of the cones that are connected. Then a tension is created on their common surface, causing normal pressure and the appearance of friction on this surface.

Such friction forces balance action of the axial compressive dynamic force, as well as create conditions for the grip of crowns, while ensuring the stability and stability of the position of the denture. In the absence of an axial compressive torque-active force friction can completely disappear (ceases to act), in a fixed position the connection is kept "lock". When repeated cyclic actions of such a dynamic force, a pattern of stress-strain state periodically repeated.

Regarding the value of the axial torque-acting compressive dynamic force from the effect of the denture during its installation, one of the conditions for its restriction is to adhere to the following: this force is normalized, and it should not create a level of excess elastic deformation of the material of the cone connection. Subject to this condition, the forces of elastic restoration and the fixation of double crowns will be provided by the force of the deformation elasticity of the replica [8] on the surface of the collision of the external and internal cones.

Under the influence of such forces will not appear and accumulate plastic deformation in the materials of the connection. Under such conditions, in the absence of an axial torque-acting compressive dynamic force, deformed surface layers of the outer and inner cones under the action of elastic restoration forces will return to its original position, providing minimal operational wear.

Therefore, it should be considered that non-compliance with the above-mentioned condition will contribute to the accumulation of irreversible plastic deformations, which, in turn, will eventually lead to their increase and inoperability or the need for premature repair of the conical connection.

CONCLUSIONS

1. The obtained dependences establish a connection between the individual geometric parameters of the elements of the telescopic conical joint and the various internal and external forces acting between them. This, in turn, when creating various individual modifications of these connections, provides the possibility of attracting the values of the corresponding geometric or power elements, which are normalized or accepted by the results of measurements or scans, to calculate other parameters, which are determined depending on the predetermined ones.
2. The given mathematical dependences can be represented as algorithms of calculation and realized by computer programs. In this way, it will be easy to perform the appropriate calculations in order to find the optimal values of different data parameters for designing numerous variants of individual modifications of telescopic connections for different patients.

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Conflicts of interest:
Author declare no conflict of interest.

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Received: 24.07.2019
Accepted: 18.02.2020

A – Work concept and design, **B** – Data collection and analysis, **C** – Responsibility for statistical analysis, **D** – Writing the article, **E** – Critical review, **F** – Final approval of the article