

CORRELATIONS BETWEEN THE LONG-SPAN FIXED DENTAL PROTHESES AND PERIODONTAL TISSUES MODIFICATIONS

Alice Arina Ciocan-Pendefunda ¹, Alina Mihaela Apostu ^{2,*}, Magda-Ecaterina Antohe ³
^{*, Cristina Gena Dascălu ⁴, Oana Țănculescu ⁵}

¹ „Grigore T. Popa” University of Medicine and Pharmacy, Iasi, Romania, Faculty of Dental Medicine;

² „Grigore T. Popa” University of Medicine and Pharmacy, Iasi, Romania, Faculty of Dental Medicine;

³ „Grigore T. Popa” University of Medicine and Pharmacy, Iasi, Romania, Faculty of Dental Medicine;

⁴ „Grigore T. Popa” University of Medicine and Pharmacy, Iasi, Romania, Faculty of Medicine;

⁵ „Grigore T. Popa” University of Medicine and Pharmacy, Iasi, Romania, Faculty of Dental Medicine;

Corresponding author: Alina Mihaela Apostu, Ph.D., Lecturer

e-mail: alina_apostu@yahoo.com

Magda – Ecaterina Antohe, Ph.D., Assistant. Professor

e-mail :magda.antuhe@yahoo.com

ABSTRACT

The aim of the study is to determine by finite element analysis the existence of direct correlations between the abutment periodontal tissues condition and the cantilever bridge in the context of functional occlusion. A 3D reconstruction of the mandible, premolars, canines, incisors and of the dental bridge was created, using AutoCAD 2019 and ALGOR 15 FEMPRO software for mesh-area of the structures. The maximum stress was recorded in the periodontal ligament of the first premolar since this load configuration produces a first-degree lever effect with a fulcrum located on the 35 root apex. When the support is on 35, the stress is lower in the bridge area, mainly due to the elimination of the tilting effect, unlike the support at level 34, when the stress distribution is lower than in the first case and the stress on the bridge is higher in the support area, with compression of 34 ligament towards the canine and an elongation from 35. The overstress of periodontal ligament under occlusal forces leads implicitly to the tearing of the ligament fibers either in their body, or in its insertion into the dentin and bone.

Key words: long-span FDP, periodontal stress, finite element analysis (FEA)

INTRODUCTION

A significant part of a dentist's activity is dedicated to reconstructing the integrity of the teeth and of dental arches by means of prosthetic works, executed with specific materials and technological processes. In the context of restorative therapy, the biological tolerance of the tissues is a particularly important and complex issue, with numerous clinical implications. The onset of local complications set a pattern for the

specialized literature, which focused more and more on the complex process that interferes in their integration in the biology of the oral cavity and of the organism. This biological aspect is imposed precisely by the different reactivity of the tissues in the presence of any restorative treatment. The success of prosthetic therapy depends, on the one hand, on the periodontal health and on the other hand on the observance of the principles of technological construction and on the choice of the restoration material.

The clinical impact of the simulation

performed has defining aspects by quantifying the forces at the periodontal level, in correlation with the forces induced in the context of influence, type of biomaterials, teeth preparation, without neglecting the type of occlusion, which are essential long-term aspects regarding the choice of dental bridges as a therapeutic solution for the partially reduced edentation. It is worth mentioning that, in the context of spectacular implant-prosthetic restorations, there are still numerous clinical cases that benefit from oral rehabilitation by means of dental bridges.

The fixed dental prosthesis (FDP) induces adaptative modifications in support periodontal tissues. The functions of the stomatognathic system are possible due to mandibular dynamics with and without dental contact. The FDP are subjected to loads with different directions, points of application and intensities. The prosthodontic therapy is depending on periodontal health and on biomechanical and biological principles that guide the clinical and technological stages, including the choice of the restoration materials [1, 2, 3].

Regardless of the type of prosthodontic restoration chosen to restore the functionality of the stomatognathic system, there is always a response of the dento-periodontal support because of the stress resulted from the activity of the entire system. Unfortunately, the consequences of this stress cannot always be predictable, the only way to estimate a subsequent behavior is based on statistical data [4].

The purpose of this study is to determine by finite element analysis (FEA) if there are correlations between periodontal modifications and the long-span FDPs in the

context of various location of occlusal load.

Evaluations of stress distribution of FDPs have been conducted with FEA in many studies [5,6,7,8]. Alternative reliable strain and stress measurements can be made by electronic strain gauges and photoelastic techniques, providing the most accurate strain values [9,10].

MATERIAL AND METHODS

The evaluation in vivo or in vitro of the forces acting on the periodontal ligament is quite difficult to be carried out. Finite element analysis can provide useful information on stress distribution, specific deformations and displacements of the ligament and bone [11]. In this regard, four-unit pontic FDP with two cover crowns as retainers was tested. The edentulous space was in the left lower quadrant, from the first premolar to the second molar and abutment teeth were the canine and the third molar [12]. The following aspects were considered:

1. biomechanical evaluation of the periodontal ligament
2. biomechanical evaluation of the mandibular bone
3. establishing the role of occlusal forces on the biomechanical behavior of the periodontal ligament
4. FEA analysis of stress distribution, specific deformations and displacements at the periodontal ligament.

For a proper simulation of the biomechanical phenomena, the geometric model needs to be as close as possible to reality [13, 14, 15]. In this sense, the 3D reconstruction included the mandibular bone, the teeth – from lateral left incisor to third right molar, the prepared abutments, with their periodontal ligament, the FDP with the pontic and retainers. The three-dimensional reconstruction was made in AutoCAD 2009 software (Figure 1), and the mesh in Algor 15 FEMPRO software (Figure 2) [16].

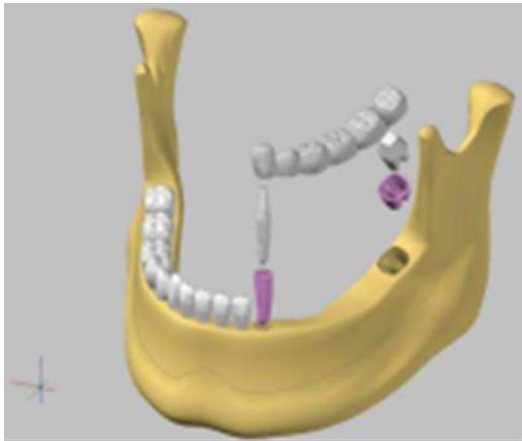


Figure 1. The 3D model for the mandible, abutments and their periodontal ligaments, and FDP

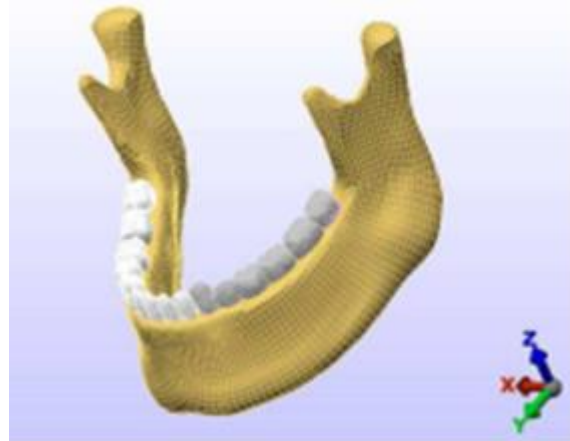


Figure 2. The mandible and FDP model

The considered material properties were the modulus of elasticity, the Poisson's ratio and the density of the material. Nickel-chromium alloy was chosen as material for the FDP (Table I).

Table 1. Material characteristics for each component of the analyzed structure.

Component	Modulus of elasticity (MPa)	Poisson's ratio	Density (Kg/m ³)
Bone	14200	0,33	1450
Dentine	13800	0,31	1900
Periodontal ligament	11,8	0,45	1250
Ni-Cr Alloy	207000	0,31	8931,7

As load application, the resultant of masseter and medial pterygoid muscles contraction during mastication was considered. The force value was 350N and the orientation was 150° upward and forward relative to the horizontal plane (Figure 3). As boundary conditions, the top of the condyles was fully fixed.

The action of the forces developed by the masticatory muscles generates, during mastication, reaction forces at the level of the temporo-mandibular joint and in the area

where the FDP is in contact with the food. At the level of the FDP, the following situations were considered (Figure 4):

- contact on the area corresponding to the missing first molar,
- contact on the area corresponding to the missing second premolar,
- contact on the area corresponding to the missing second premolar,
- contact on the area corresponding to the missing first premolar.

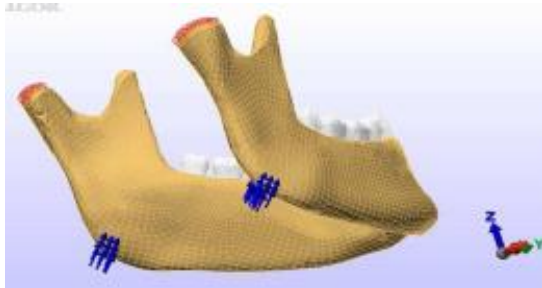


Figure 3. Applied forces corresponding to masseter and medial pterygoid muscles

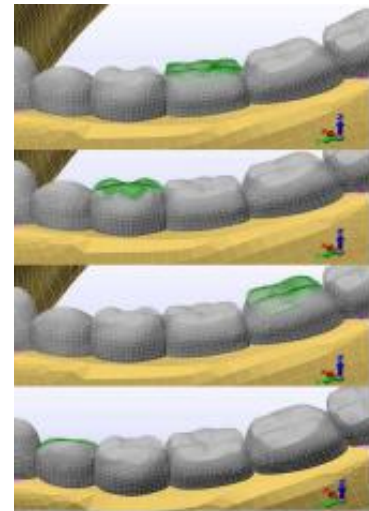


Figure 4. The FDP applied supports

RESULTS AND DISCUSSIONS

The periodontal ligament is the main element of the periodontium and consists of collagen fibres embedded in the lamina dura and cementum providing support for the teeth during functions [17, 18].

For this situation, the highest recorded tensile stress, higher than 75 MPa, is found at the level of the FDP, in the connectors area. This can be explained by the large distance between the abutment teeth, the resulting of a high bending moment at the point of constraints application (contact with the food) and implicitly the appearance of a high tension in the pontic (Figure 5).

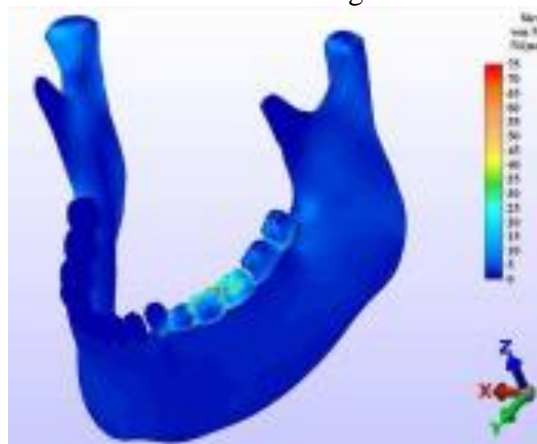


Figure 5. Distribution of tensions in the mandible - FDP assembly

Although in static tensile test the FDP pontic is subjected to a tension below the maximum tensile strength, in dynamic loading conditions, specific to mastication and due to mechanical fatigue, the cracks might appear leading to FDP failure.

a. Contact on missing first molar:

The tension in FDP is localized in the mucosal aspect of the pontic, especially at

the level of connectors where the maximum displacements are recorded, due to the pontic bending (Figure 6).

The ligaments were isolated and the distribution of specific stresses and deformations are analyzed (Figure 7). It is observed that the maximum tensile stress in the ligaments is 1.5 MPa, and the specific deformation is 0.15 mm / mm. There is a

stretching of the third molar ligament in its distal area, while at the level of the canine the ligament deformation is in the tooth axis.

This can be explained by the displacement of FDP toward the mandible due to the deformation of the ligaments and

implicitly, by the shortening of the distance between the abutments on which the FDP is supported. This tension of the collagen fibers can lead to their rupture compromising the implantation of the teeth.

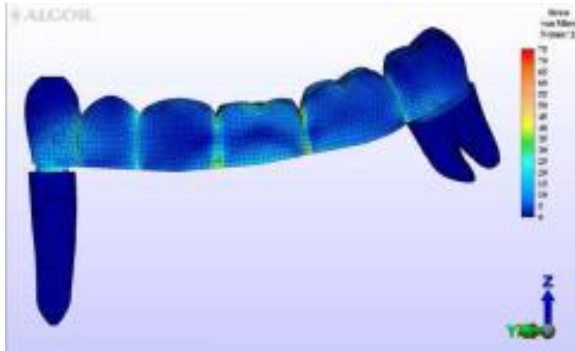


Figure 6. Tension distribution for the FDP - abutment - periodontal ligaments assembly, when the constraints are on the first molar

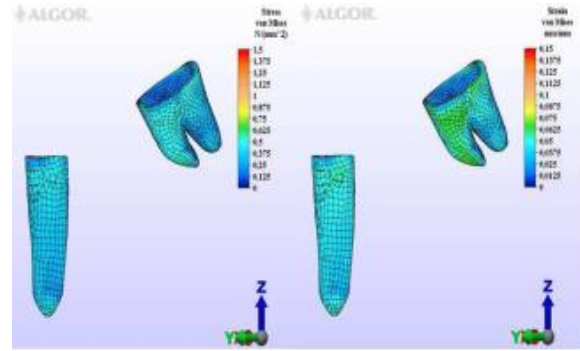


Figure 7. Distribution of strain (left) and specific deformations (right) for the abutments periodontal ligaments when the constraints are on the first molar

b. Contact on missing second molar:

The tensions in this case are illustrated in figure 8.

The maximum tensile strength was 75MPa, and tensile stress in the FDP are lower. The stress and strains are at the same values as in the previous case.

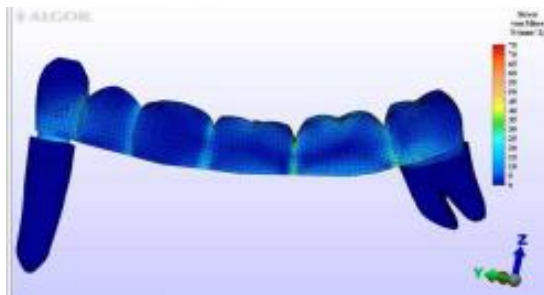


Figure 8. Tension distribution for the FDP - abutments - periodontal ligaments assembly when the constraints are on the second molar

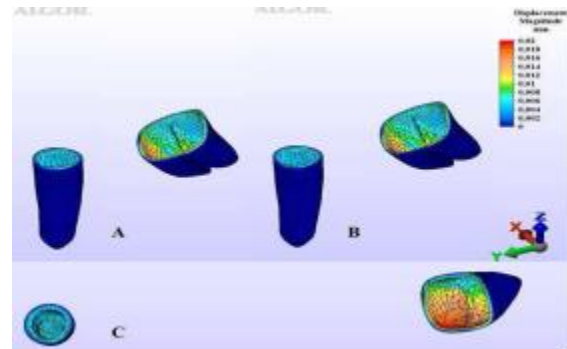


Figure 9. Deformations at the level of the abutment periodontal ligaments, when the constraints are on the second molar: A - unstrained ligament; B – ligament strains; C- top view of the ligament strains distribution

c. Contact on missing second premolar:

Compared to the previously analyzed situation, the tensions in the FDP are higher,

because this time the load is closer to the canine inducing the maximum displacement (Figure 10).

The specific tensions and deformations at the level of the two ligaments differ from the previous case, the highest deformation appears at the level of the canine, in the



Figure 10. Stress distribution for the FDP - periodontal ligaments - abutments assembly, when the constrain is on the second premolar

lateral area. The molar ligament is less solicited because the load is closer to the canine and its implantation is more reduce compared to the molar (Figure 11).

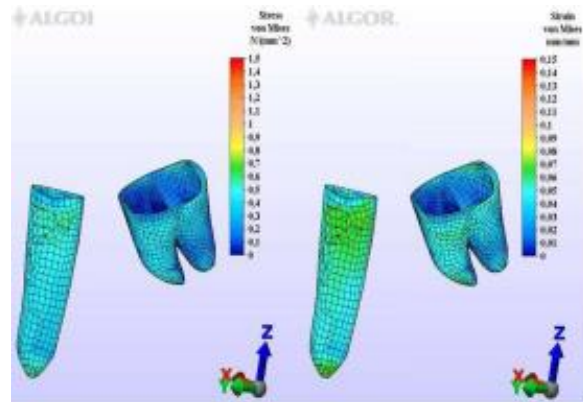


Figure 11. Distribution of stresses (left) and specific deformations (right) for the abutment periodontal ligaments, when the constraint is on the second premolar

d. Contact on missing first premolar:

In this case the maximum stresses in FDP are maximum at the level of connectors (Figure 12). Regarding the specific tensions and deformations, they have a high level in the canine, because it takes over almost all the load developed by the resistance of the

food. High value stresses are explained by the smaller transverse area than in the case of the other ligaments analyzed previously.

In contrast, for the third molar ligament the specific tension and deformation decreases significantly, being protected in this situation (Figure 13).

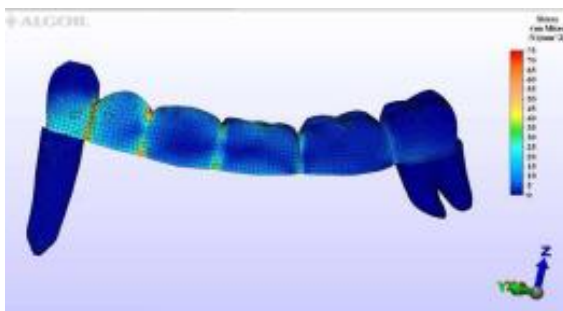


Figure 12. Stress distribution for the FDP - periodontal ligaments - abutments assembly, when the constrain is on the first premolar

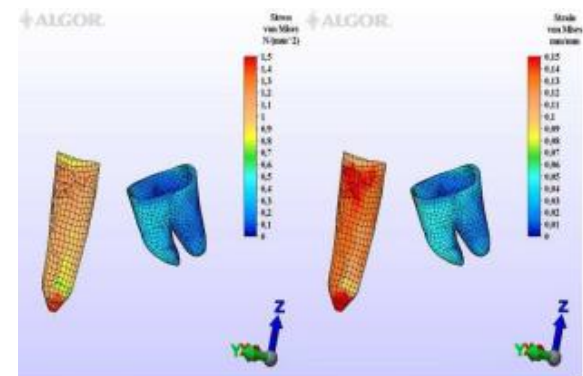


Figure 13. Distribution of stresses (left) and specific deformations (right) for the abutment periodontal ligaments, when the constraint is on the first premolar

The displacements are quite large for the canine ligament, being 1.5 times higher than in the previous cases, which leads to the conclusion that even in this situation there

can be a rupture of the ligament or of its insertion on the bone and cement. The function of the periodontium is to support the teeth during mastication. Therefore, there

must be a permanent balance between occlusal stresses and the health of periodontal structures.

The vertical forces appear during mastication and deglutition, but also during certain parafunctions, and their intensity depends on the contraction capacity of the masticatory muscles, which is higher in case of the young compared to the older people, on the nature of the food and on the sensitivity degree of the periodontium. The tangential horizontal forces are exercised at the level of the contact points, annihilating the tendency of mesialization of all teeth, which is more pronounced with young people. In partially reduced edentation, when the contact point is eradicated, the tangential forces can no longer be transmitted beyond the breaches and will determine the migration of teeth towards the potential prosthetic space. The migration of the bordering teeth can take place either by version, or by translation, both cases being based on the phenomena of apposition and bone resorption. The quality of the resistance that opposes the force of action depends on the mechanical properties of the periodontal tissues, on the vascularization and quality of the dental alveoli. The radial horizontal forces have a direction from the arch, being generated by the outwards tilt at the maxillary arch and the frontal region at the mandibular level. Roy considers that to stabilize a conjoint device against horizontal forces it is necessary to apply pillar teeth in various areas of the arch, in relation to the distribution of the prosthetic space and the health condition of the periodontium. The biomechanical principal in conjoint prosthetics aims at knowing the solicitation forces of the dental – periodontal complex and, on the other, hand, the configuration required by the dental-prosthetic structure so that the conjoint gnathic-prosthetic device can counteract the solicitation forces and the system can find a static and dynamic balance. To achieve a proper biomechanical balance, it is necessary to ensure a dental-periodontal support able to balance the soliciting forces. The biomechanical value of pillar teeth is influenced by a multitude of factors.

The teeth, the support periodontium and the implantation bone offer, from a mechanical perspective, a different resistance to the mechanical efforts they stand. From this point of view, pluri-radicular teeth show good implantation compared to mono-radicular teeth. The divergence of the roots increases the implantation value by the creation of a stabilization triangle between the apexes. The position of the teeth on the arch is a determining factor in the evaluation of the biomechanical competence of each dental unit, since each dental group has a well-determined function in the mandibular dynamics, a function imposed by the localization of each tooth on the arch and their morphology. The coronary dental lesions decrease the coronary resistance, in proportion to their degree of extension in surface and in depth. Generally, an interruption of the cohesion between the enamel prisms and, in evolution, of the dentinal structures has direct implication on the coronary resistance. Under the conditions of the same solicitation, the surface that takes over and transmits the masticatory force is low, which leads to a supra-solicitation of the remaining dental structures. Chronic periapical lesions influence the biomechanical resistance of the pillar teeth by re-ingravesence or the development of osteolytic processes. In the osteolytic – periapical areas, following the solicitations, the gradual sinking of the tooth can occur, the periodontal ligament giving in. The vitality of the teeth ensures a certain elasticity of the pillar teeth, providing a greater resistance compared to the devitalized teeth, which are brittle and can fracture easily. For this reason, de-pulping teeth for a prosthetic purpose is performed only in certain conditions. The tooth without an antagonist is deemed precarious from the perspective of resistance after a period of approximately two weeks from the loss of contact with the antagonist due to the diminution of the number of periodontal ligaments. Occlusion is an important factor in the biomechanical evaluation of dental – periodontal units. In the case of pathological occlusions, there takes place an over

solicitation of the present teeth through a non-uniform and para-axial distribution of functional solicitations. In relation to the way the pillar teeth fulfill the criteria of biomechanical resistance, various authors tried to synthesize the biomechanical value of the teeth, suggesting certain biomechanical indices.

The preoccupations for simulation, with reiteration conditions that are as faithful as possible to the clinical context, are materialized in an important research direction, so that Lang and col. and Brägger and col. outlined, in their relatively recent studies, the importance of the load distribution at the level of the natural teeth, as well as at the level of dental implants during the various approaches of prosthetic rehabilitation [19,20] particularly important aspects to allow for an efficient prognosis of the long-term prosthetic success rate.

Styraniivska and col. conducted similar studies, approaching various scenarios of simulating the forces induced by the masticatory forces at the level of fixed prostheses, with various degrees of amplitude of the dental bridge [21]. During a modelling scenario of partially fixed prostheses supported by the first premolar and the third premolar, the maximum tension occurred in the linking points with the intermediary part of the prosthesis. The

highest tensions were localized in the area of the distal tooth, reaching 190,88 MPa, while the lowest value of 29,94 MPa was recorded in the intermediary part of the fixed prostheses, where the load was applied.

CONCLUSIONS

Finite element analysis has shown that there is a correlation between the long-span FDP and the modifications of the periodontal ligaments of the abutment teeth according to the position of occlusal load.

An overload of the periodontal ligament leads, implicitly, to the rupture of the ligament fibres, either in the ligament or in its insertion area in the cement and the bone, compromising the dental implantation.

Fixed dental prostheses with support on the canine and third molar have a long span for replacing the four missing teeth. Due to the large amplitude, it has an increased effect of flexion of the pontic accompanied by the overloading of the ligaments of the abutment teeth. To achieve a proper biomechanical balance, it is necessary to provide a dento-periodontal support capable of annihilating the demanding forces, which is not possible in this situation. This type of long-span FDP is contraindicated considering the negative effect induced in the abutment teeth.

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