PONTIFÍCIA UNIVERSIDADE CATÓLICA DE MINAS GERAIS
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A INFLUÊNCIA DO TIPO DE CARGA APLICADA SOBRE COMPONENTES PROTÉTICOS UTILIZADOS EM REABILITAÇÃO ESTÉTICA SOBRE IMPLANTES NA REGIÃO ANTERIOR: análise por método de elementos finitos

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Orientador: Prof. Dr. Alberto Nogueira da Gama Antunes

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Dedico este trabalho à minha família,
em especial a meus pais e a meu irmão,
que sempre me apoiaram
e sempre me fizeram acreditar,
depositando em mim, com todas as suas forças,
confiança e amo

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Primeiramente a Deus.

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RESUMO

A zircônia é um material cerâmico com excelentes propriedades mecânicas e estéticas, tornando-se uma opção terapêutica, principalmente para subestruturas em próteses parciais fixas na região anterior. No entanto, sabe-se que a natureza deste tipo de material o torna sensível técnicas de confecção e instalação, além de menos resistentes a falhas, principalmente se comparados com materiais metálicos. Este fato deve ser considerado sobretudo em reabilitações protéticas sobre regiões em que cargas oclusais tem grande influência dos componentes verticais e horizontais de força, como em pilares caninos. Sabe-se que sobrecarga funcional resulta em tensões que, como resultado, podem levar a fratura e/ou afrouxamento de parafuso de conexão protética, fratura de componente, fratura de prótese e deformação estrutural do implante e dos tecidos de suporte. Assim, este trabalho avaliou, por métodos de elementos finitos, as tensões mecânicas geradas sobre o sistema de prótese sobre implante, com pilares de zircônia e titânio submetidos a diferentes tipos de carga. Foi utilizado o método de elementos finitos para simular diferentes cargas em modelos virtuais de um implante intraósseo de titânio e de uma restauração cerâmica acoplada a um componente cerâmico, preconizados para reabilitação estética, principalmente em região anterior da maxila. Foram utilizadas cargas que visam simular a oclusão funcional e exacerbada, localizada na face palatina de uma coroa cerâmica de um elemento canino, cimentada sobre o pilar. A intensidade da carga variou de 100 a 200N para o componente horizontal da força, e 0 a 200N para o componente vertical da força.

Palavras-chave: Implantes dentários. Prótese dentária. Fenômenos biomecânicos.

ABSTACT

Zirconia is a ceramic material with excellent mechanical and aesthetic properties, becoming a therapeutic option, especially for substructures in fixed partial dentures in anterior region. However, it is known that the nature of this type of material makes it sensible to manufacturing and installing techniques, in addition to being less resistant to mechanic failure, especially when compared with metallic materials. This fact should be considered particularly in prosthetic rehabilitations on regions where occlusal loads have great influence of vertical and horizontal components of force, as in canine element pillars. It is a fact that functional overload results in stresses which, as a result, can lead to loosening or frature of prosthetic fitting screw, abutment fracture, prosthesis fracture and structural deformation of the implant and supporting tissues. Thus, this work evaluated, by using finite elements method, the mechanical tensions generated on the prosthesis system on the implant, with zirconia and titanium abutments submitted to different types of load. To simulate different loads, virtual models of an intraosseous titanium implant, a ceramic restoration cemented to a ceramic component, recommended for aesthetic rehabilitation, were created. Loads were used to simulate functional and exacerbated occlusion, located on the palatine face of a ceramic crown of a canine element. The load intensity ranged from 100 to 200N for horizontal force component, and 0 to 200N for the vertical component of force.

Keywords: Dental implants. Dental prosthesis. Biomechanical phenomena.

LISTA DE ABREVIATURAS E SIGLAS

ATM	Articulação temporo-mandibular
BLT	Bone Level Tapered
CAD	Computer aided design
CAM	Computer aided manufacturing
DTM	Disfunção temporo-mandibular
MEF	Método de elementos finitos
mm	milímetros
N	Newtons
RC	Regular CrossFit

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SUMÁRIO

1 INTRODUÇÃO

A zircônia é um material cerâmico que tem se apresentado como potencial alternativo para utilização de subestruturas metálicas em próteses fixas parciais unitárias e múltiplas. Este fato se deve a excelentes propriedades mecânicas do material, aliadas a biocompatibilidade e propriedades estéticas, principalmente quando são consideradas reabilitações protéticas em regiões anteriores (SILVA et al., 2012).

São cada vez mais evidentes estudos que demonstram a associação de implantes do tipo conexão protética interna, que parecem promover uma melhor estabilidade e perfil de tecidos peri-implantares em longo prazo, e também a utilização de pilares estéticos para prótese confeccionados em materiais como cerâmicas e zircônias (NAKAMURA et al., 2002; AKÇA; CEHRELI; IPLIKÇIOGLU, 2003; MEIJER et al., 2005).

No entanto, apesar de haver a demanda por mais estudos nesta área, sabe-se que estes materiais são mais sensíveis à técnica de confecção e instalação. Além disso, quando submetidos a cargas mastigatórias em alguns estudos se mostraram menos resistentes a falhas se comparados com materiais menos estéticos, porem mais embasados cientificamente (BUSER; MARTIN; BELSER, 2004).

É descrito na literatura, que diferentes materiais utilizados em reabilitação protética podem transferir diferentes valores de tensão baseados em seu módulo de elasticidade. Materiais como zircônia e cerâmica transferem maiores valores de carga aplicada que resina e ligas metálicas. Estruturas de zircônia resistem melhor à carga e apresentam menor deformação, porém transferem mais tensão ao abutment, ao parafuso de conexão protética, ao implante e ao tecido de suporte, podendo resultar em deformação destas estruturas ou até mesmo à fratura do componente e da prótese (GOODACRE et al., 2003; STOPPIE et al., 2009; JORN et al., 2014).

O potencial deletério resultante de tensões geradas a partir da aplicação de cargas deve ser particularmente considerado, quando houver um direcionamento de forças composto, como por exemplo para pilares caninos, onde há carga há carga vertical resultante da força de oclusão, e também carga horizontal resultante da mastigação funcional e guias de desoclusão (ESKITASCIOGLU et al., 2004; SOLIMAN et al., 2015).

Com isso, existe a necessidade de se desenvolver cada vez mais pesquisas que permitam simular a utilização de materiais restauradores sobre implantes, quando submetidos a cargas, além de estudar a distribuição de tensão sobre os componentes reabilitadores e tecidos adjacentes, e também buscar prever os limites de falha para cada tipo de material (ERKMEN et al., 2011).

Respeitando suas limitações, existem métodos de simulação virtual que permitem, através de procedimentos numéricos e computacionais específicos, simular e analisar de forma qualitativa e quantitativa tensões e deformações provenientes de cargas aplicadas a materiais com propriedades mecânicas específicas (GENG; YAN; XU, 2008).

A partir de imagens obtidas através de modelos tomográficos pré-existentes e mensuração de dispositivos reais, são gerados modelos numéricos através de algoritmos paramétricos para uma abordagem tridimensional de simulação de materiais. A eficácia e a precisão das simulações são validadas por meio de uma análise quantitativa e qualitativa de convergência (BAGGI et al., 2008)

Assim sendo, é possível simular uma situação clínica real, aplicando-se o conhecimento das propriedades mecânicas dos materiais, às formas geométricas e fórmulas matemáticas. Portanto o potencial deste tipo de estudo está em analisar os resultados in vitro da simulação de problemas reais permitindo que o clínico torna-se mais bem preparado para interpretar os resultados dos estudos e extrapolá-los às situações clínicas (VASCO et al., 2015).

2 OBJETIVOS

2.1 Objetivo geral

Avaliar através do Método de Elementos Finitos (MEF) as tensões geradas sobre os componentes do sistema de prótese sobre implante na região anterior da maxila.

2.2 Objetivos específicos

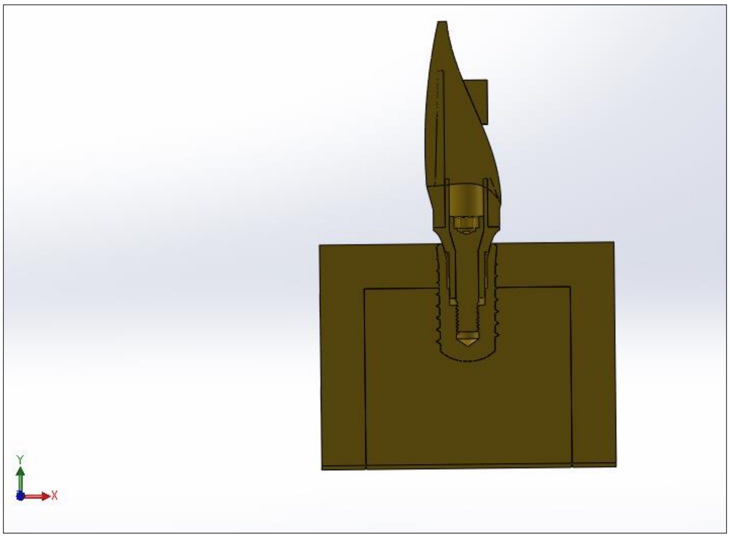
a) avaliar as tensões geradas sobre sistema prótese sobre implante de conexão interna e com pilar de zircônia, sob cargas horizontais e verticais de diferentes intensidades;
b) avaliar as tensões geradas sobre sistema prótese sobre implante de conexão interna e com pilar de titânio, sob cargas horizontais e verticais de diferentes intensidades.

3 MATERIAL E MÉTODOS

Para avaliar os valores máximos de stress transmitidos ao sistema de prótese sobre implantes, resultantes da aplicação de cargas, foi utilizada simulação em software de análise em elementos finitos. Desta forma é possível, através de simulações matemáticas e conhecendo as propriedades mecânicas e formato real dos materiais aplicados, submetê-los a testes de simulação de comportamento mecânico das estruturas.

Para fase de obtenção de modelos, foi preconizada a obtenção de estruturas componentes do sistema de implantes como: corpo do implante Bone Level Regular Crossfit 4mm de diâmetro e 8mm de altura, conexão protética interna, parafuso para conexão protética e componente pré-fabricado de titânio, através da fixação e secção laboratorial destes elementos. Assim sendo se tornou possível a análise interna precisa e detalhada, através de microscópio de precisão, com o objetivo de obtenção de uma maior fidelidade estrutural posteriormente exportada para software de modelagem Solidworks (SolidWorks Corp, Waltham, MA, USA) (Fig. 1). Esta fase compõe um dos muitos métodos propostos pela literatura científica atual (MERIÇ et al., 2011; VASCO et al., 2015).

Figura 1: modelagem das estruturas no software Solidworks (SolidWorks Corp, Waltham, MA, USA)



Fonte: Elaborado pelo autor

A obtenção do pilar de zircônia (Figs. 1, 2 e 3) seguiu o planejamento real laboratorial para obtenção de uma coroa protética unitária em porcelana para região anterior da maxila. O pilar foi obtido através de um modelo de trabalho laboratorial pertencente ao acervo de modelos referentes a pacientes da Faculdade de Odontologia da Pontifícia Universidade Católica de Minas Gerais, disponíveis para pesquisa. Através de um análogo do implante Bone Level RC 4.1 (Institut Straumann AG, Basiléia, Suíça) foi planejado e fresado um componente em zircônia, seguindo princípios de preparos protéticos (SHILLINGBURG et al., 2012; DE MENDONÇA E BERTOLINI et al., 2014). Em seguida este pilar foi modelado através de mensuração microscópica e os dados obtidos foram também transferidos para o software Solidworks.

Figura 2: obtenção de um pilar de zircônia, parafusado sobre análogo do implante 4.1 BLRC.

Fonte: Elaborado pelo autor

Figura 3: pilar de titânio personalizado

Fonte: Elaborado pelo autor

Figura 4: parafuso de base para pilar RC

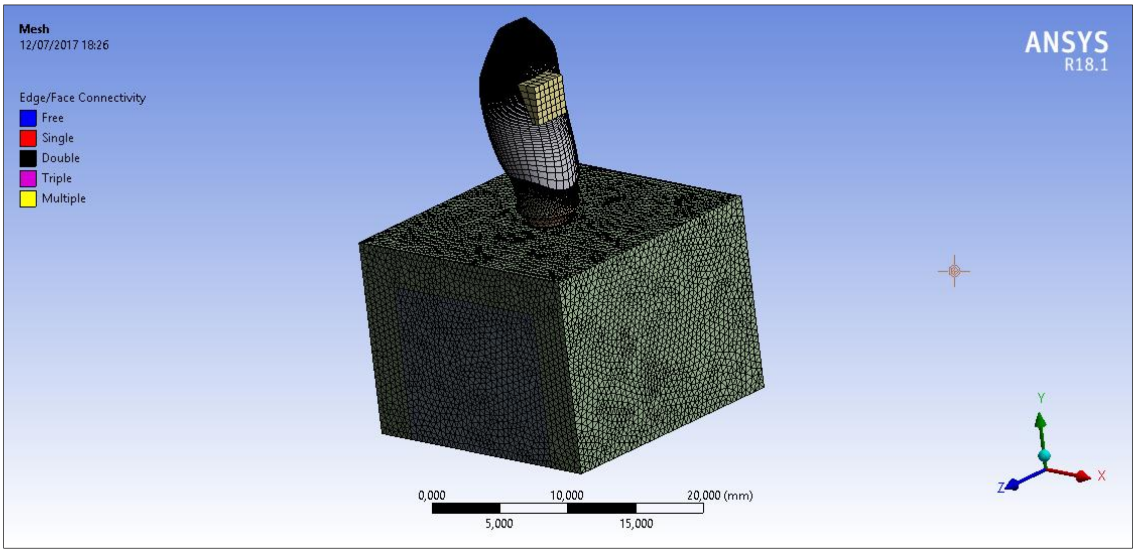
Fonte: Elaborado pelo autor

Para modelagem do tecido de suporte, composto por osso medular envolto por uma camada de 2 mm de osso cortical, simulando composição óssea de uma estrutura maxilar, foi construída uma estrutura no próprio software do tipo CAD (SolidWorks Corp, Waltham, MA, USA) (SHAPURIAN et al., 2006).

A mesma metodologia foi seguida para desenvolvimento estrutural de uma coroa protética em porcelana feldspática, para reabilitação de um elemento canino superior, respeitando princípios dimensionais descritos na literatura científica (MAGNE; GALLUCCI; BELSER, 2003). O material de revestimento cerâmico foi também selecionado através de revisão de literatura (FURHAUSER et al., 2005, JUNG et al., 2008, BRESSAN et al., 2011, LANG; ZITZMANN, 2012, LINKEVICIUS; VAITELIS, 2015).

Para a simulação, as informações obtidas através do software de modelamento, foram então transferidas para o software de análises e testes estruturais ANSYS Workbench (ANSYS, Inc., USA). Durante esta fase é gerada uma malha, formada por elementos tetraédricos contendo 4 nós, formando uma espécie de rede, através da qual são propagadas as tensões consequentes das aplicações de cargas via testes mecânicos. Assim sendo, foi gerada uma malha com 270886 elementos e 1320640 nós (Fig. 4).

Figura 5: Construção da malha de elementos finitos, aplicada para simulação de uma estrutura composta por diferentes materiais através de software ANSYS Workbench (ANSYS, Inc., USA)



Fonte: Elaborado pelo autor

Para determinação de forças a serem aplicadas foi criada uma estrutura com propriedades semelhantes ao esmalte dental humano, a fim de se obter a simulação de carga funcional de um elemento dental antagonista natural. A aplicação das cargas foi constituída de vetores e valores correspondentes as relações de posicionamento e oclusão funcional de um elemento dental canino, bem como situações de oclusão forçada e/ou hábitos parafuncionais. (LUNDGREN; LAURELL, 1994, PAPHANGKORAKIT; OSBOM, 1997; DARVENIZA, 2001; FERRARIO et al., 2004; BUTZ et al., 2005; ATT et al., 2006; MISCH, 2014).

O componente de força que resulta nos valores de tensão e deformação obtidos, foi resultante da combinação de forças verticais e laterais, gerando uma força oblíqua correspondente ao direcionamento de cargas oclusais na região de um elemento dental anterior (VON SPEE, 1890; BEYRON, 1954; SCHUYLER et al., 1959; BELSER; HANNAM, 1985; HOCHMAN, 1987; BUDTZ-JORGENSON, 1987; THORNTON, 1990; AKOREN; KARAAGACLIOGLU 1995; DARVENIZA, 2001; ABDUO, 2015).

Os parâmetros utilizados para análise da propagação de forças através das estruturas foram: o stress de von Mises, com o registro de seu alcance máximo como principal fator para identificar possíveis desgastes, fadiga e falhas dos materiais, e também os valores e padrões de distribuição de força de deslocamento, para verificar tendência de movimento de corpos e modificação estrutural deletéria (VERRI et al., 2015).

Para representar de forma correta o comportamento mecânico de cada componente, os diferentes elementos dos modelos serão configurados com um módulo de elasticidade e coeficiente de Poisson descritos na literatura, conforme a tabela 1. Todas as estruturas foram consideradas isotrópicas, homogêneas e linearmente elásticas.

Tabela 1: Propriedades mecânicas dos materiais

Material	Módulo de Young (GPa)	Coeficiente de Poisson
Porcelana feldspática (ZARONE et al., 2006)	69	0,3
Cerâmica a base de zircônia (GUAZZATO et al., 2002).	242	0.26
Esmalte dental (MEZZOMO et al., 2011)	84,1	0,33
Osso cortical (HOLMES; DIAZ-ARNOLD; LEARY, 1996)	13,7	0,3
Osso Medular (HOLMES; DIAZ-ARNOLD; LEARY, 1996)	1,37	0,3
Titânio comercialmente puro grau 4 (GENG; TAN; LIU, 2001; WANG, 2002).	110	0,33

Fonte: Elaborado pelo autor

4 ARTIGO

A influência do tipo de carga aplicada sobre componentes protéticos utilizados em reabilitação estética sobre implantes na região anterior: análise por método de elementos finitos

Artigo preparado dentro das normas da revista Brazilian Oral Research (Qualis A2 Quadriênio 2013-2016)

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Implantology – Prosthetic Clinic

TYPE OF LOAD AND ITS INFLUENCE OVER THE AESTHETIC ABUTMENTS USED IN IMPLANT PROSTHETIC REHABILITATION ON ANTERIOR MAXILLARY AREA: a finite element analysis

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ABSTACT

Zirconia is a ceramic material with excellent mechanical and aesthetic properties, becoming a therapeutic option, especially for substructures in fixed partial dentures in anterior region. However, it is known that this material is sensible to manufacturing and setup techniques, in addition to being less resistant to mechanic failure, especially when compared with metallic materials. This fact should be considered particularly where occlusal loads have great influence of vertical and horizontal components of force, as in canine element pillars. It is a fact that functional overload results in stresses which, as a result, can lead to prosthetic complication and failure. Thus, this work evaluated, by using finite elements method, the mechanical tensions generated on the prosthesis system on the implant, with zirconia and titanium abutments submitted to different types of load. To simulate different loads, virtual models of an intraosseous titanium implant, a ceramic restoration cemented to a ceramic component, recommended for aesthetic rehabilitation, were created. Loads were used to simulate functional and exacerbated occlusion. The load intensity ranged from 0 to 200N. The lateral forces were main responsible for the maximum values and distribution of tension. Intermediate prosthetic components as abutment and screw concentrate most tension. Zirconia as abutment material result in most stress over screw and implant neck, when submitted to lateral isolated forces, with values of 310N and 320N respectively, when compared to titanium, with values of 347N and 318N. Both, as abutment materials, presented maximum stress values not significantly different when compared.

Keywords: Dental implants. Dental prosthesis. Biomechanical phenomena.

INTRODUCTION

Zirconia is a ceramic material that has been presented as a potential alternative material for metallic restoration in fixed prosthodontics, especially as a substructure material. This indication is due to excellent mechanical properties, applied to biocompatibility and aesthetic properties, mainly when oral rehabilitation involves anterior aesthetic zone[1].

Studies are increasingly publishing evidence that demonstrate the association of internal abutment implant connection, that seems to promote greater stability to peri-implant tissues in long term follow-up, with aesthetic abutment materials such as glass ceramic and zirconia[2-4].

However, there is a need for more scientific publication that consolidate the causes of ceramic sensibility to manufacturing and setup techniques. In addition, when submitted to masticatory load in some scientific studies, this type of material presented less resistance to failure, when compared to non-aesthetic scientifically consolidated materials[5].

It is been described in literature that different type of materials used in prosthetic rehabilitation could transfer different values of tension loads, based on its elasticity modulus. Materials such as zirconia and glass ceramic transfer greater values of applied load, than composite and metal alloys. Zirconia structures resist better to load and to deformation, however transfer this tension to the abutment, prosthetic screw, implant neck and support tissue. This could lead to deformation of this elements, or even complete fracture of prosthetics components and crown[6-8].

The deleterious potential resulting from generated tension of applied load must be particularly considered when the directions of forces is formed over a combination of vectors. This situation is presented for canine element pillars, where the vertical load is most resulted from occlusion, and the horizontal load resulted from the functional masticatory activity and disocclusion patterns[9,10].

Thus, there is slack of develop more researches that allow simulate the use of restorative materials over implant systems, when submitted to load, as well as studying the tension distribution over prosthetic components and surrounding tissues, and prevent failure limits for each type of material[11].

Respecting the inherent limitations, there are methods of virtual simulation that allow, by numerical procedures and specific computer programs, simulate and analyze quantitatively and qualitatively, tensions and deformations resulting from applied loads of specific mechanical properties materials[12].

From images obtained over tridimensional tomographic pre-existing models, in addition of detailed measuring of real subjects, numerical models were generated by parametric algorithms for the simulation. The efficacy and precision of the simulations need to be validated by means of a quantitative and qualitative analysis of convergence[13].

Therefore, it is possible to simulate a real clinical situation, applying knowledge of mechanical properties of different materials to geometrical forms and mathematical formulas. For that reason, the potential of this type of study is in analyze the in vitro results of a simulation of real problems, allowing the clinician to be more prepared to interpret the results of these studies and extrapolate it to real clinical situations[14].

METHODOLOGY

To evaluate the distribution of loads and maximum stress values transmitted to the implant prosthodontics system resulting from the application of loads, it was used a simulation in a specific finite element analysis software. Thus, it is possible through mathematical simulation and knowledge of mechanical properties and real structural forms of materials used, submit it test of mechanical performance.

For the model obtaining phase, were measured original commercial structures such as internal connection implant Straumann Bone Level Regular Crossfit 4.1mm diameter and 8mm length, prosthetic screw and pre-fabricated base component Variobase (Institut Straumann AG, Basiléia, Suíça). The internal structures were detailed measured through fixation in acrylic resin patterns and half section that permits the detailed visualization. Posteriorly, the data was compiled and exported to a modeling software SolidWorks (SolidWorks Corp, Waltham, MA, USA)[14,15].

The obtaining of the zirconia abutment was carried by sequence of laboratorial planning of a real ceramic single crown for anterior maxilla. The abutment was milled through a real analogue installed over a real plaster work model from the research available collection of the Pontifical Catholic University School of Dentistry, The laboratorial sequence followed the prosthetic preparation principles in fixed prosthodontics literature[16,17]. Then, this milled abutment was microscopically measured, modeled and exported to the SolidWorks software.

To obtain the model of the peri-implant tissues, composed by medular bone, surrounded by cortical bone of 2mm thickness, simulating the osseous composition of a maxillary structure, it was used the CAD (SolidWorks Corp, Waltham, MA, USA)[18].

The same methodology was followed for the structural development of a prothetic crown in feldspatic ceramic material, for the rehabilitation of a maxillary canine element, with respect of the anatomical dimensions principles described in scientific literature[19-24].

The information obtained from the modeling software were transfered for the simulation and analysis software ANSYS Workbench (ANSYS, Inc., USA). During this phase, a mesh is generated by tetraedrical elements linked by 4 knots, forming a network, and through this the tension is porpagated. Thus this network was formed by 270886 elements e 1320640 knots (Fig. 1).

For the determination of the load to be applied it was developed a structure with similar properties as dental human enamel, in objective to simulate functional antagonist load. The load to be applied was constituted of vectors and values corresponding to positioning relation and functional occlusion of a maxillary canine element, as well as in forced occlusion and parafunctional habits[25-31].

The final direction of load was result of a combination of lateral and vertical forces, creating and oblique load corresponding to functional load direction of anterior superior[27,32-40].

The parameters preconized for analysis of tension propagation through the structures were: von Mises stress, with maximum limit as a main fator to identify possible failures and fractures, and the displacement to verify the patterns of distribution of tension and the tendency of movement and surface modification of structures

To represent the correct mechanical performance of each element, the different structures were configured based on Young's modulus and Poisson's ratio, according to table 1. All the structures were considered isotropic, homogeneous and linearly elastics.

RESULTS

The values and patterns of total displacement of structures, analyzed separated and in complex integration form, and the maximum Von Mises tensions were the parameters chosen to measure the structural performance as a result of load application.

Primarily, the quantification of total deformation of each structure and also of the system, characterized for the tendency of dislodgment and structural modification was realized. The collected data was presented in table 2, evidencing that the most external components of the system, that is the closer to the load application region, such as the abutment and the prosthetic crown, were the elements that suffered greater deformation,

The horizontal component of force exerts most influence over the deformation of structures. This is confirmed in table 2, where the variation of vertical forces, associated with maximum lateral forces did not produced more variation on deformation. In fact, for the zirconia material, it produced decreasing deformation for structures such as the abutment and prosthetic crown. When analyzed in separate form, the horizontal load increase produces directly proportional increase in deformation, to be observed in table 3.

For the phase of Von Mises stress analysis, data was generated and registered in table 4 and 5. The same pattern situation can be observed for the lateral forces as predominant in determination of tension. However it can be observed that the cortical bone presented stress values that were 10 times greater or more, if compared to medullar bone.

In table 4 it is possible to analyze that the intermediate components such as zirconia abutment pillar and prosthetic screw were the elements presenting the higher values of stress generated.

The gradual increase on lateral forces also leads to increase in stress values. However it can be noticed that greatest values of lateral load results in tensions over the implant body that overcome loads over the screw, as shown in table 5.

In table 7, it is been evidenced less deformation for the implant body and prosthetic screw using a titanium abutment over lateral isolated forces, in comparison to a zirconia abutment.

The titanium material as a abutment, results in less concentration of tension over the abutment body, and more tension accumulated for the screw, according to table 8. When lateral force is applied in isolated form, it can be noticed that the implant body concentrate less tension and the screw more tension, if compared to the results for the ceramic abutment, as demonstrated in table 9.

The patterns of distribution of tension over the implant structure, osseous structure and prosthetic screw were constant in location, even varying the material of the abutment (Figs. 2,3,4 and 5). However analyzing the abutment structure, it is possible to notice that the tension for the zirconia was located in the region corresponding to the cervical palatine (Fig. 6). Otherwise for the titanium material, the tension accumulated in cervical vestibular (Fig. 7).

DISCUSSION

The finite element method is a mathematical simulation of materials performance, based on mechanical properties and structural real form. Therefore this researches are classified as a valid method for a real physic simulation, stablishing comparison patterns based on suggestions that can be extended to real clinic situations. However, this methodology needs to be corroborated and associated with clinical and laboratory experiment studies. Inherent limitations of this type of research is the structural simplification phase, necessary for generate the virtual models, but has the negative consequence of lack of accuracy and fidelity on results analysis[14,41].

In this study, the models were considered homogeneous, isotropic and linearly elastic. The non-corresponding structure of models, according to the complex geometrical real structures, structural density, anisotropy of real mechanical properties and questionable simplifying structures are inherent factors that do not prevent, but limit the extrapolation of results in a real clinical level.

The high success rate of the implantology therapy led to implication of these modality of treatment, not only for complex extensive rehabilitations, but also for restorative localized conservative and aesthetic treatments Along with the recognition of the technique, the commercial expansion and aesthetic demand and exigence of the patient community increased associated. Thereby, more often, treatment modalities that promote harmonization and biomimetization associated with natural dentofacial structures[20-24].

However the properties of aesthetic materials most used actually such as glass ceramics and zirconia often differ from classical materials such as metal alloys, titanium and metal-ceramic restorations. Even consolidated by several studies that the resistance of these ceramic materials overcome physiologic occlusal loads, some factors such as long term clinical follow-ups associated with structure characterized as rigid and friable, these materials are correlated with reports of fractures and local trauma[42-48].

In this study, it was evidenced that the material properties exerted fundamental influence over distribution of tension, to each component of the implant-prosthetic complex and the system as a conjunct. The ceramic material concentrates more tension and distributes it in mode that could affect noble structure such as implant neck. Otherwise the prosthetic abutment associated with the prosthetic screw, presented an intermediate system that absorbs tension and distributes it, favoring less complex complications such as screw failures, mostly when the abutment material is titanium.

The abutment of zirconia was obtained by means of a laboratorial sequence, following the process of planning a prosthetic restorations and milling a substructure respecting the material space principles in fixed prosthodontics. Thereby, in many situations is necessary to promote the union of this ceramic component to a metal structure that is linked to the implant neck, such as cementation to another component, since the commercial industrial production of zirconia abutments with direct implant connection is still in progress. This fact can lead to deviation in results since there is no uniform pattern in structural composition and manufacturing process of compared subjects.

The results in this study evidenced that the lateral forces are predominant in determination of tension overs prosthetic implant components. This type of direction vector force is present in occlusion of canine maxillary elements, essential structures for maintance of aesthetics, phonetics and masticatory function. This elements are involved in prevention of worn dentition and articulation, influencing activity and muscular effort. Therefore overload can affect these occlusal pillars, concentrating stress that can lead to failures such as loss of osseointegration, screw loosening, prosthetic abutment fracture and prosthetic crown fracture[7,49-52].

The current implementation of implantology science as a rehabilitation conservative practice, the main goals of these therapy are to reestablish the masticatory function equilibrium, preserving remaining support components. The demand for more researches including studies of material properties and mechanical characteristics is clear, since the knowledge of its performance, especially in extreme situations such exacerbated occlusal function intensity and direction, seems to be a predictable conduct to prevent complications and material failures.

CONCLUSION

The horizontal component of force was the predominant in determination of maximum tensions and deformations. The abutment and prosthetic screw were the elements that showed the greatest values of generated stress. The ceramic abutment concentrates greatest tension and distributes it in a different modus, compared to titanium, which can lead to wear of noble structures such as implant neck. Both, as abutment materials, presented maximum stress values not significantly different when compared. Therefore, the zirconia abutment seems to be a predicable alternative material for use in fixed partial prosthodontics, especially in aesthetic zone.

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TABLES

Table 1 – Mechanical properties of materials

Material	Youngs's Modulus (GPa)	Poisson's Ratio
Feldspatic porcelain[53]	69	0,3
Zirconia[54]	242	0.26
Dental Enamel[55]	84,1	0,33
Cortical bone[56]	13,7	0,3
Medular bone[56]	1,37	0,3
Titanium[57,58]	110	0,33

Table 2 – Total deformation values (mm) for structures submitted to different values of load (N), for the implant prosthetic system with zirconia abutment.

Load	MB	CB	I	V	S	ZA	C	A	Total
X=150N Y=150N	0,01	0,02	0,02	0,04	0,03	0,08	0,11	0,08	0,11
X=150N Y=200N	0,01	0,02	0,02	0,04	0,03	0,08	0,10	0,08	0,10
X=175N Y=175N	0,01	0,02	0,02	0,05	0,03	0,09	0,13	0,10	0,11
X=175N Y=200N	0,01	0,02	0,02	0,05	0,03	0,09	0,12	0,09	0,12
X=200N Y=150N	0,02	0,02	0,02	0,06	0,04	0,11	0,15	0,12	0,15
X=200N Y=175N	0,02	0,02	0,02	0,06	0,04	0,10	0,15	0,11	0,15
X=200N Y=200N	0,02	0,02	0,02	0,05	0,03	0,11	0,14	0,11	0,14

*X = horizontal vector of force, Y = vertical vector of force, OM = medullar bone, OC = cortical bone, I = implant, V = variobase, S = screw, ZA = zirconia abutment, C = crown, A = antagonist

Table 3 – Total deformation values (mm) for structures submitted to different values of horizontal load (N), for the implant prosthetic system with zirconia abutment.

Load	MB	CB	I	V	S	ZA	C	A	Total
X=100N Y=0N	0,01	0,01	0,01	0,03	0,02	0,06	0,09	0,07	0,09
X=125N Y=0N	0,01	0,01	0,01	0,04	0,02	0,08	0,11	0,08	0,11
X=150N Y=0N	0,01	0,02	0,02	0,05	0,03	0,09	0,13	0,10	0,13
X=175N Y=0N	0,01	0,02	0,02	0,05	0,03	0,11	0,16	0,12	0,16
X=200N Y=0N	0,01	0,02	0,02	0,06	0,04	0,12	0,18	0,13	0,18

*X = horizontal vector of force, Y = vertical vector of force, OM = medullar bone, OC = cortical bone, I = implant, V = variobase, S = screw, ZA = zirconia abutment, C = crown, A = antagonist

Table 4 – values of Von Mises tensions (MPa) for structures submitted to different load values (N), for the implant prosthetic system with zirconia abutment.

Load	MB	CO	I	V	S	ZA	C	A	Total
X=150N Y=150N	4,0	59,2	184,2	302,0	202,1	284,9	69,8	67,2	302,4
X=150N Y=200N	4,3	59,9	129,1	290,9	190,6	274,5	73,5	83,6	209,1
X=175N Y=175N	4,7	69,1	214,9	352,8	234,6	332,5	81,4	78,4	352,8
X=175N Y=200N	4,9	69,5	212,3	347,0	229,4	327,2	72,4	86,5	347,1
X=200N Y=150N	5,1	78,3	260,2	414,7	278,7	390,7	112,9	73,5	414,7
X=200N Y=175N	5,2	78,7	250,3	408,9	273,4	385,3	113,0	81,5	408,9
X=200N Y=200N	5,4	79,0	245,7	403,2	268,2	379,9	93,0	89,6	403,2

**X = horizontal vector of force, Y = vertical vector of force, OM = medullar bone, OC = cortical bone, I = implant, V = variobase, S = screw, ZA = zirconia abutment, C = crown, A = antagonist

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Table 5 – values of Von Mises tensions (MPa) for structures submitted to horizontal load values (N), for the implant prosthetic system with zirconia abutment.

Load	MB	CB	I	V	S	ZA	C	A	Total
X=100N	2,4	38,5	160,0	224,7	155,3	223,9	86,3	37,3	224,7
X=125N	2,9	48,1	200,0	280,8	194,1	279,8	107,8	46,6	280,8
X=150N	3,5	57,1	240,0	337,0	252,9	335,8	129,5	55,9	337,0
X=175N	4,1	67,3	280,0	393,2	271,8	391,8	151,1	65,2	393,2
X=200N	4,7	76,9	320,0	449,3	310,6	447,8	172,6	74,5	449,4

**X = horizontal vector of force, Y = vertical vector of force, OM = medullar bone, OC = cortical bone, I = implant, V = variobase, S = screw, ZA = zirconia abutment, C = crown, A = antagonist.

Table 6 - Total deformation values (mm) for structures submitted to different values of load (N), for the implant prosthetic system with titanium abutment

Load	MB	CB	I	V	S	TA	C	A	Total
X=150N Y=150N	0,01	0,01	0,01	0,04	0,02	0,08	0,11	0,08	0,11
X=150N Y=200N	0,01	0,01	0,01	0,04	0,02	0,08	0,10	0,08	0,10
X=175N Y=175N	0,01	0,01	0,02	0,04	0,03	0,10	0,13	0,10	0,13
X=175N Y=200N	0,01	0,02	0,02	0,04	0,03	0,09	0,13	0,09	0,13
X=200N Y=150N	0,01	0,02	0,02	0,05	0,03	0,11	0,16	0,12	0,16
X=200N Y=175N	0,01	0,02	0,22	0,05	0,03	0,11	0,16	0,12	0,16
X=200N Y=200N	0,01	0,02	0,02	0,05	0,03	0,11	0,15	0,11	0,15

X = horizontal vector of force, Y = vertical vector of force, OM = medullar bone, OC = cortical bone, I = implant, V = variobase, S = screw, TA = titanium abutment, C = crown, A = antagonist.

Table 7 - Total deformation values (mm) for structures submitted to values of horizontal load (N), for the implant prosthetic system with titanium abutment

Load	MB	CB	I	V	S	TA	C	A	Total
X=150N	0,01	0,01	0,01	0,04	0,02	0,09	0,14	0,10	0,14
X=175N	0,01	0,01	0,01	0,05	0,03	0,11	0,16	0,12	0,16
X=200N	0,01	0,02	0,02	0,06	0,03	0,13	0,19	0,14	0,19

X = horizontal vector of force, Y = vertical vector of force, OM = medullar bone, OC = cortical bone, I = implant, V = variobase, S = screw, TA = titanium abutment, C = crown, A = antagonist.

Table 8 – values of Von Mises tensions (MPa) for structures submitted to different load values (N), for the implant prosthetic system with titanium abutment.

Load	MB	CB	I	V	S	TA	C	A	Total
X=150N Y=150N	4,0	58,9	183,5	302,3	224,7	228,3	81,9	67,3	4,0
X=150N Y=200N	4,3	59,6	178,5	291,1	213,5	220,7	73,8	83,7	4,3
X=175N Y=175N	4,6	68,7	214,0	352,7	262,1	266,3	95,6	78,5	4,6
X=175N Y=200N	4,8	69,0	211,6	347,0	256,2	262,5	84,5	86,7	4,8
X=200N Y=150N	5,0	77,8	258,4	414,3	311,5	312,0	131,5	73,7	5,0
X=200N Y=175N	5,2	78,1	249,1	408,6	305,5	308,2	120,3	81,7	5,2
X=200N Y=200N	5,3	78,5	244,6	403,0	299,6	304,4	109,2	89,7	5,3

* X = horizontal vector of force, Y = vertical vector of force, OM = medullar bone, OC = cortical bone, I = implant, V = variobase, S = screw, TA = titanium abutment, C = crown, A = antagonist.

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Table 9 – values of Von Mises tensions (MPa) for structures submitted to horizontal load values (N), for the implant prosthetic system with titanium abutment.

Load	MB	CB	I	V	S	TA	C	A	Total
X=100N	3,4	57,3	238,6	336,0	260,6	331,3	149,0	57,0	3,4
X=125N	4,0	66,8	278,4	392,0	304,1	386,9	173,8	66,5	4,0
X=150N	4,6	76,4	318,1	448,0	347,5	441,8	198,6	76,0	4,6
X=175N	4,1	67,3	280,0	393,2	271,8	391,8	151,1	65,2	393,2
X=200N	4,7	76,9	320,0	449,3	310,6	447,8	172,6	74,5	449,4

* X = horizontal vector of force, Y = vertical vector of force, OM = medullar bone, OC = cortical bone, I = implant, V = variobase, S = screw, TA = titanium abutment, C = crown, A = antagonist.
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FIGURES

Figure 1 – Construction of the mesh of finite elements, applied for simulation of a structure composed of different materials by using ANSYS Workbench software (ANSYS, Inc., USA).

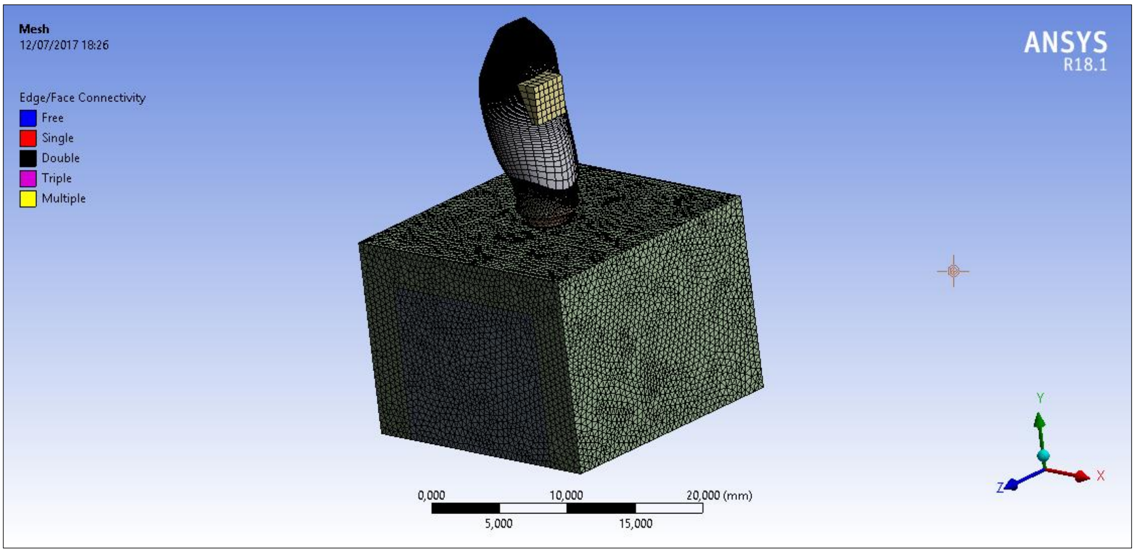


Figure 2 – Static structural analysis evidencing values of tension and distribution pattern for the implant, using zirconia abutment.

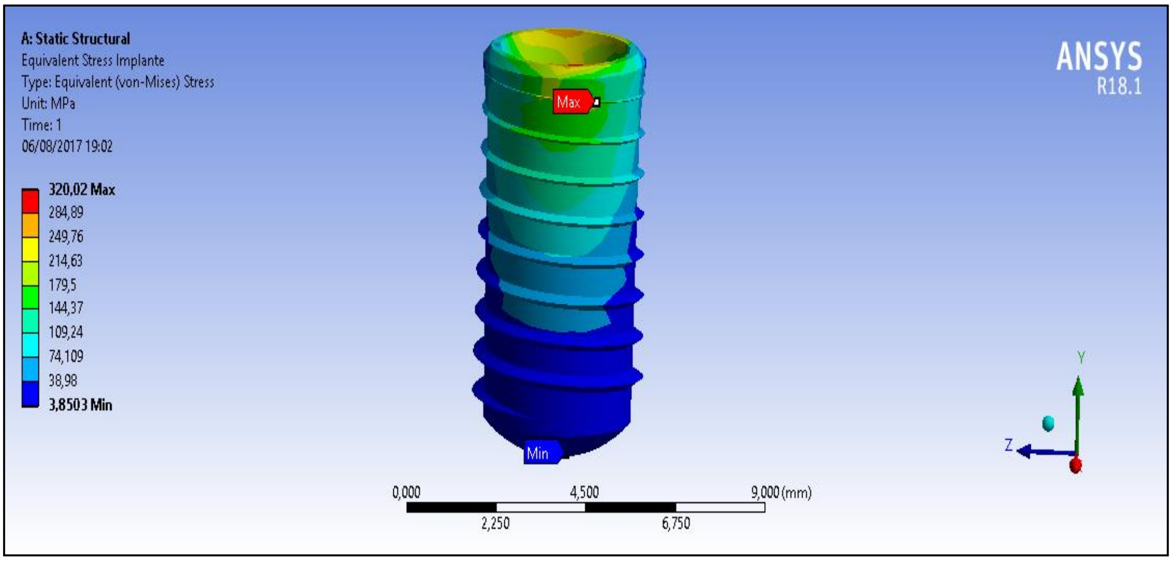


Figure 3 – Static structural analysis evidencing values of tension and distribution pattern for the implant, using titanium abutment.

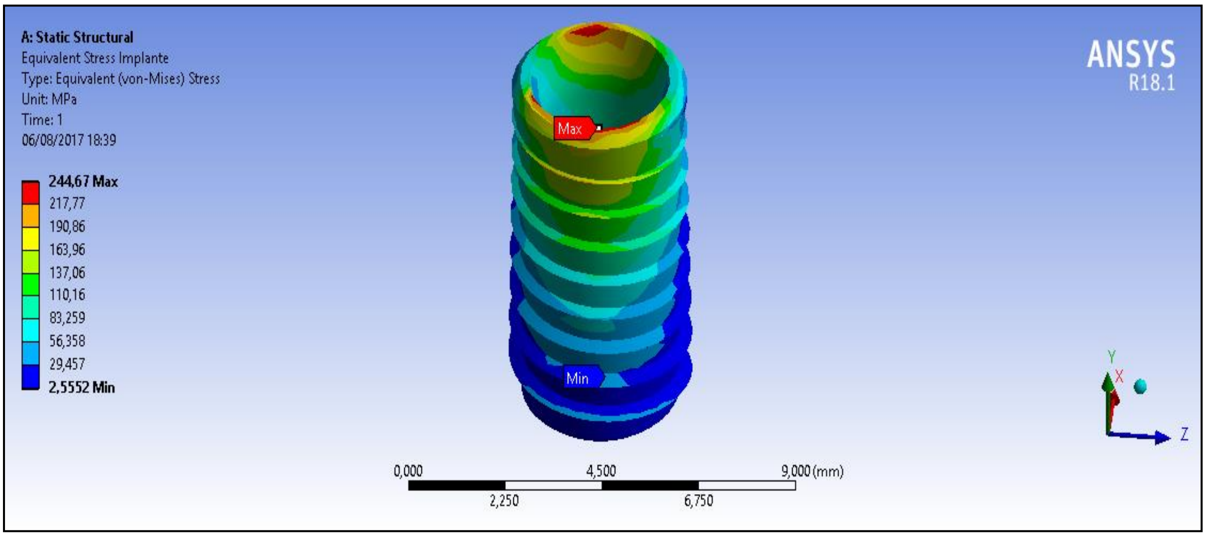


Figure 4 - Static structural analysis evidencing values of tension and distribution pattern for the prosthetic screw, using zirconia abutment.

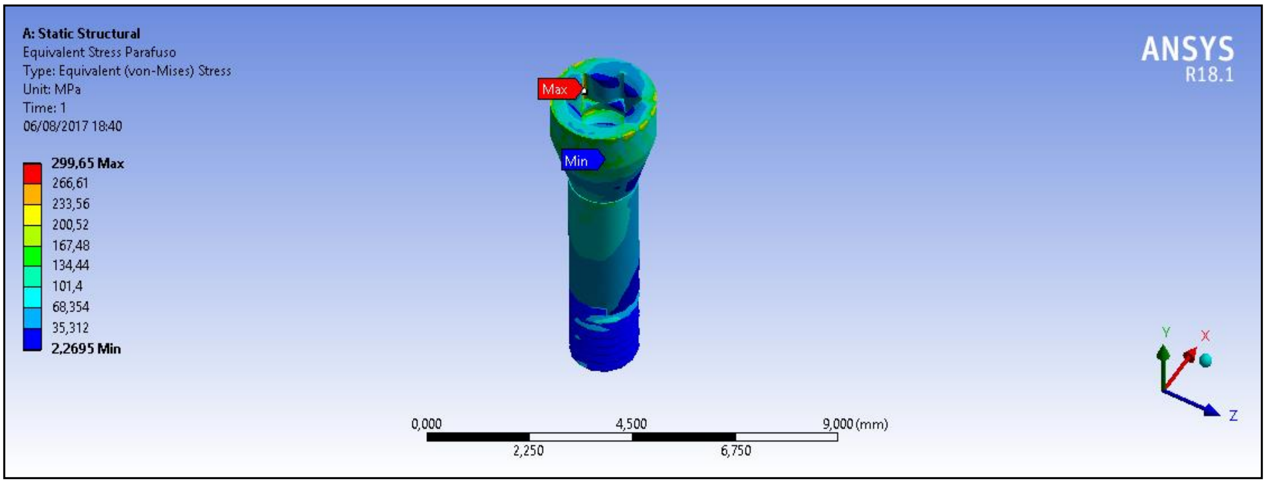


Figure 5 – Static structural analysis evidencing values of tension and distribution pattern for the prosthetic screw, using titanium abutment.

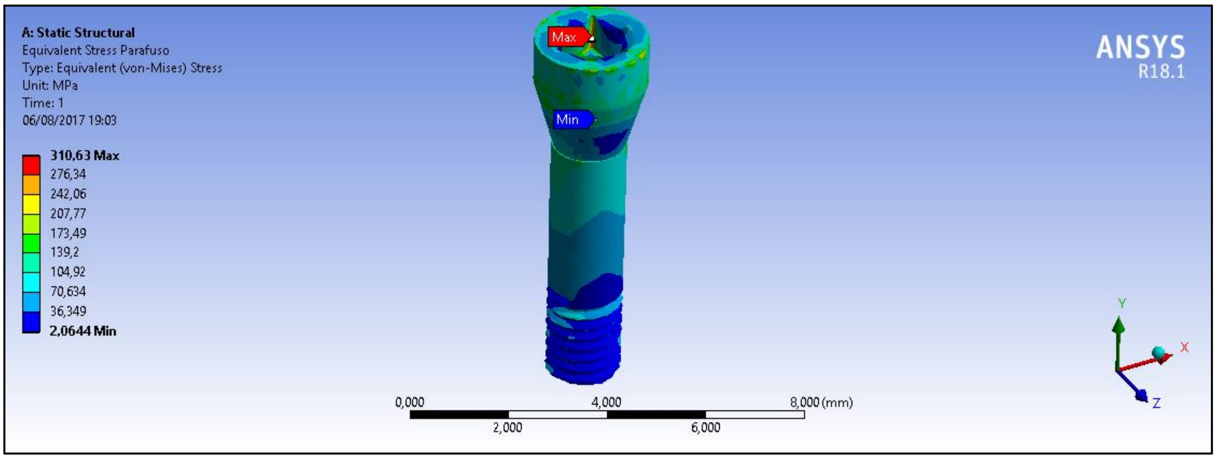


Figure 6 – Static structural analysis evidencing values of tension and distribution pattern for the abutment, using zirconia abutment.

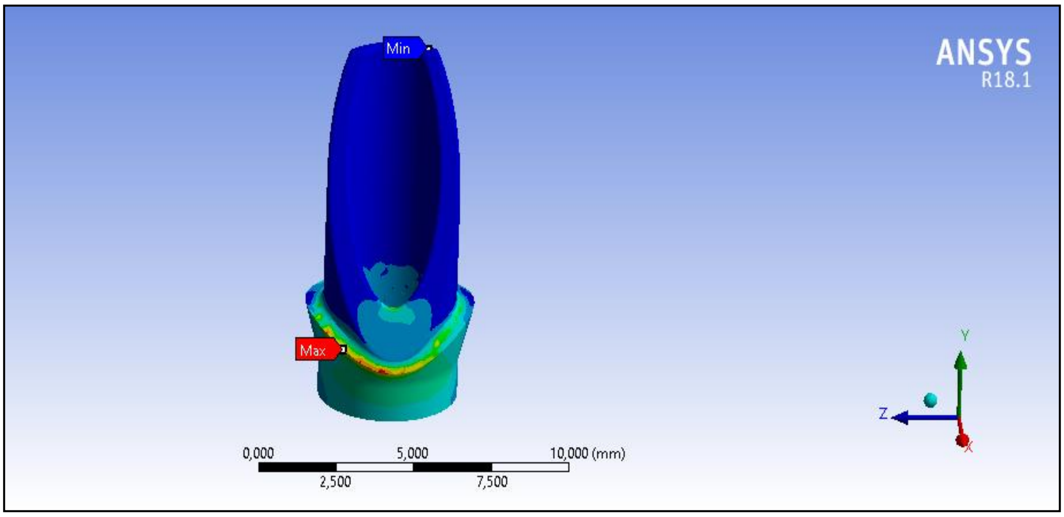
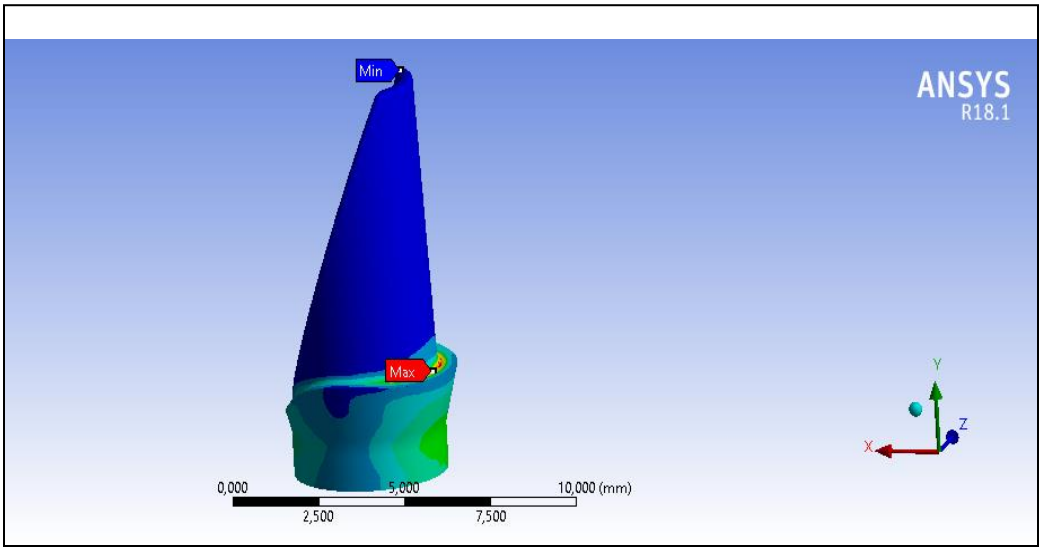


Figure 7 – Static structural analysis evidencing values of tension and distribution pattern for the abutment, using titanium abutment.



5 CONSIDERAÇÕES FINAIS

O pilar de zircônia como componente de um sistema de prótese sobre implante gerou tensões não significativamente diferentes para o corpo do pilar e para os outros elementos do sistema, se comparados com resultados obtidos para o pilar de titânio. Devido a suas excelentes propriedades estéticas, o pilar cerâmico apresenta-se como uma alternativa a materiais metálicos, principalmente para subestruturas em próteses fixas na região anterior. O pilar e o parafuso de conexão protética são estruturas responsáveis pela maior parte da absorção e distribuição de tensões resultantes de cargas aplicadas. Deve-se considerar a natureza e as propriedades mecânicas do material cerâmico como sendo fatores que contribuem para uma maior concentração de tensão e distribuição mais abrupta da mesma, principalmente sobre estruturas nobres do sistema, como o corpo do implante. Este fato deve ser especialmente considerado na presença de carga lateral predominante ou isolada.

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