

Ronaldo Silva Cruz

*Análise biomecânica envolvendo implantes
estreitos para reabilitações unitárias na região
maxilar anterior.*

Araçatuba – SP

2020

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estreitos para reabilitações unitárias na região
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Tese apresentada à Faculdade de Odontologia do
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Coorientador: Prof. Tit. Eduardo Piza Pellizzer

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*Sem sonhos, as perdas se tornam insuportáveis, as pedras do
caminho se tornam montanhas, os fracassos se transformam em
golpes fatais. Mas, se você tiver grandes sonhos. Seus erros
produzirão crescimento, seus desafios produzirão oportunidades, seus
medos produzirão coragem. Por isso, meu ardente desejo é que você
Nunca desista de seus sonhos.*

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Resumo geral

RESUMO GERAL

CRUZ, R. S. **Análise biomecânica envolvendo implantes estreitos para reabilitações unitárias na região maxilar anterior.** 2020. Tese (Doutorado em Ciência Odontológica, área de concentração Biomateriais) – Faculdade de Odontologia de Araçatuba, Universidade Estadual Paulista, Araçatuba 2020.

Proposição: Avaliar biomecanicamente a possibilidade de uso de implantes de diâmetro reduzido em reabilitações unitárias em região maxilar anterior. Foram avaliados biomecanicamente o uso de implantes de diâmetro 2,9 mm com implantes de 3,5 mm instalados a nível ósseo e 1,5 mm infraósseo, variando-se o comprimento dos implantes (7 mm, 8,5 mm, 10 mm, 11,5 mm, 13 mm e 15 mm), por meio da análise dos elementos finitos 3D.

Material e métodos: 12 modelos tridimensionais foram simulados com ajuda dos programas Invesalious, Rhinoceros 3D e SolidWorks. Cada modelo possuía um bloco ósseo da região anterior maxilar (osso tipo III) com a presença dos dentes incisivo central e canino, simulando uma reabilitação com coroa unitária metal free cimentada (dente incisivo lateral direito), suportada por um implante de 7 mm, 8,5 mm, 10 mm, 11,5 mm, 13 mm ou 15 mm, variando-se o diâmetro do implante (2,9 mm e 3,5 mm) e a instalação dos implantes no tecido ósseo (ao nível e 1,5 mm infraósseo). Os modelos foram processados pelos programas ANSYS 19.2, utilizando uma força de 178 N em diferentes inclinações (0°, 30° e 60°). Os resultados foram plotados em mapas de Tensão de Von Mises (VM), Tensão Máxima Principal (TMP), Microdeformação ($\mu\epsilon$) e Deslocamento.

Resultados: Na análise de VM houve um aumento da concentração de tensão com o aumento da inclinação da força nos implantes/componentes e tecido ósseo. Foi possível observar maiores concentrações de tensões para os implantes instalados 1,5 mm infraósseo, além disso, os implantes de 2,9 mm de diâmetro apresentaram maiores concentrações de tensões. Sob análise de TMP e $\mu\epsilon$,

o tecido ósseo apresentou maiores concentrações de tensões de tração e microdeformação sob cargas oblíquas (30° e 60°) ao redor do pescoço do implante (tecido ósseo cortical) na técnica de instalação ao infraósseo, além disso, foi possível observar que os implante menor diâmetro apresentaram maiores concentrações de tensões nos implantes/componentes e tecido ósseo e menor tendência de deslocamento na técnica de instalação ao nível ósseo.

Conclusão: Os implantes de 3,5 mm de diâmetro foram mais favoráveis biomecanicamente que os implante de 2,5 mm, independentemente do tipo de técnica de instalação utilizadas. A instalação de implantes por técnica ao nível ósseo nas condições do estudo, favoreceu uma diminuição de concentração de tensões no tecido ósseo adjacente ao implante.

Palavras chaves: Prótese dentária; Implante dentário; Análise de elementos finitos.

ABSTRACT

CRUZ, R. S. **Biomechanical analysis involving narrow implants for unitary rehabilitation in the anterior maxillary region.** 2020. Thesis (doctor in Dental Science, Biomaterials concentration area) - Faculty of Dentistry of Araçatuba, Paulista State University, Araçatuba 2020.

Proposition: Biomechanically evaluate the possibility of using small diameter implants in unitary rehabilitation in the anterior maxillary region. Biomechanically evaluated the use of 2.9 mm diameter implants with 3.5 mm implants placement at bone level and 1.5 mm subcrestal, through 3D finite element analysis.

Material and methods: 12 three-dimensional models were simulated with the help of the Invesalious, Rhinoceros 3D and SolidWorks programs. Each model had a bone block from the anterior maxillary region (type III bone) with the presence of the central and canine incisor teeth, simulating a rehabilitation with a cemented metal free unitary crown (right lateral incisor tooth), supported by implant the 7 mm, 8,5 mm, 10 mm, 11.5 mm, 13 mm or 15 mm, varying the implant diameter (2.9 mm and 3.5 mm), the placement of the implants in the bone tissue at level 1, 5 mm subcrestal. The models were processed by the ANSYS 19.2 programs, using a force of 178 N at different slopes (0°, 30° and 60°). The results were plotted on Von Mises Stress (VM), Maximum Main Stress (TMP), Microdeformation ($\mu\epsilon$) and Displacement.

Results: In the analysis of VM there was an increase in the concentration of tension with the increase of the inclination of the force in the implants/components and bone tissue. It was possible to observe higher concentrations of stresses for the implants installed in the subcrestal, in addition, the implants of 2.9 mm in diameter presented higher concentrations of stresses. Under analysis of TMP and $\mu\epsilon$, the bone tissue showed higher concentrations of tensile stresses and microdeformation under oblique loads (30° and 60°) around the implant neck (cortical bone tissue) in the placement the technique at the subcrestal, in addition , it was possible to observe that the

smaller diameter implants showed higher concentrations of stress in the implants/components and bone tissue and and less tendency of displacement in the installation technique at the bone level.

Conclusion: The 3.5 mm diameter implants were more favorable biomechanically than the 2.5 mm implants, regardless of the type of placement the technique used. The placement of implants by crestal technique under the conditions of the study, favored a decrease of stress concentration in the bone tissue adjacent to the implant.

Keywords: Dental prosthesis; Dental implants; Finite element analysis

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Lista de Abreviaturas e Siglas

N	-	Newton
Mpa	-	Mega Pascal
μϵ	-	Microstrain
mm	-	Millimeters
3D	-	Three-dimensional
MP	-	Maximum principal stress
VM	-	Von mises stress
RDI s	-	Regular-diameter implants
NDI s	-	Narrow-diameter implants
WDI	-	Wide-dental diameter
IC	-	Internal connections
EC	-	External connections
Ø	-	Diameter

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Introdução Geral

1. INTRODUÇÃO GERAL

Os implantes dentários tornaram-se uma opção com alta previsibilidade clínica para reabilitações protéticas, inclusive na região anterior da maxila (Ioannidis et al., 2015; Tolentino et al., 2015; Anitua et al., 2016; King et al., 2016). No entanto, muitas vezes essa região se apresenta com pouca quantidade óssea, tanto vestibulo-lingual quanto mesio-distal devido à reabsorção fisiológica alveolar.

Clinicamente na região anterior maxilar, principalmente na área de interesse desse estudo (incisivos laterais), algumas vezes verifica-se uma disponibilidade óssea mesio-distal inferior a 6 mm, e vestibulo-lingual inferior a 5 mm (Tarnow et al., 2000; Jung et al., 2012; Anitua et al., 2016). Assim, muitas vezes a opção para reabilitação de pacientes nessas situações acaba sendo a instalação de implantes de diâmetro reduzido (Ioannidis et al., 2015; King et al., 2016). Biomecanicamente, as variações nas dimensões dos implantes são de grande importância, visto que, podem contribuir no aumento das tensões tanto para os implantes/componentes, bem como para a região de tecido ósseo (Himmlová et al., 2004; Pellizzer et al., 2013). Dessa forma, estudos que avaliem o comportamento biomecânico dessas dimensões frente a diferentes variáveis é de interesse, uma vez que uma possível sobrecarga oclusal poderia afetar a longevidade da reabilitação (Himmlová et al., 2004; Fu et al., 2012; Pellizzer et al., 2012).

Diversos estudos que analisaram o diâmetro dos implantes sugerem que quanto menor o diâmetro maior a transferência de carga oclusal para o tecido ósseo, principalmente sob cargas oblíquas (Himmlová et al., 2004; Qian et al., 2009; Chang et al., 2012; Pellizzer et al., 2013; Santiago Junior et al., 2013). Entretanto, tais estudos consideraram a influência do diâmetro em região posterior e para implantes de diâmetro regular (3,75 mm) x largo diâmetro (5,00 mm). Além disso, a espessura da tábua óssea pode ser considerada outra característica que pode influenciar na distribuição de tensões (Alikhasi et al., 2014). Infelizmente, estudos clínicos randomizados considerando este fator na região anterior maxilar ainda são poucos, embora relatem resultados

promissores em relação a manutenção de tecido ósseo ao redor do implante, com poucas perdas de implantes (King et al., 2016). Diante disso, ainda não existe um consenso da influência biomecânica de implantes diâmetro estreito ≤ 3.75 mm (Javed et al. 2015) na região anterior de maxila.

Porém, com a diminuição do diâmetro do implante ocorre a redução da área de contato osso-implante, proporcionado menor área de superfície, podendo comprometer a osseointegração (Ivanoff et al 1997). Dessa forma, uma alternativa para aumentar a superfície de contato osso-implante poderia ser através da instalação de implantes de maiores comprimentos (Baggi et al., 2008; Pellizzer et al., 2015; Bataineh et al., 2017) Além disso, pode ser encontrado na literatura que a utilização de implantes de maiores comprimentos em situações de implantes de diâmetro reduzido pode ser eficaz no sentido de reduzir os riscos de complicações, bem como aumentar a taxa de sobrevivência dos implantes (Lemos et al., 2016).

A região anterior da maxila, quando apresenta elevada quantidade de tecido ósseo, permite a instalação de implantes de maiores comprimentos (Wakimoto et al., 2012; Lee et al., 2013). Entretanto, não existe concordância a respeito da biomecânica do comprimento dos implantes na literatura nesta região. Podem ser observados estudos que apresentam influência direta do comprimento do implante na distribuição das tensões, (Lee et al., 2013; Pellizzer et al., 2015; Sotto-Maior et al., 2015) mas também estudos que relatam não ser o comprimento influente nas distribuições das tensões (Kim et al., 2014; Sotto-Maior et al., 2016). Assim, a avaliação do comprimento em associação com fatores previamente citados, principalmente a espessura da tábua óssea, pode ser de grande interesse para nortear um tratamento com implantes na região anterior da maxila.

A literatura mostra comportamento biomecânico mais favorável para a distribuição de tensões para as conexões internas quando comparadas a conexões de hexágono externo (de Faria

Almeida et al., 2014; Torcato et al., 2015; Santiago et al., 2016). Diante disso, a utilização de implantes de conexão interna cônica, como os implantes cone Morse, tem aumentado com grande frequência para reabilitação em regiões anteriores (Mangano et al., 2012; Bidra et al., 2013). Como existe um aumento na estabilidade interna dos implantes cone Morse, com redução da micromovimentação (de Faria Almeida et al., 2014; Santaigo et al., 2016), esse fator poderia amenizar as diferenças entre as dimensões dos implantes, aumentando assim as indicações desses implantes em reabilitações implantossuportadas, além do fator periodontal que é superior aos implantes de hexágono externo.

Os implantes cones Morse podem ser instalados ao nível ósseo ou abaixo desse. A indicação de instalação a nível infraósseo tem sido feita com o intuito de se aumentar os valores de preservação do tecido ósseo (Castro et al., 2014; Fetner et al., 2015). Entretanto, existem situações clínicas em que devido a disponibilidade óssea e proximidade com estruturas anatômicas, como nesse caso a fossa nasal, poderia haver limitação para a instalação desses implantes, sendo necessário ou utilização de implantes mais curtos ou a instalação a nível do tecido ósseo ou ainda alguma técnica mais complexa de expansão óssea (levantamento de assoalho nasal) (Garcia-Denche et al., 2015; Lemos et al., 2016). Ainda são escassos estudos biomecânicos comparando a influência do nível ósseo em relação a distribuição das tensões nos implantes/componentes e tecido ósseo. Assim, essa avaliação se faz necessária principalmente na região anterior, visto que, a preservação óssea está diretamente relacionada com a manutenção tecidual e sucesso estético do tratamento reabilitador (Mangano et al., 2012; Mangano et al., 2013).

Atualmente há várias metodologias que podem ser utilizadas para estudar a biomecânica de forma estática, como a extensiometria, fotoelasticidade, imagem de correlação digital e elementos finitos. A metodologia de elementos finitos é definida como uma simulação numérica que determina a tensão e deformação através de modelos de estruturas geométricas complexas, como implante dentário, componentes protéticos e tecido ósseo (Verri et al., 2014). Este modelo

permite a simulação de aplicação de carga em pontos específicos e fornece mapas de tensão e deformação transmitidas nas estruturas circundantes, no qual, as estruturas podem ser analisadas separadamente (Akça & Iplikçioğlu, 2001, de Faria Almeida et al., 2014). Desta forma, dados destes estudos já têm sido indicados como passíveis de melhorar o entendimento biomecânico de diversos materiais utilizados em odontologia e, em seguida, cuidadosamente terem seus resultados extrapolados para a clínica diária (Van Staden et al., 2006), ou mesmo de prever pontos críticos passíveis de falha mecânica nos implantes ou componentes protéticos.

Assim, no presente estudo, 2 capítulos foram elaborados com o intuito de analisar biomecanicamente as reabilitações unitárias implantesuportadas na região anterior, através da metodologia de elementos finitos 3D, buscando respostas quanto à variação da profundidade de instalação de implantes e quanto as dimensões dos implantes utilizados nesta região.

Capítulo 1

Biomechanical influence of narrow-diameter implants placed at the crestal and subcrestal level in maxillary anterior region. A 3D finite element analysis.

2.1. ABSTRACT

Statement of problem. Tooth loss in the maxillary anterior region generally decrease the available amount of bone for implant placement and narrow-diameter implants can be indicated for positioning at level or subcrestal. However, a consensus regarding biomechanical effect of this condition is still lacking.

Purpose. This study aimed to evaluate the tendency of movement, stress distribution and microstrain of single-unit crowns in the bone tissue, implant and prosthetic components of narrow-diameter implants with different lengths placed at the crestal and subcrestal levels in the maxillary anterior region using three-dimensional (3D) finite element analysis (FEA).

Materials and methods: Six 3D models were simulated using Invesalious 3.0, Rhinoceros 4.0, and Solidworks software. Each model simulated the right anterior maxillary region including an morse taper implant of Ø 2.9 mm with different lengths (7 mm, 10 mm, and 13 mm) placed at the crestal and subcrestal level and supporting a cement-retained monolithic single crown in the tooth #12. The FEA was processed using ANSYS 19.2. The applied force was 178 N in 0, 30, and 60 degree. The results were analyzed using maps of Displacement, Von mises stress (VM), maximum principal stress (MP) and microstrain ($\mu\epsilon$).

Results: Models with implants at the subcrestal level showed greater displacement tendencies. VM increased in the implant and prosthetic component when implants were placed at the subcrestal compared with crestal level; the length of implants presented low influence on the stress distribution. Higher stress and strain concentrations was observed in the cortical bone for the subcrestal implants, independently of lengths. Non-axial loading (30 and 60 degrees) influenced to increase stress and strain in all evaluated structures.

Conclusion: Narrow-diameter implants positioned at crest level presented more favorable biomechanical behavior for cortical bone tissue, implants, and prosthetic components. The implant length presented smaller influence on stress/strain distribution compared with other variables of the study.

Clinical implications. Narrow diameter implants placement can be the option for rehabilitation in the anterior region of maxilla to avoid advanced surgical techniques. In this situation, the results suggest that when bone width and height are inadequate for placement of regular diameter implant the crestal positioning of narrow implant have a more favorable biomechanical response and could be the better option.

Keywords: Dental implants; Finite element analysis; Biomechanical Phenomena.

2.2. INTRODUCTION

Currently, oral rehabilitation using dental implants in the maxillary anterior region requires a greater aesthetic and functional perspective, which combined with the experience of the clinician lead to successful treatment.¹ Among the different criteria for successful treatment, the maintaining of the bone level around the implant presents an essential role in the long-term success and survival of dental implants,^{2,3} mainly in esthetic region.

Several treatments protocols have been proposed to reduce marginal bone loss.^{4,5,6,7} However, no treatment protocol has been conclusively more effective. Regarding the different proposed protocols, the placement of implants below the bone crest level was reported as an useful strategy to minimize this bone loss around the implant.^{8,9,10,11,12} However, controversial results have also been reported.^{13,14} Furthermore, there are clinical situations in which, due to bone availability and proximity to anatomical structures, exist limitations in the use of the subcrestal installation, requiring the installation of implants at the bone tissue level.

Morse taper implants can be indicated to place at the crestal or subcrestal bone level. Some studies that evaluated the effect of implant placement level has shown conflicting results about the influence on marginal bone loss.^{8,10} However, some studies suggested a similarity for the implant placement techniques.^{15,16} Regarding biomechanical evaluation, some studies have reported that the stress in the peri-implant bone reduced as the implant depth has been increased^{17,18}; however, some studies reported crestal bone level is better to stress distribution.¹⁹ Therefore, this evaluation is necessary mainly to the narrow-diameter implants placed in the atrophic maxillary anterior region, since bone maintenance is specially important to technical maintenance and aesthetic success of the rehabilitation.^{5,20,21}

In addition, another factor related to this area is related to bone height availability, because the inferior wall of nasal floor can compromise the placement of longer implants.²² Therefore, in

some situations, short implants can be considered an alternative treatment. A systematic review reported that short implants (< 8 mm) should be used with care because present greater risks to failures compared with conventional implants.²³ However, no consensus has been reached about the biomechanical point of view when compared short and conventional implants in this situation. Thus, this evaluation should be considered, mainly in association with the use of the implants positioned at crestal and subcrestal bone levels.

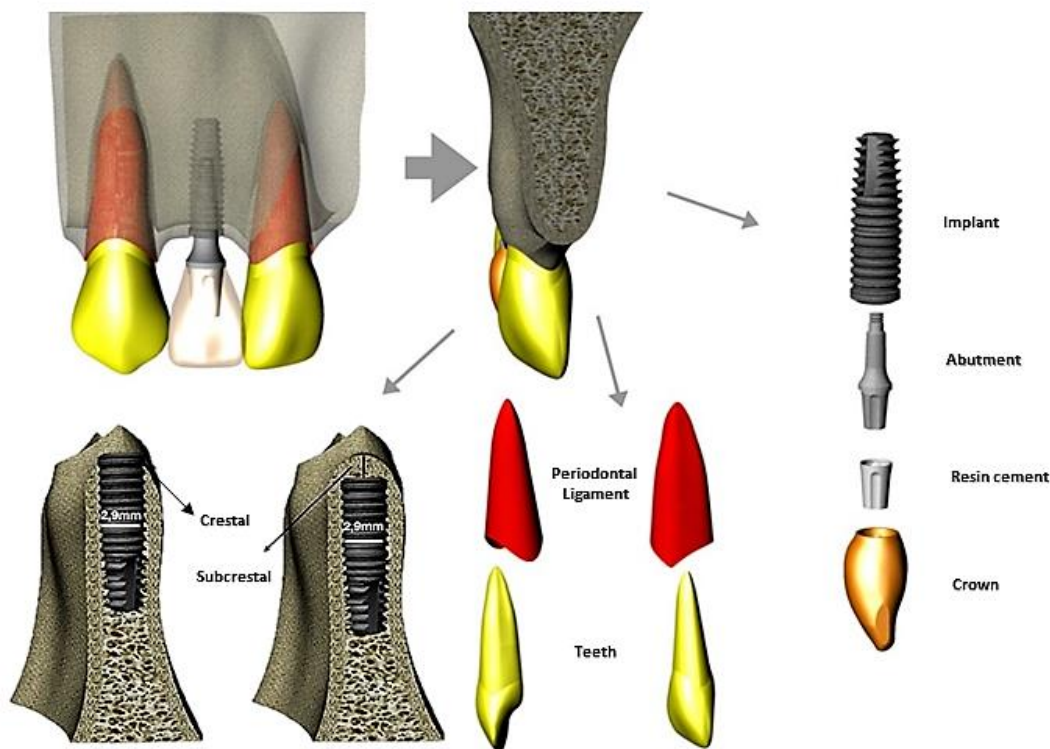
Therefore, the purpose of this study was to evaluate the stress distribution in narrow-diameter implants placed at the subcrestal (1,5 mm) and crestal bone level with different implants lengths: short (7 mm) and longer (10 and 13 mm) in the maxillary anterior region through 3D FEA. The hypotheses tested were: (1) there is no difference in the displacement/stress/strain distribution in the bone tissue, implant, and prosthetic components when implant is placed in the crestal or subcrestal positioning. (2) The implant length does not show influence on stress distribution in the evaluated structures.

2.3. MATERIAL AND METHODS

The study was developed considering the following factors: the level of the implant placement in the bone tissue (crestal and subcrestal); the implant length (7 mm, 10 mm, and 13 mm), and loading condition axial (0 degree) and non-axial (30 and 60 degrees). Six 3D FEA models were constructed (Table 1).

Each model represented a bone block from the right maxillary anterior region, corresponding from the canine to the central incisor, with the presence of a Morse taper implant in the lateral incisor positioned at crestal and subcrestal levels (1.5 mm) with different lengths supporting a single crown of zirconia cemented over universal abutment, adjacent to two natural teeth, central and canine incisors, with simulation of their ligaments interconnected to the cortical tissue of the hard lamina (Fig. 1).

Figure. 1 – Schematic models simulated in this study.



The bone block image was simplified using 3D computer graphics and computer aided design software (Rhinoceros v4.0, NURBS modeling for Windows; Robert McNeel and Associates). In the region of the dental implant (lateral incisor), the modeling of the bone was differentiated to simulate the clinical tested situation. The bone block was simulated with a 4.5 mm thick bone plate, to simulate the clinical condition commonly found in this region, being 1mm of cortical bone layer involving the trabecular bone.

The implant design was obtained by simplification of one original implant Unitite SLIM morse taper implant (CM) design (SIN, National Implant System, São Paulo-SP, Brazil), which included their specific universal abutments. The implant and abutment geometries were modeled and simplified by SolidWorks 2016 (SolidWorks Corp, Waltham, Massachusetts, USA) and

Rhinoceros 3D (NURBS modeling for Windows, Seattle, USA) programs following previous published study.²⁴ The crown design was performed with similarity from a lateral incisor tooth using Rhinoceros 3D, to simulate a monolithic zirconia single crown (IPS e.max ZirCAD) with a cemented connection in the universal abutment with a cement layer of 200 μm thickness.²⁵ The crown was simulated in the same position for both techniques and so the abutment of sub-crestal technique was simulated 1.5mm longer than one of crestal level technique. All geometries were exported for discretization in the FEA program ANSYS 19.0 (Southpointe, PA, USA).

The 3D meshes were obtained using tetrahedral parabolic solid elements for all structures. Mechanical properties were determined from values obtained of published studies and are presented in Table 2.^{22,25,26,27} All materials were homogeneous, isotropic, and linearly elastic.²⁸ The interproximal contacts between #13 and #12 and between #12 and #11 were assumed to be symmetrical contacts. All other contacts were assumed to be symmetrically welded. Constraints definitions were established as fixed in the x, y, and z axes in the plane sections mesial and distal of bone block, simulating the fixation of the maxilla to the viscerocranium. The applied force was 178 N and applied in the axial and oblique direction in relation to the implant long axis, applied in the palatal region approximately 2 mm below the incisal edge, in the region corresponding to the point of contact with the antagonist tooth.²⁹ The total number of elements and nodes in the models are shown in Table 1.

Table 1. Models used

Model	Placement bone level	Implant	Load	Nº of Nodes/Elements
M1		Ø 2,9x7 mm	0°	771480/3952876
			30°	
			60°	
M2	Crestal	Ø 2,9x10 mm	0°	993977/5122467
			30°	
			60°	
M3		Ø 2,9x13 mm	0°	1206461/6236039
			30°	
			60°	
M4		Ø 2,9x7 mm	0°	794234/4075367
			30°	
			60°	
M5	Subcrestal	Ø 2,9x10 mm	0°	1007685/5190008
			30°	
			60°	
M6		Ø 2,9x13 mm	0°	1227663/6345684
			30°	
			60°	

Displacement maps were used to evaluate the tendency of displacement of all evaluated models.³⁰ The von Mises (vM) maps were used to evaluate the biomechanical behavior of the implants and prosthetic components.³¹ The maximum principal stress (MP) maps were used as a criterion for the analysis of stress in bone tissue, since it provides values of compression (negative values) and traction (positive values).³² Additionally, microstrain ($\mu\epsilon$) analysis was used to assess deformation in the bone tissue ($\mu\epsilon$ - deformation $\times 10^{-6}$).³³ In addition, data with average of the highest 100 values for each map of all structures were evaluated.

Table 2. Properties of materials modeled

Material	Elastic Modulus (GPa)	Poisson Ratio	References
Cortical bone	13.7	0.3	Verri et al., 2017 ²⁶
Trabecular bone	1.37	0.3	Verri et al., 2017 ²⁶
Titanium	110	0.35	Verri et al., 2015 ²²
Zirconia crown (e Max Zir CAD)	210	0.26	Verri et al., 2017 ²⁶
Resin cement	8	0.33	Ha et al., 2015 ²⁵
Tooth	17	0,3	McCormack SW et al., 2017 ²⁷
periodontal ligament	0,049	0,45	McCormack SW et al., 2017 ²⁷

2.4. RESULTS

2.4.1. Analysis of general displacement maps

Under axial loading (0°), it was possible to observe a greater tendency of displacement for models of implants in the subcrestal placement (range: 0.096-0.098 mm) when compared with crestal placement (0.078-0.081 mm). In the non-axial loading (30° and 60°), the area with greater tendency of displacement was the crown closer to the applied load, mainly in the subcrestal placement (range: 30°, 0.341-0.351; 60°, 0.686-0.705). Furthermore, short implant showed more tendency to displacement (range: crestal: 0.081-0.536; subcrestal: 0.098-0.705) when compared with model with longer implants (Fig. 2; Table 3).

Figure 2 – Displacement Maps, Implants/ abutmen/prosthetic components and bone tissues (cortical and trabecular), loading 0°, 30° and 60°, lateral view. (M1= Placement crestal Ø 2,9x7 mm; M2= Placement crestal Ø 2,9x10 mm; M3= Placement crestal Ø 2,9x13 mm; M4= Placement subcrestal Ø 2,9x7 mm; M5= Placement subcrestal Ø 2,9x10 mm and M6= Placement subcrestal Ø 2,9x13 mm).

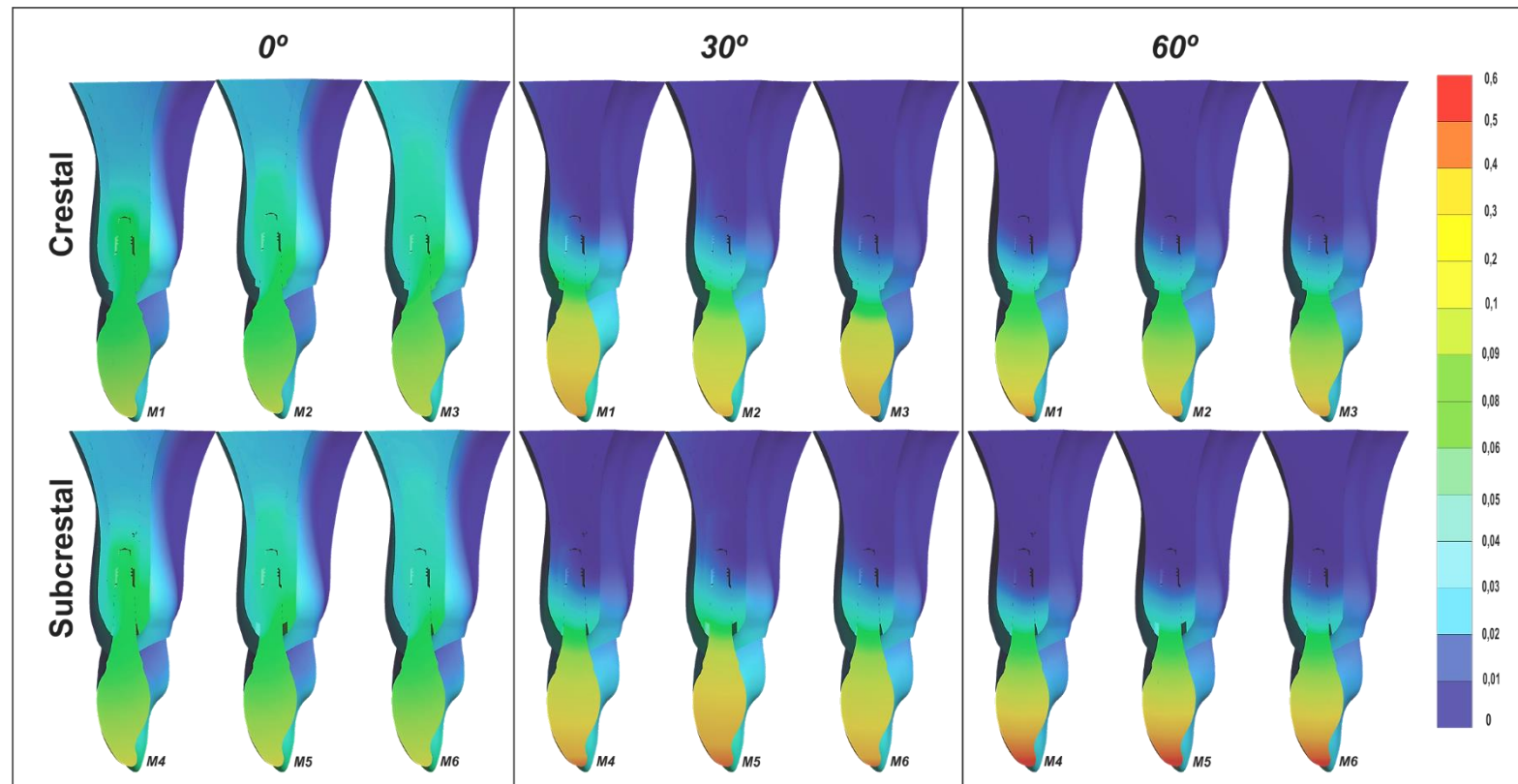


Table 3 – Displacement values of all models (mm). (M1= Placement crestal Ø 2,9x7 mm; M2= Placement crestal Ø 2,9x10 mm; M3= Placement crestal Ø 2,9x13 mm; M4= Placement subcrestal Ø 2,9x7 mm; M5= Placement subcrestal Ø 2,9x10 mm and M6= Placement subcrestal Ø 2,9x13 mm).

Table 3 - Displacement (mm)			
<i>Model</i>	<i>0°</i>	<i>30°</i>	<i>60°</i>
<i>Crestal</i>			
<i>M1</i>	<i>0,081</i>	<i>0,266</i>	<i>0,536</i>
<i>M2</i>	<i>0,079</i>	<i>0,259</i>	<i>0,521</i>
<i>M3</i>	<i>0,078</i>	<i>0,255</i>	<i>0,514</i>
<i>Subcrestal</i>			
<i>M4</i>	<i>0,098</i>	<i>0,351</i>	<i>0,705</i>
<i>M5</i>	<i>0,097</i>	<i>0,35</i>	<i>0,703</i>
<i>M6</i>	<i>0,096</i>	<i>0,341</i>	<i>0,686</i>

2.4.2. Von Mises stress (Implant/ Prosthetic components)

Under axial loading a similar stress distribution was observed for all models, with stress concentration in the palatal abutment region and first threads of the implants, independently bone level placement and implant length (Fig. 3; Table 4).

In the non-axial loading (30 and 60 degrees), a greater stress concentration was observed in the implants and prosthetic components (Table 4). It can be observed the stress concentration in the buccal and palatal of abutment and threads of implants, with high stress concentrations for the subcrestal bone level position (range: 30°, 512.96-515.64; 60°, 1053.24-1058.17) when compared with crestal bone level position (range: 30°, 390.26-464.49; 60°, 822.18-823.61). Although short implants concentrated the stress along the implant body, no difference were observed in terms of stress concentration comparing the short and longer implants (Fig. 3; Table 4).

Figure 3 –Von Mises stress maps, prosthetic components and implants, loading 0°, 30° and 60°, lateral view. (M1= Placement crestal Ø 2,9x7 mm; M2= Placement crestal Ø 2,9x10 mm; M3= Placement crestal Ø 2,9x13 mm; M4= Placement subcrestal Ø 2,9x7 mm; M5= Placement subcrestal Ø 2,9x10 mm and M6= Placement subcrestal Ø 2,9x13 mm).

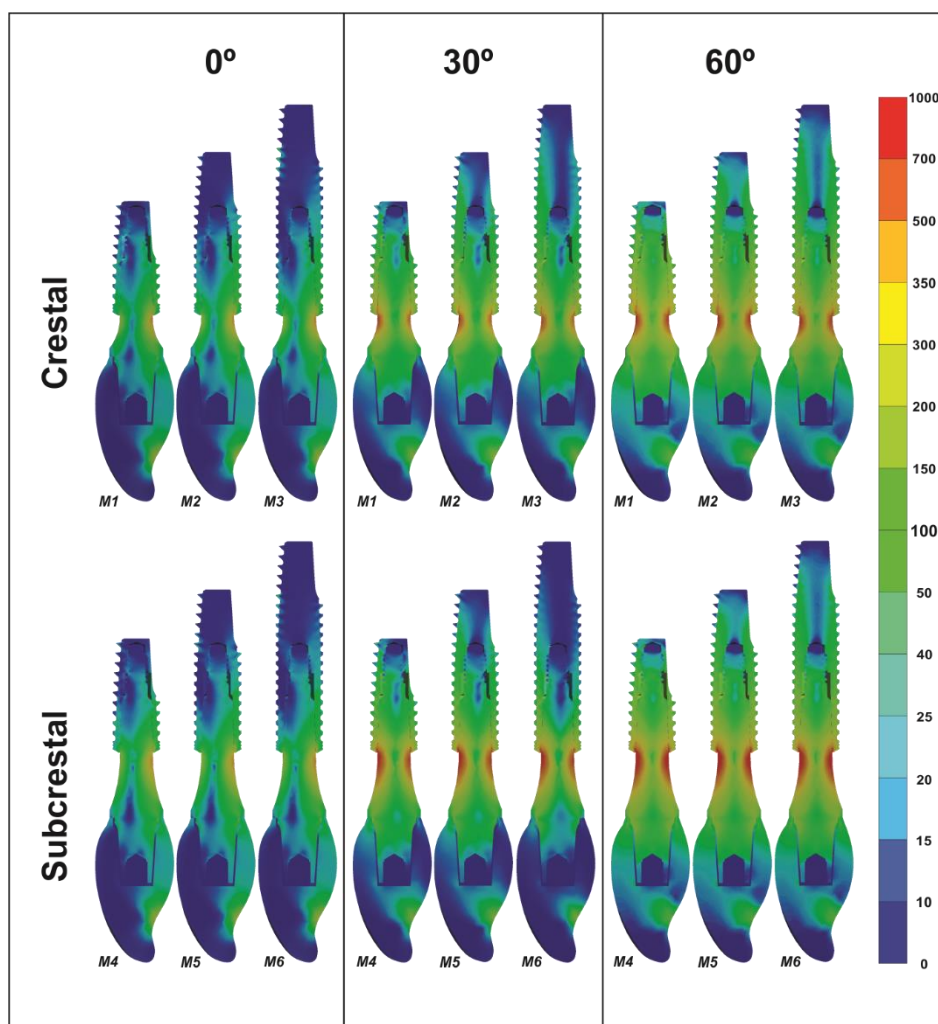


Table 4 – Von Mises stress values of implant and abutmen (Mpa). (M1= Placement crestal Ø 2,9x7 mm; M2= Placement crestal Ø 2,9x10 mm; M3= Placement crestal Ø 2,9x13 mm; M4= Placement subcrestal Ø 2,9x7 mm; M5= Placement subcrestal Ø 2,9x10 mm and M6= Placement subcrestal Ø 2,9x13 mm).

Table 4 - Von Mises stress							
Abutmen				Implant			
Model	0°	30°	60°	Model	0°	30°	60°
Crestal							
M1	190,43	464,49	823,61	M1	170,08	461,52	933,38
M2	190	390,71	822,63	M2	169,99	460,64	940,08
M3	189,42	390,26	822,18	M3	165,29	390,38	931,77
Subcrestal							
M4	200,94	515,64	1058,17	M4	174,66	551,46	1083,03
M5	201,77	514	1054,97	M5	173,54	537,41	1063,97
M6	201,33	512,96	1053,24	M6	170,14	534,48	1054,07

2.4.3. Maximum principal stress (Bone tissue)

In the axial loading it can be observed a difference in the stress concentration with a high tensile stress in the buccal and compressive stress in the palatal region of the cortical and trabecular bone when subcrestal technique was used (Fig. 4; Table 5). Under non-axial loading (30 and 60 degrees) the same pattern of stress distribution was observed. The models whit implants installed at the subcrestal bone level showed higher areas of concentration of tensile and compressive stresses, when compared with implants installed at crestal level (Fig. 4; Table 5). Moreover, we observed that the greater the angulations, the higher values of tension and compression were found, both in the cortical and trabecular bone. In addition, it was possible to verify that the cortical bone presented higher values of traction and compression when compared with the trabecular bone for both tested techniques. (Table 5). Regarding the length of the implants, short implants showed higher values of traction and compression in bone tissue than longer implants, mainly in subcrestal technique (Fig. 4; Table 5).

Figure 4 - Maximum principal stress maps, cortical and trabecular bone, loading 0° , 30° and 60° , lateral view. (M1= Placement crestal $\varnothing$ 2,9x7 mm; M2= Placement crestal $\varnothing$ 2,9x10 mm; M3= Placement crestal $\varnothing$ 2,9x13 mm; M4= Placement subcrestal $\varnothing$ 2,9x7 mm; M5= Placement subcrestal $\varnothing$ 2,9x10 mm and M6= Placement subcrestal $\varnothing$ 2,9x13 mm).

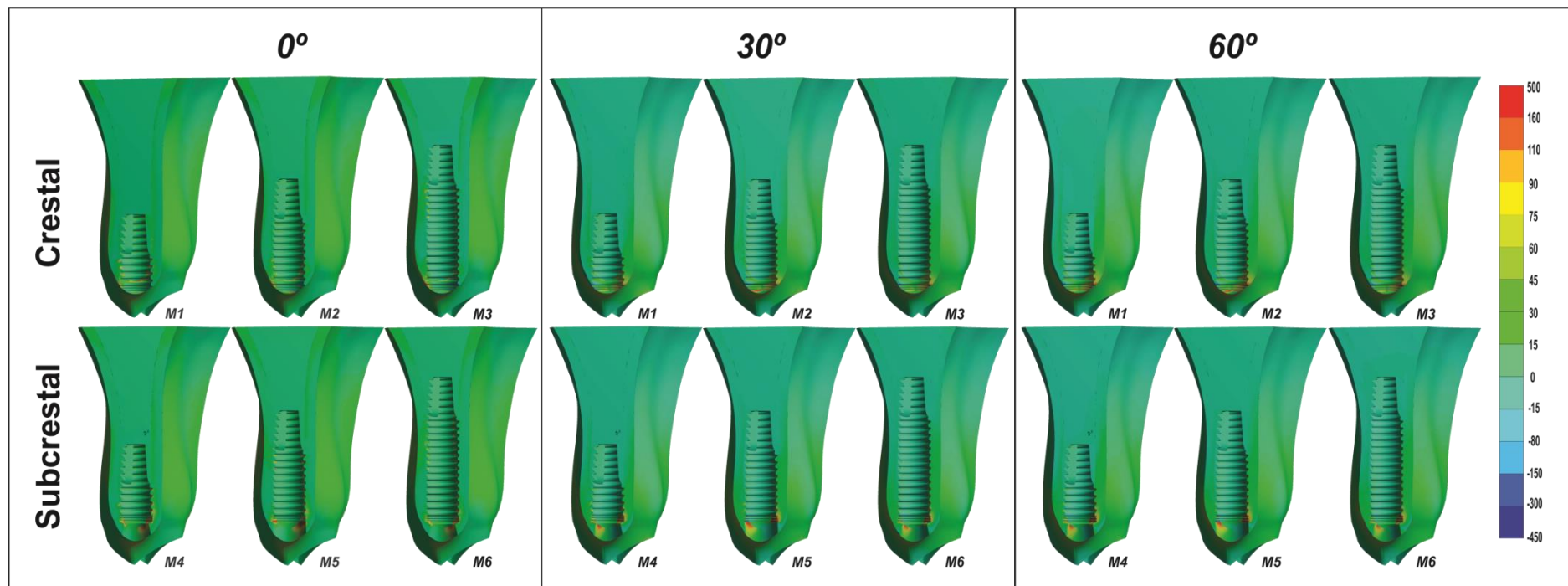


Table 5 - Maximum principal stress values of cortical and trabecular bone, Tensile stress (positive values) and Compression stresses (negative values) (Mpa). (M1= Placement crestal Ø 2,9x7 mm; M2= Placement crestal Ø 2,9x10 mm; M3= Placement crestal Ø 2,9x13 mm; M4= Placement subcrestal Ø 2,9x7 mm; M5= Placement subcrestal Ø 2,9x10 mm and M6= Placement subcrestal Ø 2,9x13 mm).

Table 5 - Maximum principal stress															
Cortical bone								Trabecular bone							
Tensile stress				Compression stresses				Tensile stress				Compression stresses			
Model	0°	30°	60°	Model	0°	30°	60°	Model	0°	30°	60°	Modelos	0°	30°	60°
Crestal								Crestal							
M1	16,05	80,63	194,55	M1	-8,64	-19,74	-26,73	M1	3,78	7,27	12,14	M1	-1,13	-1,41	-2,6
M2	15,16	76,98	176,86	M2	-7,39	-18,3	-23,48	M2	2,33	6,23	9,01	M2	-0,97	-0,99	-1,74
M3	14,53	73,02	172,26	M3	-6,43	-18,54	-15,42	M3	1,51	4,23	7,08	M3	-0,56	-0,76	-1,13
Subcrestal								Subcrestal							
M4	31,9	149,39	253,84	M4	-10,69	-21,52	-36,37	M4	4,21	20,88	35,05	M4	-1,16	-1,56	-2,8
M5	30,2	119,76	252,68	M5	-5,84	-12,53	-35,11	M5	3,9	12,43	29,37	M5	-1,8	-1,19	-2,6
M6	24,29	115,85	236,83	M6	-3,63	-8,03	-34,63	M6	2,9	13,36	28,2	M6	-0,47	-0,65	-1,02

2.4.4. Analysis of microstrain ($\mu\epsilon$) (bone tissue)

Under axial loading (0°), it is possible to observe a similar microdeformation distribution for all models with a slight deformation in the cervical region close to the implant neck, in the first threads and at the apex of implants, mainly in the subcrestal placement (range: cortical, 4.405-4.569; trabecular: 3.024-3.970) when compared with crestal placement (range: cortical, 2.236-3.775; trabecular: 2.189-2.658). However, no difference in the microdeformation for different implant length was observed (Fig.5; Table 6).

In the oblique loading (30° and 60°), the implants placed at the subcrestal level presented higher microdeformation (range: cortical– 30° , 12.098-13.306; 60° , 24.549-25.555; trabecular– 30° , 10.523-12.010; 60° , 19.058-24.927) when compared with the implants placed at the crestal level (range: cortical– 30° , 6.652-7.558; 60° , 13.100-17.919; trabecular– 30° , 3.533-6.875; 60° , 5.713-10.263) (Fig.5). Regarding to the short implants, it was possible to observe that provided greater microdeformation for the cortical and trabecular bone tissue than the longer implants, verified mainly in the subcrestal technique (Table 6).

Figure 5 - Microdeformation maps, cortical and trabecular bone, loading 0° , 30° and 60° , lateral view. (M1= Placement crestal $\varnothing$ 2,9x7 mm; M2= Placement crestal $\varnothing$ 2,9x10 mm; M3= Placement crestal $\varnothing$ 2,9x13 mm; M4= Placement subcrestal $\varnothing$ 2,9x7 mm; M5= Placement subcrestal $\varnothing$ 2,9x10 mm and M6= Placement subcrestal $\varnothing$ 2,9x13 mm).

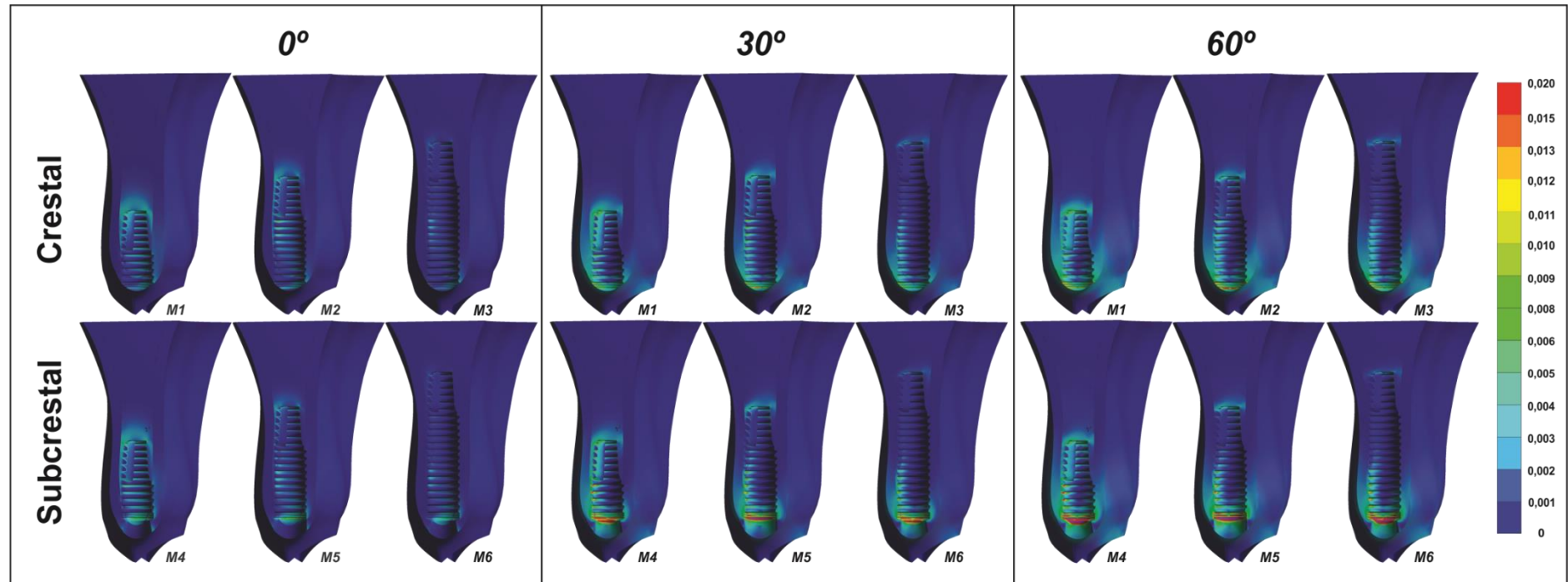


Table 6 - Microstrain values of cortical and trabecular bone ($\mu\epsilon$). (M1= Placement crestal $\varnothing$ 2,9x7 mm; M2= Placement crestal $\varnothing$ 2,9x10 mm; M3= Placement crestal $\varnothing$ 2,9x13 mm; M4= Placement subcrestal $\varnothing$ 2,9x7 mm; M5= Placement subcrestal $\varnothing$ 2,9x10 mm and M6= Placement subcrestal $\varnothing$ 2,9x13 mm).

Table 6 - Microstrain (Strain $\times 10^{-6}$)							
Cortical boné				Trabecular bone			
Model	0°	30°	60°	Model	0°	30°	60°
Crestal							
M1	3.775	7.558	17.919	M1	2.658	6.875	10.263
M2	3.142	9.211	14.605	M2	2.568	5.570	7.357
M3	2.236	6.652	13.100	M3	2.189	3.533	5.713
Subcrestal							
M4	4.569	13.306	25.555	M4	3.970	12.010	24.927
M5	4.521	12.330	25.320	M5	3.436	12.206	20.916
M6	4.405	12.098	24.549	M6	3.024	10.523	19.058

2.5. DISCUSSION

The hypothesis tested that the implant placement did not interfere the stress and strain distribution in the bone tissue, implants and prosthetic components was rejected, because subcrestal implant placement showed slightly higher stress and strain concentration in the bone tissue, and stress in the implants and prosthetic components when compared with at the crestal bone level positioning. These results is corroborated with previous studies.^{19,34} This could be justified by the fact that the subcrestal implant placement increased the length of the lever arm and the height of abutment that can contribute to increase the stress and strain in the structures evaluated.^{22,32,35,36} The results agree with Bordin et al., 2019,³⁶ who reported that the use of long height abutment increased the stress on the abutment, fixation screw, and cortical bone in 250%, 40%, and 92%, respectively, when compared with short height abutment.

Another reason could be related to the smaller contact between the cortical bone and the implant in the subcrestal placement when compared bone level resulting in weak cortical fixation on the neck region.³⁴ The literature reported that the cortical bone is engaged on load transfer

reducing the stress concentrations.³⁷ This may be explained by the cortical bone displaying greater resistance of 7 to 10 times greater elasticity modulus than trabecular bone.³⁸ In this study, the results obtained in the trabecular bone showed low stress compared with cortical bone in all models. These data are expected and in agreement with other studies^{32,38,39,40} that reported a lower stress concentration in the trabecular bone. It is also necessary to emphasize that this study did a simulation of a clinical real situation encountered in the left incisor region, an anatomic thin bone layer disponible to the implant placement. So, the limited amount of trabecular bone could contribute to transfer the stress to the cortical bone using buccal and palatal alveolar walls and in a different way of transferring in other studies. Even more, some implant threads were engaged directly with cortical bone in these areas. Moreover, it was not simulated in this study but, clinically, there is an indication to sub-milling the bone bed to improve the primary locking, mainly for immediate provisionalization technique. So, theoretically, it is possible to perform a bone condensation that becoming even more effective to stress transferring.

Regarding the displacement tendency of the models, the subcrestal placement showed high displacement values. Despite this, it is important to highlight that this difference in displacement values are small between the evaluated techniques, which clinically could not be harmful since this difference was around of 0,018 mm (0°), 0,096 mm (30°) and 0,191 mm (60°) considering the entire model.

The hypothesis that the implant length did not show influence on the stress distribution in the evaluated structures was accepted. This results is in accordance with previous studies.^{41,42,43,44} These results are agreement with a recent systematic review which reported that 44% of included studies consider implant diameter a more effective design parameter than implant length to reduce stress concentrations and to avoid an overload of periimplant bone.⁴⁵ In this study, implant insertion depth (crestal or subcrestal placement) showed more influence in the stress and strain distribution for the bone tissue, implants, and prosthetic components than the implant lengths. This

should be considered because the choice of implant length indirectly depends on the amount of bone tissue presented in each clinical situation. Thus, longer implants can be difficult to place due to the proximity of anatomical structures, especially when there is little amount of vertical bone tissue.⁴⁶ Thus, short implants can be considered a possible alternative on the biomechanical point of view. However, since shorter implants have a higher failure rate clinical control of occlusal factors must be carefully performed to ensure treatment success.

Even though, it was not a hypothesis of this study, but non-axial loading presented higher strain and stress in the all evaluated structures, regardless of the variable. These findings corroborate with other studies that observed that the oblique forces are more damaging to the prosthetic components, implant, and consequently the peri-implant bone tissue.^{22,26,27,47}

The results of this study should be interpreted with caution, because is a computational simulated analysis and present some limitations, such as material simulated properties being isotropic, homogenous and linear, differing from the clinical real situations. Furthermore, bone tissues present morphology and the density in the trabeculae that is not homogeneous and not uniform. However, this methodology allows to evaluate comparatively different variables to suggest the better clinical option from a biomechanical point of view.

2.6. CONCLUSION

Within the limitations of this study it was possible to conclude that subcrestal placement of narrow-diameter implants increased the strain and stress in the structures evaluated when compared with crestal placement in the maxillary atrophic anterior region, and the implant length presented smaller influence on stress/strain distribution compared with other variables of the study.

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Conflicts of interest

The authors declare that there was no conflict of interest in the elaboration of this study.

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Capítulo 2

Influence of narrow diameter implants in single-implant restoration placed in the anterior region of the maxillary. A three-dimensional finite element analysis

3.1. ABSTRACT

The purpose of this study was to compare the stress and strain distribution between prosthetics planning considering single-implant restoration in the anterior maxillary region supported by NDI with 2.9mm and 3.5mm of diameter. Six 3D models were simulated with Invesalius, Rhinoceros 3D and SolidWorks software. Each model was composed by a bone block from the anterior maxillary region with the presence of the central incisor and canine teeth (bone type III) and single all-ceramic restoration supported by dental implant with a diameter of 2.9 mm or 3.5 mm, varying the length: 8.5 mm, 11.5 mm and 15 mm in the lateral incisor. The models were processed by the ANSYS 19.2 software, using a force of 178 N at different directions (0°, 30° and 60°). The results of dental implants were plotted on maps of von Mises Stress (VM) and the bone tissue was plotted by Maximum principal stresses (MP), Microdeformation ($\mu\epsilon$) maps.

The VM analysis showed an increase in the stress concentration for dental implants with 2.9 mm of diameter. The increase in the force inclination increased the stress concentration in the implants/abutments and bone tissue. In the analysis of bone tissue, under the MP and $\mu\epsilon$ maps, higher concentrations of traction and microdeformation stresses were found in the oblique loads (30° and 60°) around the dental implant neck (cortical bone), especially when using dental implants 2.9 mm.

Under the conditions of the study, the use of dental implants with a 3.5mm diameter favored a decrease in stress in the bone tissue adjacent to the dental implant, regardless of the length of the implant used.

Keywords: Dental implants; Finite element analysis; Biomechanical Phenomena.

3.2. INTRODUCTION

Rehabilitation with implant-supported prostheses in the anterior region is currently a favorable option with high rates of survival and success.^{1,2} However, the success of this treatment depends on an appropriated reverse planning, making it possible to check the available bone for the best choice of implant dimensions.³ Clinically, the available bone in the mesiodistal and buccolingual in the anterior maxilla is reduced when compared with other regions,^{4,5} which may difficult the use of regular-diameter implants (RDIs). However, one of the options for these clinical situations is the use of narrow-diameter implants (NDIs) (<3.75 mm).^{6,7,8}

The NDIs classification is problematic due to the lack of consensus in the literature.^{9,10} Some researchers have considered dental implants with diameters ranging from 3.0 to 3.7 mm as RDIs.^{11,12} However, although the reduced diameter implant range is debatable, the 3.5 mm and 2.9 mm diameter size addressed in the present study is considered as a NDIs by several researchers.^{13,14,15,16}

Clinically, NDIs allow minor aesthetic problems, and reduce the chances of failure of the dental implant in atrophic alveolar bone when compared to the conventional implant diameter.¹⁷ Furthermore, Yang et al., 2019 suggest the advantage in the use of NDIs regarding to the reduction in surgical complications and the prolonged healing time for patients, especially when using guided bone regeneration procedures.¹⁸ Therefore, NDIs may be a relatively simple and less invasive procedure in compromised situations.

Several clinical studies have reported similar survival rates between NDIs and RDIs (≥ 3.75).^{2,19,20} However, an important disadvantage must be considered in the use of NDIs regarding to its lower fracture resistance compared to RDIs, providing greater risk of fracture for the dental implants and prosthetic abutments.²¹ Additionally, biomechanical studies about the effect of the implant diameter have suggested that the reduction of the

diameter may increase the transfer of occlusal load to bone tissue, especially under oblique loads.^{22,23,24,25,26} However, these biomechanical studies have evaluated the influence of diameter in the posterior region between RDIs (3.75 mm) and wide-dental diameter (WDI)(5.00 mm).

Another important biomechanical factor, which may contribute to a higher concentration of stress in bone tissue, is the implant geometry.²⁷ Regarding the implant geometry, the length parameter has been reported as one of the main characteristics that may mitigate the transfer of load to the bone tissue.^{28,29} However, long dental implants may not be used in some clinical situations, thus the use of short dental implants may be an alternative.¹⁵ However, to analyze the efficacy and safety of this type of dental implant, a biomechanical analysis of the interactions between the dental implant and bone tissue is important, especially when associated with a narrow diameter.

The literature has reported more favorable biomechanical behavior for the stress distribution in the internal connections (IC) when compared to external connections (EC) dental implants.^{30,31} Therefore, the use of IC – such as Morse taper dental implants – has increased in cases of aesthetic rehabilitation.^{32,33} In addition, Verri et al., 2014 reported that dental implant with greater length offers lower stress distribution for bone tissue, especially when using this type of connection.³⁴ However, there are still few biomechanical studies comparing the influence of the diameter and length of the dental implants in the biomechanical behavior of dental implants/prosthetic abutments and bone tissue placed adjacent to natural teeth in the anterior region. Therefore, this assessment is necessary – essentially in the anterior region – since bone preservation is directly related to tissue maintenance and aesthetic success of the rehabilitation treatment.^{35,36}

The purpose of study was to compare the stress and strain distribution in dental implant and cortical bone, retrospectively, between prosthetic planning considering single-implant

restoration in the anterior maxillary region supported by NDI with 2.9mm and 3.5mm of diameter. The hypotheses tested were: (1) there would not be difference in the stress and strain distribution between the diameters. (2) The implant length would not show influence to stress and strain distribution in the evaluated structures.

3.3. MATERIAL AND METHODS

This study was designed to simulate a 3D finite element model of the maxillary anterior region with single-implant restoration. The study was developed considering the following factors: The dental implant diameter ($\varnothing$ 2.9 mm and $\varnothing$ 3,5 mm), the dental implant length (8,5 mm, 11,5 mm and 15 mm), under axial (0°) and oblique (30° and 60°) loading. Six 3D finite element models were simulated (Table 1). Each model represented a bone block from the upper right maxillary region (type III), corresponding from the canine to the central incisor, presenting two natural teeth, central and canine incisors, with simulation of their ligaments interconnected to the cortical tissue of the hard lamina and a Morse taper dental implant placed in the lateral incisor (SIN , National Implant System, São Paulo / SP, Brazil), positioned at bone level supporting single all ceramic restoration (zirconia) cemented at abutment universal. The Figure 1 illustrates the clinical situations simulated.

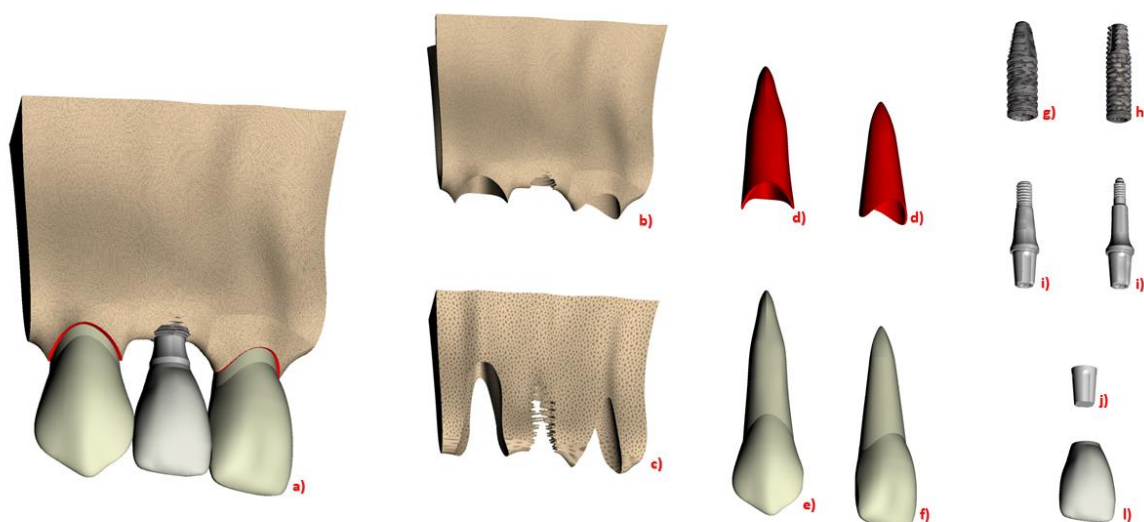


Figure - 1 – Schematic models simulated in this study; a) Schematic view of structures b) Cortical bone; c) Trabecular bone; d) Periodontal Ligament; e) Canine; f) Central incisor; g) Implant Ø 3,5mm; h) Implant Ø 2,9mm; i) Abutment; j) Resin cement; l) Crown.

The bone block image was simplified using 3D computer graphics and computer aided design software (Rhinoceros v4.0, NURBS modeling for Windows; Robert McNeel and Associates). In the region of the lateral incisor tooth, the modeling of the bone plate was differentiated to simulate the clinical situation tested. The bone block was simulated with a 4.5 mm thick bone plate, the bone section was composed of trabecular bone in the center, surrounded by a 1-mm cortical bone layer which was obtained by decomposition of a computed tomography (sagittal section), to simulate the clinical situation commonly found in this region.

Table 1. Specifications of the models.

Model	Implant diameter	Implant length	Load	No.of Nodes/elements
M1		8,5 mm	0°	925052/4763529
			30°	
			60°	
M2	Ø 2,9	11,5 mm	0°	1136908/5870036
			30°	
			60°	
M3		15 mm	0°	1326360/6856955
			30°	
			60°	
M4		8,5mm	0°	749495/3832619
			30°	
			60°	
M5	Ø 3,5	11,5 mm	0°	928283/4758255
			30°	
			60°	
M6		15 mm	0°	1159080/5951550
			30°	
			60°	

All dental implants and prosthetic abutments were of the Conite Morse Unitite STANDARD type (3.5 mm narrow diameter implants) and SLIM (2.9 mm narrow diameter implants) (SIN, National Implant System, São Paulo / SP, Brazil), which included their specific prosthetic abutments. The dental implant and prosthetic abutment geometries were simplified by 3D computer-aided design software SolidWorks 2016 (SolidWorks Corp, Waltham, Massachusetts, USA) and software Rhinoceros 3D (NURBS modeling for Windows, Seattle, USA). All, geometries were exported for discretization in the finite

element program ANSYS 19.0 (Southpointe, PA, USA). The crown/prosthetic abutment and prosthetic abutment/dental implant contacts were assumed to be symmetrical contacts. All other contacts were also assumed to be symmetrically welded. Constraints definitions were established as fixed axes in the x, y, and z, simulating the fixation of the maxilla to the viscerocranium. Moreover, the mechanical properties of each simulated material were attributed to the meshes using values from previous studies (Table 2). All materials were considered isotropic, homogeneous, and linearly elastic and the numbers of nodes and elements are presented in table 1. The applied force was 178 N³⁷ and applied in the axial and oblique direction, in relation to the long axis of the dental implant, applied in the palatal region approximately 2 mm below the incisal edge, in the region corresponding to the point of contact with the antagonist tooth.

Table 2. Properties of materials modeled

Material	Elastic Modulus (GPa)	Poisson Ratio	References
Cortical bone	13.7	0.3	Verri et al., 2017 ⁵⁸
Trabecular bone	1.37	0.3	Verri et al., 2017 ⁵⁸
Titanium	110	0.35	Verri et al., 2016 ⁶⁶
zirconia crown (e Max Zir CAD)	210	0.26	Verri et al., 2017 ⁵⁸
Resin cement	8	0.33	Ha et al., 2015 ⁶¹
Tooth	17	0,3	McCormack SW et al., 2017 ⁶⁷
periodontal ligament	0,049	0,45	McCormack SW et al., 2017 ⁶⁷

The von Mises (VM) maps were used to evaluate the biomechanical behavior of the dental implants and prosthetic abutments.³⁸ The maximum principal stress (MP) map was used as a criterion for the analysis of stress in bone tissue, since it provides values of

tractive and compressive stresses.³⁴ Additionally, microstrain ($\mu\epsilon$) analysis was used to assess deformation around the cortical bone tissue. ($\mu\epsilon$ - deformation $\times 10^{-6}$).³⁹ In addition, the average of the 100 highest values of prosthetic abutment for each model were obtained to confection of graphics regarding to VM analysis. Also, 100 highest values of cortical and trabecular bones for each model were obtained to the confection of graphics regarding to maximum principal stress and microstrain analyzes.

3.4. RESULTS

3.4.1. Von Mises stress – dental implant and prosthetic abutment

The loading 0° showed a similar stress distribution pattern between the evaluated models. Although a similarity was observed between the models, a slight increase in stress in the 2.9 mm dental implants (M1), in the palatal region of the intermediates was observed. (Figure 2)

The loading of 30° and 60° showed a considerable increase in the stress between the interface of dental implant/prosthetic abutment, both palatal and buccal for all models, mainly to dental implants of 2.9 mm of diameter (M1, M2 and M3) (Figure 2). Influence of the dental implant diameter was also observed in relation to stress distributions with higher concentrations at the 2.9 mm dental implants (30°, range: 465,62 – 473,35 Mpa; 60°, range: 936,47 – 956,28 Mpa) when compared with 3,5 mm implants (range: 30°, 289,48 – 294,05 Mpa; 60°, range: 574,76 – 583,38 Mpa) (Figure 3). Clear differences were not observed regarding to the length of the dental implants, although the longer length of the dental implant showed a better dissipation of stress in the body of the dental implant (Figure 2). In addition, a slight concentration of stress was also observed in the region of the first threads of the dental implants (M1, M2, M3, M4, M5 and M6), and a lower concentration at the apex of the dental implants of all models (Figures 2 and 3).

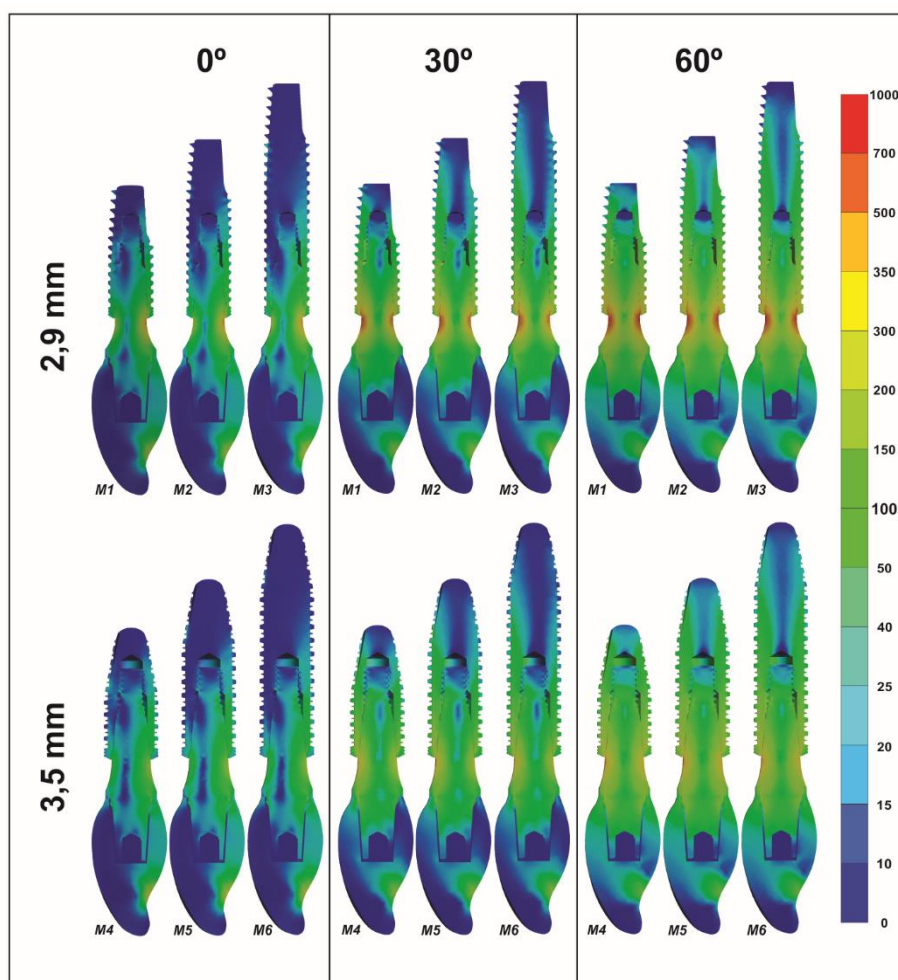


Figure - 2 –Von Mises stress maps, prosthetic components and implants, loading 0°, 30° and 60°, lateral view. (M1= Ø 2,9x 8,5mm; M2= Ø 2,9x 11,5mm; M3= Ø 2,9x 15mm; M4= Ø 3,5x 8,5mm; M5= Ø 3,5x 11,5mm and M6= Ø 3,5x 15mm)

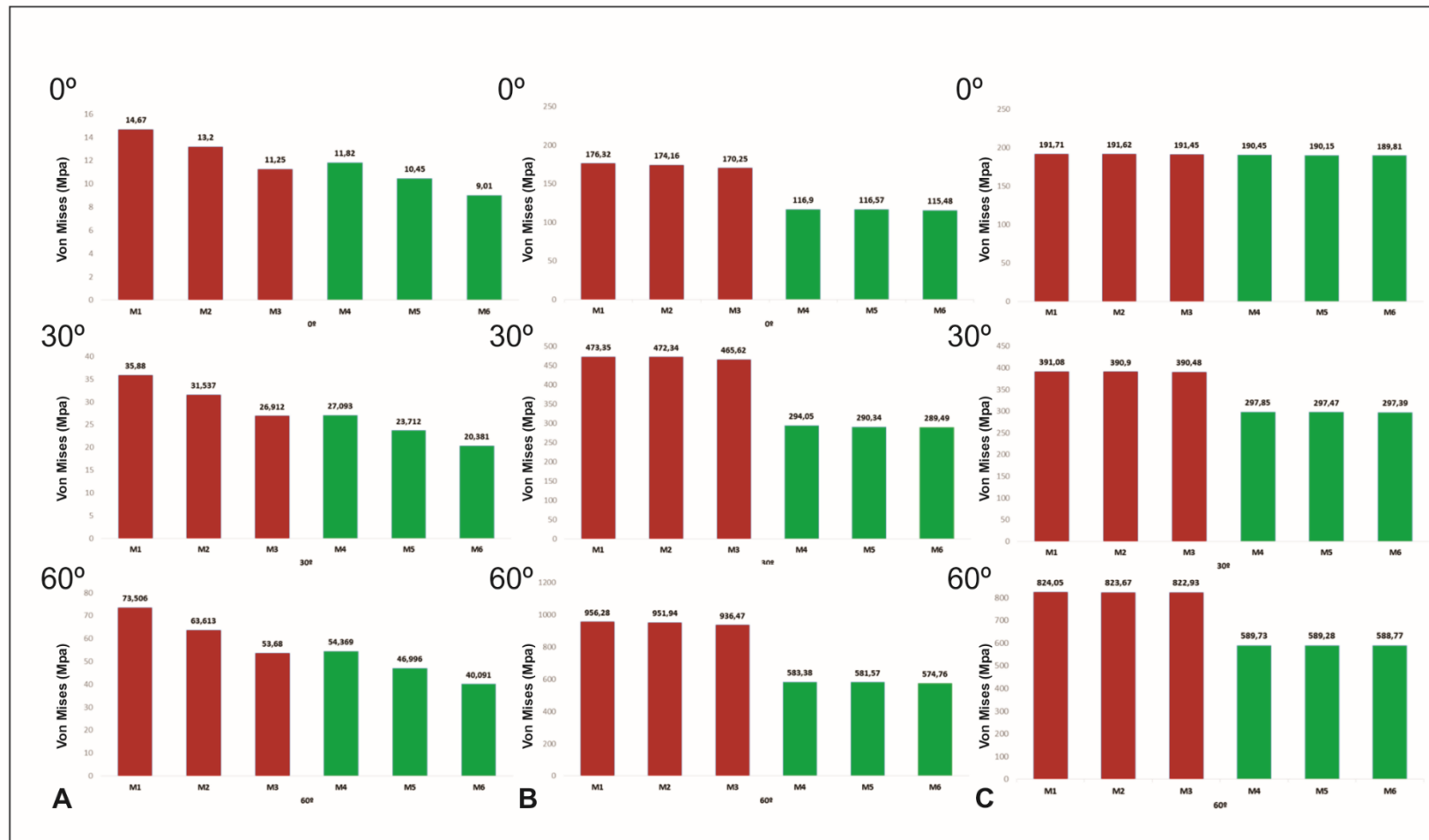


Figure - 3 – Graphs with values of Von Mises stress maps, loading 0°, 30° and 60°. A) Values of the general model; B) Values of implant values; C) Values of abutment values.

(M1= Ø 2,9x 8,5mm; M2= Ø 2,9x 11,5mm; M3= Ø 2,9x 15mm; M4= Ø 3,5x 8,5mm; M5= Ø 3,5x 11,5mm and M6= Ø 3,5x 15mm)

3.4.2. Maximum principal stress – bone tissue

In occlusal view under 0° loading, the implant diameter showed influence in relation to the pattern of concentrations of tractive and compressive stresses in the region of the cortical and trabecular bones. The 2.9 mm dental implants (M1, M2 and M3) showed the highest concentrations (tractive stress range to: 14,73 – 17 Mpa to cortical bone; 1,2 – 2,81 to trabecula bone) and (compressive stress range to: 6,4 – 8,13 Mpa to cortical bone; 0,59 – 107 Mpa to trabecular bone). (Figures 4, 5 and 6)

In the loading of 30° and 60°, it was possible to observe a higher concentration of tensile/compressive stresses in the cortical bone (tractive stress range to: for 30°, 72,53 – 82,68 Mpa; for 60°, 170,49 – 196,38 Mpa and compressive stress range to: for 30°, 17,52 – 20,61 Mpa; for 60°, 29,47 – 38,79 Mpa) and trabecular (tractive stress range: for 30°, 4,36 – 6,31 Mpa; for 60° 7,38 – 9,78 Mpa and compressive stress range: for 30° 0,81 – 1,2 Mpa; for 60° 1 – 2,11 Mpa) in the 2.9 mm of diameter models (M1, M2 and M3). (Figures 4, 5 and 6) Furthermore, the values of tractive and compression stresses were higher in the cortical bone than in the trabecular bone, independent of the implant diameter assessed. Regarding the length of the dental implant, the shorter length dental implants showed higher concentrations of tractive and compressive stresses in the bone tissue (cortical and trabecular), mainly in the 60° loading. (Figures 4, 5 and 6)

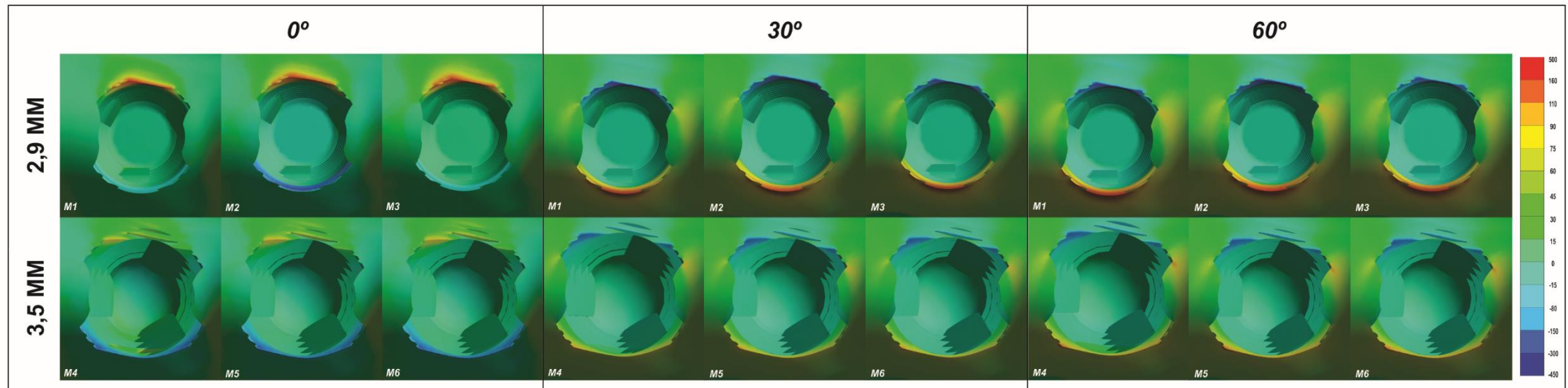


Figure - 4 - Maximum principal stress maps, cortical and trabecular bone, loading 0°, 30° and 60°, occlusal view. (M1= Ø 2,9x 8,5mm; M2= Ø 2,9x 11,5mm; M3= Ø 2,9x 15mm; M4= Ø 3,5x 8,5mm; M5= Ø 3,5x 11,5mm and M6= Ø 3,5x 15mm)

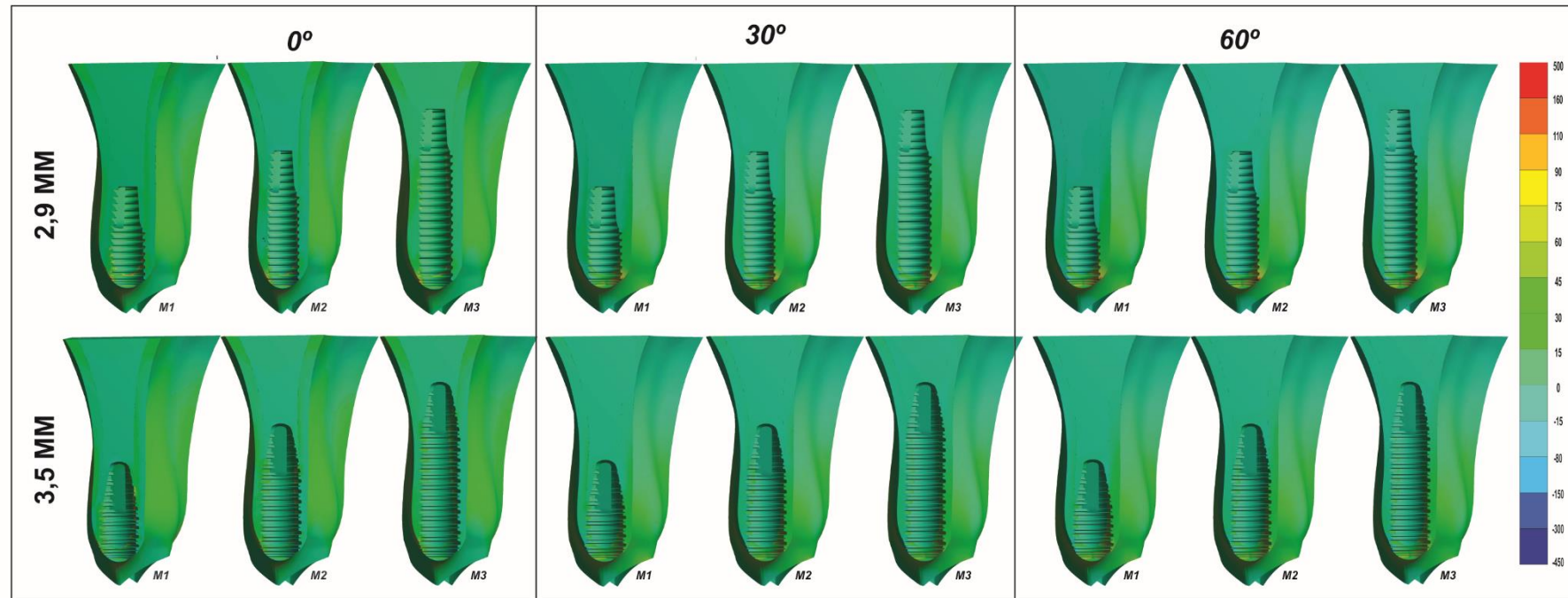


Figure - 5 - Maximum principal stress maps, cortical and trabecular bone, loading 0°, 30° and 60°, lateral view. (M1= Ø 2,9x 8,5mm; M2= Ø 2,9x 11,5mm; M3= Ø 2,9x 15mm; M4= Ø 3,5x 8,5mm; M5= Ø 3,5x 11,5mm and M6= Ø 3,5x 15mm)

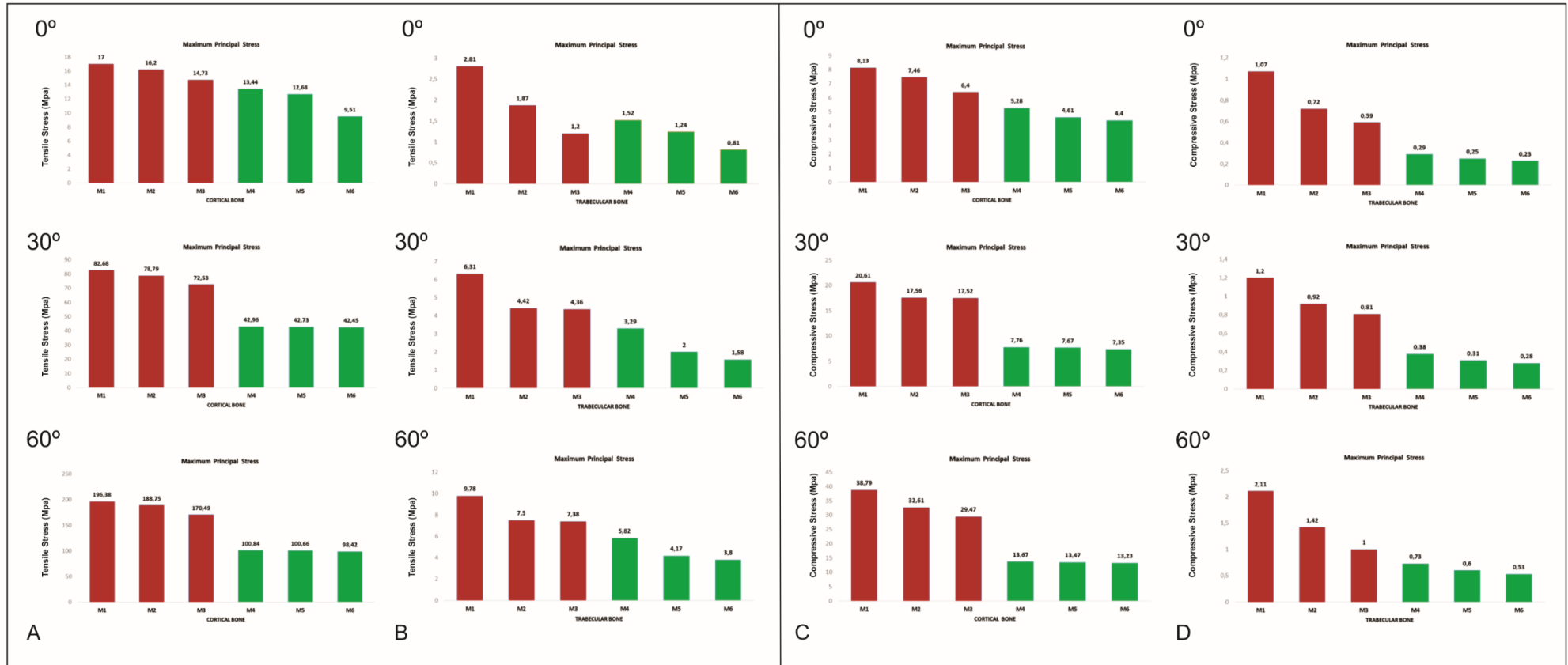


Figure - 6 - Graphs with values of Maximum principal stress maps (tensile and compressive), loading 0°, 30° and 60°. A) cortical bone tensile stress values; B) Trabecular bone tensile stress values; C) cortical bone compressive stress values; B) Trabecular bone compressive stress values. (M1= Ø 2,9x 8,5mm; M2= Ø 2,9x 11,5mm; M3= Ø 2,9x 15mm; M4= Ø 3,5x 8,5mm; M5= Ø 3,5x 11,5mm and M6= Ø 3,5x 15mm)

3.4.3. *Microstrain ($\mu\epsilon$) – bone tissue*

In occlusal view under 0° loading, a similar pattern of strain distribution was observed for all models, showing a slight concentration of microstrain in the cervical region near to the implant neck (Figure 7), however, in lateral view, short dental implants showed a concentration of microdeformation in the first threads and in the apex of the implants greater than the dental implants of longer length (M1 and M4), mainly in the 2.9 mm diameter implants (M1) with values range to 2471 – 2291 $\mu\epsilon$ for 2,9 mm implant diameter and 1185 – 2203 $\mu\epsilon$ for 3,5 mm implant diameter (Figures 8 and 9).

At 30° and 60°, in the occlusal view, the 2.9 mm diameter implants showed a more values of microstrain compared to the 3.5 mm diameter implants, with a slight deformation concentration in the internal region of the tissue cortical. In addition, when analyzed in lateral view, a greater value of microstrain in around the neck and body area of 2.9 mm dental implants was observed. Regarding to the length of the implant, the strain distribution pattern followed the pattern described in the loading of 0°, however, with values more elevate, in which the dental implants of greater length presenting lower values of microstrain. The increase of the angulation of the load increased the microstrain values, regardless of the implant diameter used. (Figures 7, 8 and 9).

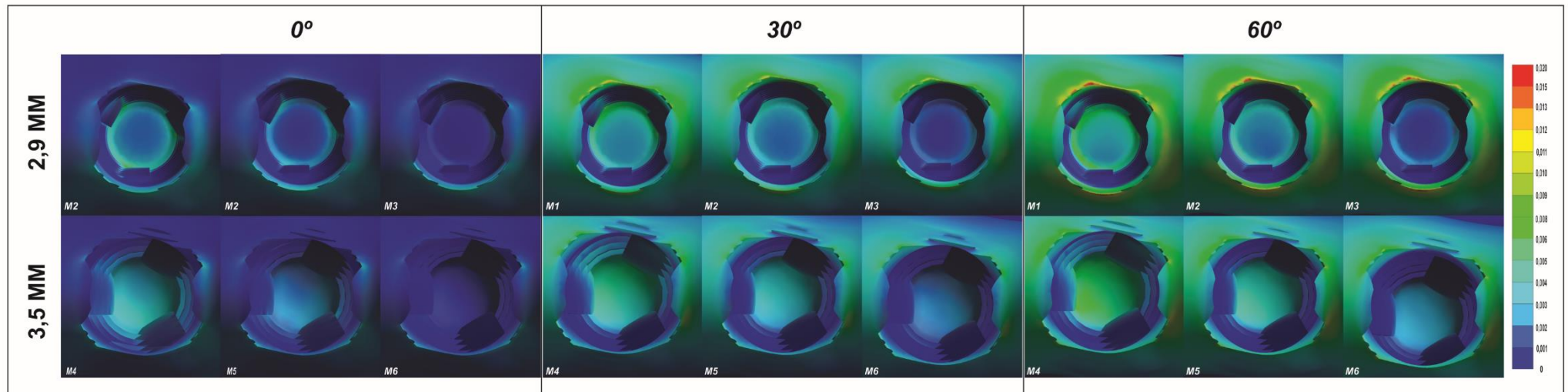


Figure - 7 - Microdeformation maps, cortical and trabecular bone, loading 0°, 30° and 60°, occlusal view. (M1= Ø 2,9x 8,5mm; M2= Ø 2,9x 11,5mm; M3= Ø 2,9x 15mm; M4= Ø 3,5x 8,5mm; M5= Ø 3,5x 11,5mm and M6= Ø 3,5x 15mm)

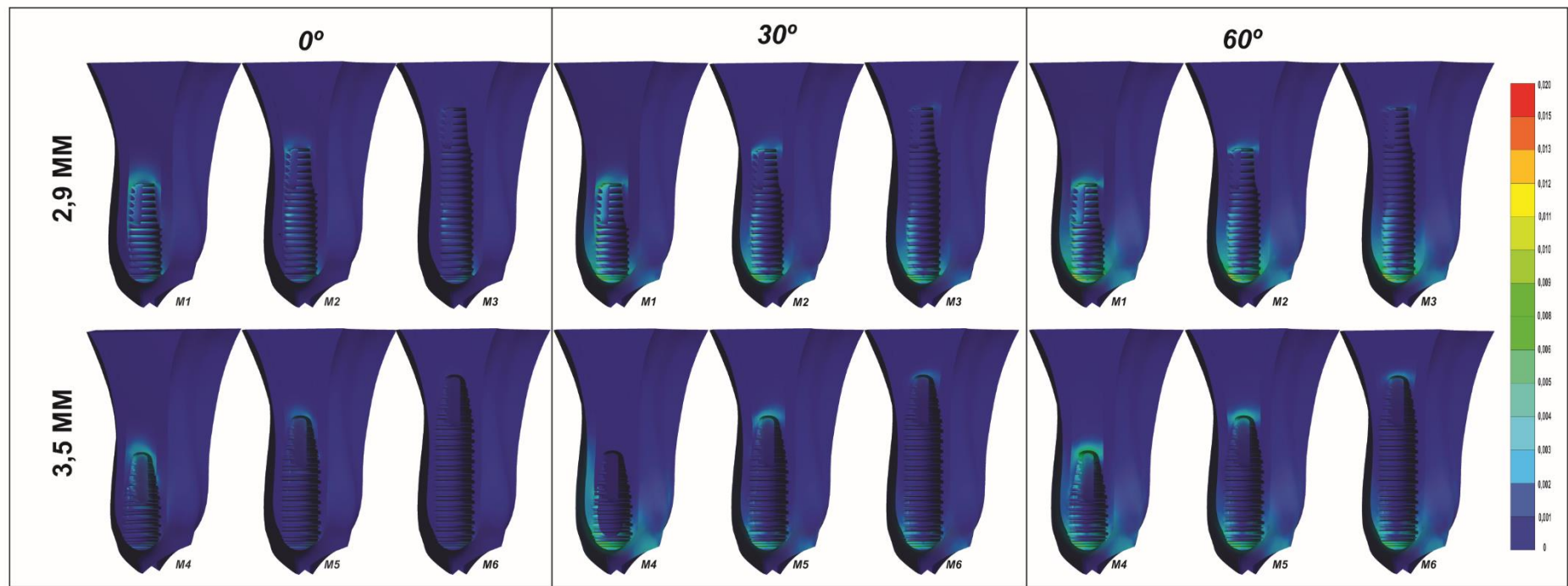


Figure- 8 - Microdeformation maps, cortical and trabecular bone, loading 0°, 30° and 60°, lateral view. (M1= Ø 2,9x 8,5mm; M2= Ø 2,9x 11,5mm; M3= Ø 2,9x 15mm; M4= Ø 3,5x 8,5mm; M5= Ø 3,5x 11,5mm and M6= Ø 3,5x 15mm)

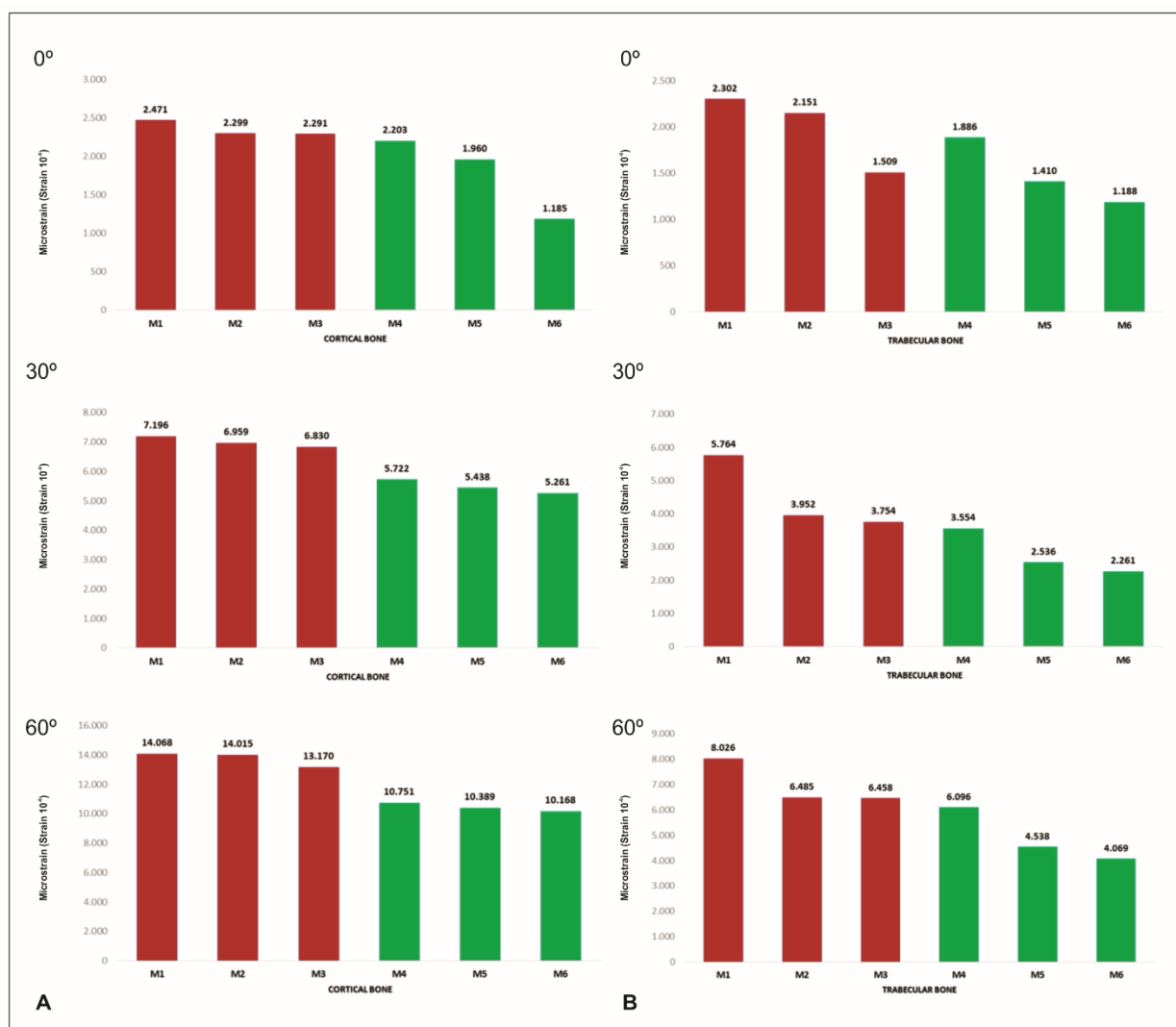


Figure - 9 - Graphs with values of Microdeformation maps, loading 0°, 30° and 60°. A) Values in the cortical bone B) Values in the trabecular bone. (M1= Ø 2,9x 8,5mm; M2= Ø 2,9x 11,5mm; M3= Ø 2,9x 15mm; M4= Ø 3,5x 8,5mm; M5= Ø 3,5x 11,5mm and M6= Ø 3,5x 15mm)

3.5. **DISCUSSION**

The tested hypothesis, which states that there would not be difference in the stress and strain distribution between the diameters was denied, since the 2.9mm of implant diameter showed a greater stress concentration in the dental implants, prosthetic abutments and stress and strain concentration of bone tissue, regardless of the length of the implants used. This result corroborated with studies that showed the larger the diameter of the implants, the better the stress/strain distribution.^{23,40} Furthermore, the decrease in the diameter of the implant – as well as its location in the dental arch – may influence in the mechanical strength, thus increasing the probability of fracture of the implants.²⁶ The present study simulated dental implants placed in the anterior region of the maxillary, where the magnitude of masticatory forces is less than in the posterior region. However, the found results may be considered similar to studies that analyzed this variable in the posterior region, since the reduction of the implant diameter may contribute to the increase of stresses.^{23,22,41} Nonetheless, a recent systematic review and meta-analysis demonstrated no difference between NDI compared to RDI in the anterior region of the maxilla, in terms of implants survival rate, marginal bone loss and the review concluded that NDI is an effective alternative to be used clinically.⁴²

The results of the present study showed that the 3,5mm of diameter combined with a longer implant length (>11,5mm) reduced the stress and strain transferred to bone tissue. Clinically, the insertion of large diameter implant may be more favorable, as it allows a larger area of counted between the dental implant and bone tissue, thus generating better primary stability.^{43,44,45} However, in regions where there is less than 6 mm mesiodistal bone availability and less than 5 mm buccal-lingual the only option for rehabilitation of patients is the use of NDIs.^{4,5} In addition, the use of NDIs may reduce the risk of exposure of dental implant threads (fenestration cortical bone), thus avoiding the appearance of darkened

spots and retractions in the gingival tissue that may compromise the treatment aesthetics, especially in the anterior maxilla region.^{46,47} Furthermore, the use of NDIs may avoid more complex surgical procedures as alternative surgeries to increase bone volume which has been associated with complications such as swelling, pain, hematoma and infection.⁴⁸

Although dental implants with 3.5 mm of diameter showed a lower stress concentration in the prosthetic abutments, dental implants and bone tissue when compared to dental implants with 2.9 diameter, the difference in stress concentration was small, indicating that the dental implant with 2.9 mm of diameter may also be indicated in situations where the amount of bone tissue present is restrict being the only option in an implant-supported rehabilitation. However, the literature suggest that is necessary to perform a precise occlusal adjustment to mitigate the risks of using dental implant less than 3,5 mm of diameter, in order to provide a better dissipation of the occlusal forces as well as the necessity to avoid premature occlusal contact on the dental implants, especially during protrusive and lateral movements.^{38,49}

Regarding to the microstrain analysis, a higher concentrations in the models with dental implant of 2.9 mm diameter was observed. These results corroborate with the results obtained through the maps of maximum principal stress (tractive and compressive stress), where higher values were found. It should also be noted that under axial loading conditions, the physiological limits pre-established in the literature for stresses (100 to 170 MPa)⁵⁰ and microstrain (3000 $\mu\epsilon$)⁵¹ were not exceeded for the bone tissue. Nevertheless, when oblique loads were considered the limits of physiological strength were exceeded for the cortical and trabecular bones which might suggest a risk of bone loss, especially in dental implants with 2.9 mm of diameter. Furthermore, these high values have indicated that the oblique loads are more damaging to the bone tissue, especially in the situation tested where the thickness of the simulated bone plate was reduced, thus increasing the risk of bone loss in

the region.

The comparison of the magnitude of stress between the cortical and the trabecular bone revealed that the cortical bone was subjected to much higher stresses compared to the trabecular bone and these data are in agreement with other studies that reported a lower concentration of stress in the trabecular bone.^{30,31,34,39} Possible, this occurred because the cortical bone has a higher elasticity module and resistance to deformation than the trabecular bone. In addition, it is assumed that compressive stress may generate greater bone resorption compared to tractive stress,^{52,53} and in our present study a greater compressive stress in the cortical and trabecular bones in dental implants with 2.9 mm of diameter was observed. Rodríguez et al., 2009,⁵⁴ suggesting that the peri-implant bone may be more susceptible to bone loss when using the dental implant with 2,9 mm diameter.⁵⁵

The literature has reported that the diameter of the dental implant seems to influence the increase in stress in the cortical bone, while the implant length mainly influences the trabecular bone,^{26,50} however, the results of the present study showed that the diameter of the implant may affect both cortical and trabecular bones more than the length of the implant. This result is in agreement with Baggi et al., 2014,⁵⁶ who carried out a study of the influence of the diameter and length of the dental implant on the stress distribution and they observed that the diameter of the implant may be a more effective biomechanical parameter than the length of the implant. Furthermore, the combined use of longer implants with 3,5mm of diameter generated a favorable biomechanical behavior in bone tissue when compared to combined use of short implants with 2,9mm of diameter, corroborating with previously published studies.^{40,57}

In our study, longer length implants (11.5 and 15 mm) showed better stress distribution, especially in bone tissue. Thus, the second hypothesis tested that the influence of the implant length on the stress distribution in the evaluated structures was accepted. These

results are in accordance with previous.^{38,40,58} In addition, this fact may be confirmed clinically, since larger implants have a higher survival rate compared to short implants.⁵⁹ It should also be emphasized that mechanically there was no tendency to failure or undesirable distributions in the dental implants or prosthetic abutments tested in this study, consequently, the bone tissue was more favored by the use of a 3.5 mm diameter implant, especially considering that in the cervical region is where bone resorption starts around the dental implants when there is overload and precisely in this region the 3.5 mm implants showed relief from stress. however, our result showed that the diameter design parameter affected the stress distribution more than the length.

The literature is scarce of studies evaluating the biomechanical behavior of small diameter implants in the anterior region of the maxilla and adjacent to permanent teeth. Thus, the present study may contribute to a better understanding of clinical situations where there is a need to work with small diameter implants with morse Taper dental implants. However, the present study evaluated only two types of reduced diameter (2.9 mm and 3.5 mm) and it is noteworthy that studies that analyze more diameter with other variables, such as the type of implant connection (internal hexagon and external hexagon), bone quality, type of fixation in bone tissue (at the level or subcrestal) and type of geometry of the implants (conical or cylindrical), as well as the design of intermediates (single body or with through screw) is necessary in future studies.

Finite element analysis has been considered a useful tool for evaluating preclinical situations,⁶⁰ determining stresses and strain in structures individually.^{58,61,62} In this way, these studies have already been indicated for a better understanding of biomechanical behavior and, subsequently, to have its results extrapolated to the daily clinic.⁶³ However, the results must be interpreted with caution, since it is a computational analysis, and thus has some limitations, such as the fact that the simulated the structures as isotropic,

homogeneous and linear properties,^{62,64} unlike living tissues that are more dynamic being able to present different results.⁶⁵

3.6. CONCLUSION

Within the limitations of this study, the following conclusion was obtained:

- The dental implants with 3.5 mm of diameter implants were more biomechanically favorable than the 2.9 mm of diameter.
- Longer implant length (>11,5mm) combined with diameter 3.5 mm reduced the stress and strain transferred to bone tissue

Conflict of interest statement

The authors declare that there was no conflict of interest in the elaboration of this study.

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4. ANEXO A– Referências da Introdução Geral

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5. ANEXO B— Normas das revistas selecionadas para a publicação dos



JOURNAL OF PROSTHETIC DENTISTRY

GUIDE FOR AUTHORS

Instructions in Other languages

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Abstract (approximately 400 words): Create a structured abstract with the following subsections: Statement of Problem, Purpose, Material and Methods, Results, and Conclusions. The abstract should contain enough detail to describe the experimental design and variables. Sample size, controls, method of measurement, standardization, examiner reliability, and statistical method used with associated level of significance should be described in the Material and Methods section. Actual values should be provided in the Results section.

Clinical Implications: In 2-4 sentences, describe the impact of the study results on clinical practice.

Introduction: Explain the problem completely and accurately. Summarize relevant literature, and identify any bias in previous studies. Clearly state the objective of the study and the research hypothesis at the end of the Introduction. Please note that, for a thorough review of the literature, most (if not all references) should first be cited in the Introduction and/or Material and Methods section.

Material and Methods: In the initial paragraph, provide an overview of the experiment. Provide complete manufacturing information for all products and instruments used, either in parentheses or in a table. Describe what was measured, how it was measured, and the units of measure. List criteria for quantitative judgment. Describe the experimental design and variables, including defined criteria to control variables, standardization of testing, allocation of specimens/subjects to groups (specify method of randomization), total sample size, controls, calibration of examiners, and reliability of instruments and examiners. State how sample sizes were determined (such as with power analysis). Avoid the use of group numbers to indicate groups. Instead, use codes or abbreviations that will more clearly indicate the characteristics of the groups and will therefore be more meaningful for the reader. Statistical tests and associated significance levels should be described at the end of this section.

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Discussion: Discuss the results of the study in relation to the hypothesis and to relevant literature. The Discussion section should begin by stating whether or not the data support rejecting the stated null hypothesis. If the results do not agree with other studies and/or with accepted opinions, state how and why the results differ. Agreement with other studies should also be stated. Identify the limitations of the present study and suggest areas for future research.

Conclusions: Concisely list conclusions that may be drawn from the research; do not simply restate the results. The conclusions must be pertinent to the objectives and justified by the data. In most situations, the conclusions are true for only the population of the experiment. All statements reported as conclusions should be accompanied by statistical analyses.

References: See Reference Guidelines and Sample References page.

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Writing Guidelines

General Policies and Suggestions

Authors whose native language is not English should obtain the assistance of an expert in English and scientific writing before submitting their manuscripts. Manuscripts that do not meet basic language standards will be returned before review. The Journal does not use first person (I, we, us, our, etc.). "We conducted the study" can be changed easily to "The study was conducted." Avoid the use of subjective terms such as "extremely", "innovative" etc. The JPD uses the serial comma which is the comma that precedes the conjunction before the final item in a list of three or more items: The tooth was prepared with a diamond rotary instrument, carbide bur, and carbide finishing bur. We prefer the nonpossessive form for eponyms: the Tukey HSD test rather than Tukey's HSD test, Down syndrome rather than Down's syndrome and so on. Describe experimental procedures, treatments, and results in passive tense. All else should be written in an active voice. Describe teeth by name (eg, maxillary right first molar), not number. Hyphens are not used for common suffixes and prefixes, unless their use is critical to understanding the word. Some prefixes with which we do not use hyphens include: pre-, non-, anti-, multi-, auto-, inter-, intra-, peri-. Eliminate the use of i.e. and e.g. as they are not consistent with Journal style. Spell out seconds, minutes, hours, etc. Only use abbreviations in the Tables. Avoid the repeated use of Product names in the manuscript. Please initially identify all the products used in the experiment and subsequently refer to them by generic terms. It is generally better to paraphrase information from a published source than to use direct quotations. Paraphrasing saves space. The exception is a direct quotation that is unusually pointed and concise. When long terms with standard abbreviations (as in TMJ for *temporomandibular joint*) are used frequently, spell out the full term upon first use and provide the abbreviation in parentheses. Use only the abbreviation thereafter. Even very common acronyms should still be defined at first mention. We do not italicize foreign words such as "in vivo", "in vitro." Abbreviate units of measurement without a period in the text and tables (9 mm). Insert a nonbreaking space between all numbers and their units (100 mm, 25 MPa) except before % and °C. There should never be a hyphen between the number and the abbreviation or symbol except when in adjectival form (100-mm span). Spell out "degrees" for angles. Use the degree symbol only for temperature, include a space between the number and degree symbol (e.g., 37 °C). Contractions such as don't, it's, wouldn't, etc are not used in scientific writing. Avoid using the words "respectively" or "former/latter." Both force the reader to stop and backtrack. For the common statistical outcomes P, a, β omit the zero before the decimal point as these cannot be greater than 1. Proprietary names function as adjectives. Nouns must be supplied after their use, as in *Vaseline petroleum jelly*. Wherever possible, use only the generic term. Do not use trademark symbols as they are not consistent with Journal style.

Some Elements of Effective Style

Short words. Short words are preferable to long ones if shorter word is equally precise. Familiar words. Readers want information that they can grasp easily and quickly. Simple, familiar words provide clarity and impact. Specific rather than general words. Specific terms pinpoint meaning and create word pictures; general terms may be fuzzy and open to varied interpretations. Brisk opening. Plunge into your subject in the first paragraph of the article. Limited use of modifying words and phrases. Check your adjectives, adverbs, and prepositional phrases. If they are not needed, strike them out. No unnecessary repetition. An idea may be repeated for emphasis—so long as that repetition is effective. Short sentence length. Twenty words or less is recommended. Rambling sentences cluttered with subordinate clauses and other modifiers are hard to read and may cause readers to lose their train of thought. Short sentences should, however, be balanced with somewhat longer ones to avoid monotony. Paragraphs. Break up long sections into paragraphs but avoid the use of single sentence paragraphs. Restraint. Writers who use flamboyant words or overstate their proposition or conclusions discredit themselves. Facts speak for themselves. Clearly stated conclusions. Don't hedge. If you don't know something, say so.

Objectionable Terms

The following are selected objectionable terms and their proper substitutes. For a complete list of approved prosthodontic terminology, consult the eighth edition of the *Glossary of Prosthodontic Terms* (J Prosthet Dent 2005;94:10-92).

Or visit JPD <http://www.prosdent.org> and click on Collections/Glossary of Prosthodontic Terms. Alginate use Irreversible hydrocolloid Bite use Occlusion Bridge use Partial fixed dental prosthesis Case use Patient, situation, or treatment as appropriate Cure use Polymerize Final use Definitive Freeway space use Interocclusal distance Full denture use Complete denture Lower (teeth, arch) use Mandibular Model use Cast Modeling compound use Modeling plastic impression compound Muscle trimming use Border molding Overbite, overjet use Vertical overlap, horizontal overlap Periphery use Border Post dam, postpalatal seal use Posterior palatal seal Prematurity use Interceptive occlusal contact Saddle use Denture base Study model use Diagnostic cast Take impressions, photographs, radiographs use Make Upper (teeth, arch) use Maxillary X-ray, roentgenogram use Radiograph. In addition, *specimen* should be used rather than *sample* when referring to an example regarded as typical of its class.

Additional Terminology Guidelines

Acrylic

An adjective form that requires a noun, as in acrylic resin.

Affect, effect

Affect is a verb; effect is a noun.

African American

Spelled thus and preferred over Negro and black in both adjective (African American patients) and noun (... of whom 20% were African Americans) forms.

Average, mean, median

Mean and average are synonyms. Median refers to the midpoint in a range of items; the midpoint has many items above as below it.

Basic

Like fundamental, this word is often unnecessary. An example of unnecessary use: Dental implants consist of two basic types: subperiosteal and endosteal.

Between, among

Use between when 2 things are involved and among when there are more than 2.

Biopsy

This noun should NOT be used as a verb. A biopsy was performed on the Tissue, rather than: The tissue was biopsied.

Centric

An adjective that requires a noun, as in centric relation.

Currently, now, at present, etc.

These expressions are often unnecessary, as in: This technique is currently being used...

Data

Use as a plural, as in: The data were...

Employ

Should not become an elegant variation of use, as in This method is employed ...

Ensure

Preferred over insure in the sense of to make certain.

Fewer, less

Use fewer with nouns that can be counted (fewer patients were seen) and less with nouns that cannot be counted (less material was used).

Following

After is preferred.

Imply, infer

The speaker implies; the listener infers.

Incidence

The rate at which a disease occurs in a given time; sometimes confused with prevalence (the total number of cases of a disease in a given region).

Majority

Means more than half; use most when you mean almost all. **Male, female**

For adult humans, use men and women. For children, use boys and girls.

Must, should

Must means that the course of action is essential. Should is less strong and means that the course of action is recommended.

Numbers

Spell out numbers used in titles or headings and numbers at the beginning of a sentence. The spelled version may also be preferable in a series of consecutive numbers that may confuse the reader (eg, 2 3.5-inch disks should be written two 3.5-inch disks). In all other cases, use Arabic numerals.

Orient

Proper form; avoid orientate.

Pathologic

Use instead of pathological. Other words in which the suffix -al has been dropped include biologic, histologic, and physiologic.

Pathology

The study of disease; often mistaken for pathosis (the condition of disease)

Percent

Use the percent sign in the text, as in The distribution of scores was as follows: adequate, 8%; oversized, 23%; and undersized, 69%. But spell out when the percent opens a sentence, as in Twenty percent of the castings ...

Prior to

Before is preferred.

Rare, infrequent, often not, etc.

Whenever possible, these vague terms should be backed up with a specific number.

Rather

Like very, this word should be avoided.

Regimen

A planned program for taking medication, dieting, exercising, etc. Not to be confused with regime, meaning a system of government or management.

Sex

Use “sex” rather than “gender” unless you are referring to the socially constructed roles, behaviors, activities, and attributes that a given society considers appropriate for men and women.

Symptomatology

The science or study of symptoms; this word is not a synonym for the word symptoms.

Technique

Preferred over technic.

Using

Avoid the dangling modifier in sentences such as “The impression was made using vinyl polysiloxane impression material.” Write “with” or “by using” instead.

Utilize

Use is preferred.

Vertical

An adjective that needs a noun, as in vertical relation.

Via

Use through, with, or by means of.

White

Preferred over Caucasian. This is true only if the patient is from the Caucasus region of Eastern Europe. If not, use the term, white to describe the patient.

Sample Manuscript

https://www.elsevier.com/____data/promis_misc/ymprsamplemanuscript.pdf

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The International Journal of Oral & Maxillofacial Implants

Guidelines for Authors

Manuscript Submission

Submit manuscripts via JOMI's online submission service: www.manuscriptmanager.net/jomi

Manuscripts should be uploaded as a Word (doc/ docx) file with images saved as separate high- resolution art files. (See "Figures and Tables.")

- **Acceptable material.** Original manuscripts are considered for publication on the condition they have not been published or submitted for publication elsewhere (except at the discretion of the editors). Manuscripts concerned with reports of basic or clinical research, clinical applications of implant research and technology, proceedings of pertinent symposia or conferences, quality review papers, and matters of education related to the implant field are invited.
- **Number of authors.** Authors listed in the byline should be limited to six. Secondary contributors can be acknowledged at the end of the article. (Special circumstances will be considered by the editorial board.)
- **Adherence to guidelines.** Manuscripts that are not prepared in accordance with these guidelines will be returned to the author before review.

Manuscript Preparation

The journal will follow as much as possible the recommendations of the International Committee of Medical Journal Editors in regard to preparation of manuscripts and authorship (Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals; www.icmje.org/recommendations).

Manuscripts should be double-spaced with at least a one-inch margin all around. Number all pages. Do not include author names as headers or footers on each page.

- **Title page.** The title page should include the title of the article and the name, academic degrees, and professional affiliation of each author. Phone, fax, and email address must also be provided for the corresponding author. If the paper was presented before an organized group, the name of the organization and the date and location of the presentation should be included.
- **Abstract/Keywords.** The abstract should include a maximum of 350 words. A list of keywords should be provided, not to exceed six. Abstracts for basic and clinical research articles must be structured with the following four sections: Purpose, Materials and Methods, Results, and Conclusion. Abstracts of short communications should also be structured but should be a maximum of 250 words. For all other types of articles (ie, literature reviews, technical and case reports), abstracts should not exceed 250 words and need not be structured.
- **Article text.** Currently there is no article page limit (within reason).
- **Acknowledgments.** Persons who have made substantive contributions to the study can be acknowledged at the end of the article. Also specify grant or other financial support, citing the name of the supporting organization and grant number. Conflict of interest: State any conflict of interest of any of the authors, or include a statement that the authors have no conflict of interest related to the study.
- **Figure legends.** Figure legends should be typed as group at the end of the manuscript. Detailed legends are encouraged. For photomicrographs, specify original magnification and stain.
- **Abbreviations.** The full term for which an abbreviation stands should precede its first use in the text unless it is a standard unit of measurement.
- **Trade names.** Generic terms are to be used whenever possible, but trade names and manufacturer should be included parenthetically at first mention.
- **Numbers.** Per SI convention, authors are requested to use decimal points rather than commas for fractional numbers.

References

- All references must be cited in the text, numbered in order of appearance.
- The reference list should appear at the end of the manuscript in numeric sequence.
- Do not include unpublished data or personal communications in the reference list. Cite such references parenthetically in the text and include a date.
- Avoid using abstracts as references.
- Provide complete information for each reference, including names of all authors (up to six). If the reference is part of a book, also include the chapter title and names of the book's editor(s).

Journal reference style:

1. Roehling S, Gahlert M, Janner S, Meng B, Woelfler H, Cochran DL. Ligature-induced peri-implant bone loss around loaded zirconia implants. *Int J Oral Maxillofac Implants* 2019; 34:357–365.

Book reference style:

Wang HL, Decker A, Testori T. Maxillary transcrestal sinus floor elevation. In: Nevins M, Wang HL (eds). *Implant Therapy: Clinical Approaches and Evidence of Success*, ed 2. Chicago: Quintessence, 2019:263–278.

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Figures and Tables

- All figures and tables should be numbered and cited in the text.
- Figures and tables can be grouped at the end of the manuscript or uploaded individually.
- Clinical images should be at least 300 dpi at 3.5 in wide.
- Images grouped together (eg, 1a–1c) must be saved as individual files (eg, 1a, 1b, 1c).
- Line art (eg, graphs, charts, line drawings) should be provided as editable vector art (eg, Illustrator or EPS files)
- Images containing type should either be saved as a layered file or provided along with a second file with type removed.

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