



## A Comparison of Torque Stress on Abutment Screw of External Hexagon and Morse Taper Implant

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### ABSTRACT

**Aim:** This three-dimensional (3D) finite element analysis observed the stress distribution on the prosthetic screws on external hexagon implant and morse taper implant with different tightening loads.

**Materials and methods:** For this, two different 3D models assembly were obtained from the manufacturer and transferred to finite element analysis software: External hex implant model (EHM), and Morse taper implant model (MTM), both compounds by 3.75 x 7 mm implant, abutment and abutment screw. Bolt pretension force was applied on the shaft next to the threads of the prosthetic abutment. Preload was calculated using the torque on the prosthetic screw as recommended by the manufacturer (EHM30 and MTM20) and 10 Ncm torque above the manufacturer recommendations (EHM40 and MTM30). Maximum von mises equivalent stresses were obtained on the screws.

**Results:** Preload values results were 243.18N (EHM30), 229.71N (MTM20), 324.24N (EHM40) and 344.57N (MTM30). In EHM30, EHM40 and MTM20 models the maximum stresses

were below the yield strength of the abutment screw material. However, the maximum stress in MTM30 model was higher than the reference value.

**Conclusion:** The torque loads above the manufacturer recommendations can cause plastic deformation in the MT abutment screw threads. The screws of morse taper implant can be more sensitive to higher loads than external hexagon implant.

**Clinical significance:** The adequate torque can result in screw loosening, while fracture may occur if torque is excessive. Abutment screw suffers many screwing cycles in its lifetime in a way that some tightening forces are above manufacturer recommendations.

**Keywords:** Abutment, Dental implant, Dental prosthesis, Rehabilitation oral.

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### INTRODUCTION

Abutment screw is the most common instrument used to secure the abutment in the implant.<sup>1</sup> Screw loosening is the most common technical complications,<sup>2,3</sup> varying from 5.6% for fixed partial dentures to 12.7% for single crowns after 5 years.<sup>4</sup> The prevalence of screw loosening is higher for external hexagon implant systems.<sup>5</sup>

When the abutment screw is tightened to implant, preload is created along the interface of the screw, and the implant bore threaded surfaces clamping the prosthesis to the implant.<sup>6</sup> As this relationship is frictional, and they suffer varied chewing patterns and unfavorable occlusal loading<sup>7-9</sup> besides framework misfits and cantilevers<sup>10,11</sup> any occlusal loading on the implant complex is transferred directly to the abutment screw/ implant joint, leading to loosening when it exceeds the preload.<sup>12,13</sup> Screw loosening can also result from the lack of contact between the two surfaces, a consequence

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of no surface being completely smooth. When they were subjected to external loads micro-movement occurs, being called settling effect.<sup>14,15</sup> If these stresses exceed the elastic range of the abutment screw material, it will cause plastic deformation in the component<sup>9,16</sup> which can cause the fracture by fatigue, even when it's lower the tensile strength.<sup>17-21</sup>

Therefore, higher the tightening torque more stress the prosthetic screw/implant interface will bear<sup>22</sup> reaching the "optimum preload" that's between 60% and 75% of yield strength of the abutment screw.<sup>6</sup> Explaining why the use of torque 10 Ncm above the 30 Ncm recommended by the manufacturer on the prosthetic screw of external hexagon implant can be beneficial to decrease screw loosening.<sup>22,23</sup>

Finite element analysis (FEA) was chosen for being a good method for evaluation of preload in the dental implant system allowing easy modification of the model, representation of complex geometries and structures internal stresses. It allows greater control of variables related to the experiment without the risks and costs of implementation gathering elaborate data that cannot be obtained using conventional methods.<sup>6,7,16,24-26</sup>

Hence, this study aims to compare the stress distribution caused by different torque loads on prosthetic screws of external hexagon (EH) and morse taper (MT) implants. The specific objectives are: to compare quantitatively the stress distribution created by the preload simulation on the prosthetic screw of two different implant models with your respective pillars and to compare the maximum tensions generated with the recommended preload for the external hexagon and morse taper by the manufacturer and 10 Ncm above.

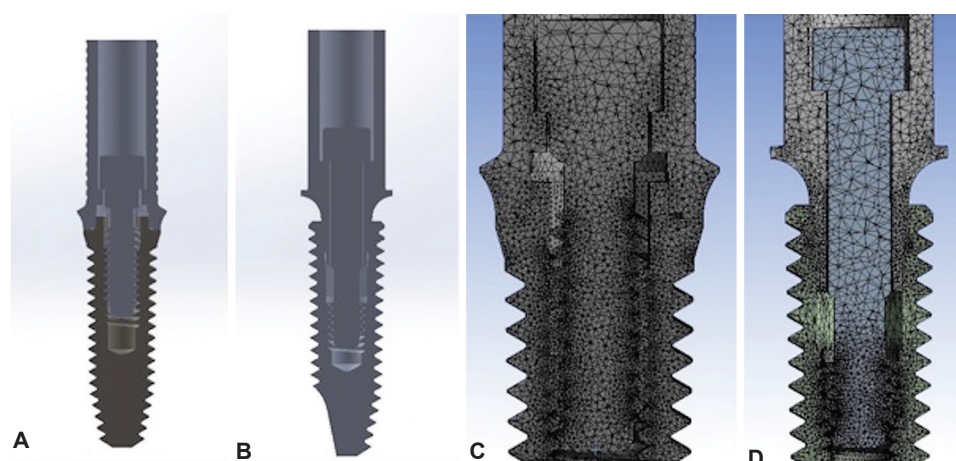
The hypothesis tested are that prosthetic screw of morse taper implant shows lower stress values than the prosthetic screw of external hexagon implant and that the recommended values by the manufacturer are below the yield strength of the material while the high values torque exceed it.

## MATERIALS AND METHODS

Two similar three-dimensional geometrical models of dental implant complex (Figs 1A and B), with 3.75 mm diameter and 7 mm length, were obtained from the manufacturer in IGES format and processed in the computer-aided design (CAD). The external hexagon model (EHM) was composed by external hex implant (DSP Biomedical), 4.1 mm titanium UCLA abutment and prosthetic screw, while the morse taper model (MTM) was composed by Morse taper implant (Soul fit; DSP Biomedical), 0.35 length and 4.8 mm diameter titanium UCLA abutment and prosthetic screw. Simplification of the models was conducted using CAD software (Solid Works 2014; Dassault Systèmes) by filling the socket in abutment screw head and by removing the groove on the upside of the abutment, in both models.

The CAD models were exported to FEA software (ANSYS Workbench 16; ANSYS Inc.) for structural, mechanical analysis. All materials were considered isotropic, homogeneous, and linearly elastic. Table 1 presents the materials mechanical properties.<sup>27</sup>

Discretization was performed using tetrahedral solid elements (element type SOLID187) and the characteristics of the constructed models were: EHM 720,530 elements



**Figs 1A to D:** 3D models assembly: (A) EHM; (B) MTM; (C) EHM; (D) MTM

**Table 1:** Mechanical properties of the materials used in present study

Objects	Reference material	Yield strength (MPa)	Young modulus (GPa)	Poisson ratio
Implant	Ti-GR4	626	104	0.37
Abutment, screw	Ti-6Al-4V	860	113	0.342

and 1,033,030 nodes; MTM 534,814 elements and 772,249 nodes (Figs 1C and D). Element size was reduced in the area of interest-retaining screw.

The contacts were located between the base of the prosthetic screw head and the internal face of UCLA, base of UCLA and implant platform, and also between the implant’s internal thread and prosthetic screw thread. All the contacts were considered frictional with a frictional coefficient of 0.36 for contact between Ti-6Al-4V/Ti-6Al-4V (38) and 0.43 for contact between Ti-6Al-4V/Ti-GR4 (42). The nodes located on the external screw of both implants were held fixed to simulate an osseointegrated implant.

Preload was calculated by equation 1 using four torque values: manufacturer recommended values of 30 Ncm for EH and 20 Ncm for MT; and 10 Ncm above the recommended value: 40 Ncm for EH and 30 Ncm for MT. Where T is the torque load, p is the thread pitch,  $\mu_t$  the friction coefficient at the thread,  $r_t$  the effective radius of thread contact,  $\beta$  half of the flank angle,  $\mu_n$  the friction coefficient at the screw head and  $r_n$  the effective radius of contact between the implant and the joint. Thus, the measurements used for preload calculation and the results are observed in Table 2.

The bolt pretension force was applied on the shaft next to the threads of the prosthetic abutment.

**RESULTS**

The abutment screw yield strength of 860 MPa was used as a reference value of the label for analysis of elastic range limit. In EHM30 e EHM40 models, the torque values of 30 Ncm and 40 Ncm resulted in a preload of 243.18 N

and 324.24 N. Stresses were concentrated in the root of the fillets close to the location of the higher stress (Figs 2A and B). The maximum stresses in EHM30 and EHM40 models were 495.55 MPa and 682.67 MPa respectively and were located at the thread root between the 4th and 5th screw thread in both models (Figs 2C and D).

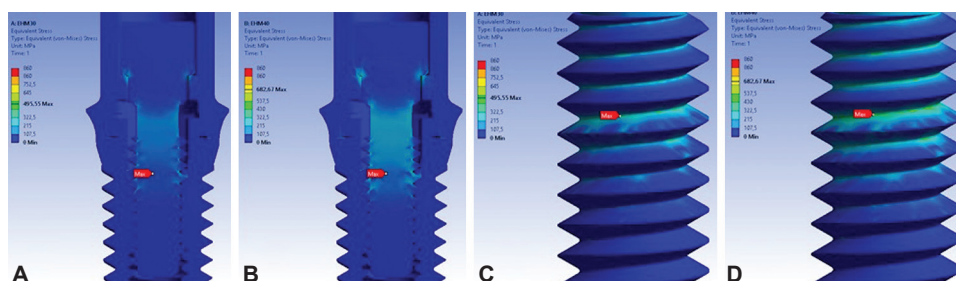
In MTM20 e MTM30 models, the torques of 20 Ncm and 30 Ncm resulted in preloads of 229.71 N and 344.57 N, respectively. Stresses were concentrated in the root of the fillets close to the location of the higher stress (Figs 3A and B). The maximum stresses in MTM20 and MTM30 models were 608.20 MPa and 918.27 MPa respectively, and were located at the thread root between the 1st and 2nd screw thread in both models (Figs 3C and D).

**DISCUSSION**

Implant success not only depends on osseointegration but also on biomechanical aspects.<sup>17</sup> Excessive tension on the prosthetic screw can cause plastic deformation which can lead screw to fracture by fatigue.<sup>12</sup> Clinical studies to show that fractures affect mostly abutment screw.<sup>17,19,20</sup> Tightening torque can extend primarily the abutment screw instead of deforming the implant due to the initial point contact interface between them<sup>8</sup> causing minor changes in morphology of implants than the prosthetic screws.<sup>15</sup> The stress distribution in the models EHM30 and MTM20 that evaluated the recommended torque by the manufacturer agrees with other studies where the use of recommended torque causes stresses below screw yield strength.<sup>1,6,16,24,28</sup> Possibly because of the smaller diameter and greater length of the MT prosthetic screw body

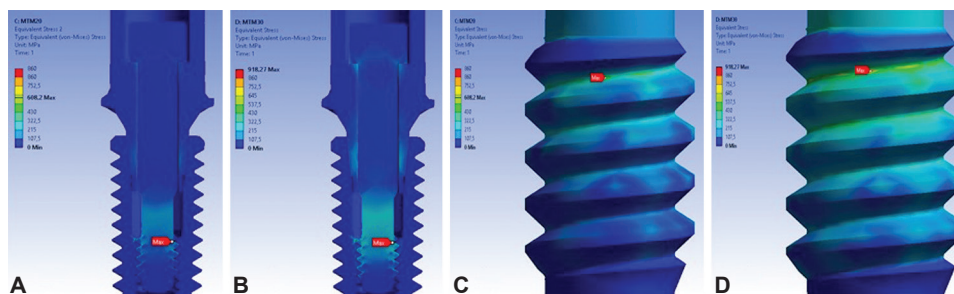
**Table 2:** Measurements and preload values for EHM and MTM models

Models	EHM30	EHM40	MTM20	MTM30
T (Nmm)	300	400	200	300
p (mm)	0.4	0.4	0.35	0.35
$\mu_t$	0.43	0.43	0.43	0.43
$\mu_n$	0.36	0.36	0.36	0.36
$r_t$ (mm)	0.87	0.87	0.735	0.735
$r_n$ (mm)	2.05	2.05	1.25	1.25
$\beta$	30	30	30	30
F (N)	243.18N	324.24N	229.71N	344.57N



**Figs 2A to D:** (A and B) Stress distribution in (A) EHM30 and; (B) EHM40 models; (C and D) Maximum stress in (C) EHM30; (D) EHM40 models





**Figs 3A to D:** (A and B) Stress distribution on (A) MTM20 e; (B) MTM30 models; (C and D) Maximum stress on (C) MTM20 e; (D) MTM30 models

compared with EH screw, when the torque was applied in the MTM the stress was higher than when applied in the EHM, rejecting the first hypothesis. Consequently, when the torque above manufacturer recommendations was used it exceeded the yield strength of the prosthetic screw in the MTM 30, while the stresses in EHM 40 were below the reference value, partially confirming the second hypothesis. The maximum stress region agrees with in vitro studies that tested the limit of the implant complex.<sup>18</sup>

As the optimum preload force is located between 60%<sup>8</sup> and 75%<sup>7</sup> of the yield strength of the material and in this study it was used the yield stress of 860 MPa for the prosthetic screw, the range of stress caused by the optimum preload should be between 516 to 645 MPa. Thus, the maximum stress 495 MPa found in EHM 30 model is close to the optimal value, but in EHM40 model the maximum stress 682 MPa exceeds the optimal margin preload.

Evaluating the optimal preload force in EHM30 may lead to weak preload force as it is lower than the 60% of yield strength, but in EHM 40 may affect the desired preload as it is higher the 75%. However, an in vitro study with HE implants found that the use of 40 Ncm torque (25% above the 32 Ncm recommended by the manufacturer) can be safely used to ensure a higher preload.<sup>23</sup> Meanwhile, in MTM 20 it is within the optimal range, but in MTM 30 the tension exceeds the elastic limit of the material which can cause plastic deformation and may reduce the fatigue resistance of the component.

The maximum stress 608 MPa found in MTM 20 model is within the optimal margin of 516 to 645 MPa, but in MTM 30 model the maximum stress 918 MPa exceeds the margin.

The results are in accord with other studies that found for both implants values lower than the optimal preload when used the torque as recommended, but the author considered as optimal preload the value of 75% of yield strength. When the two implants were compared the MT has reached higher preload values than EH implant.<sup>6</sup> Torque value for abutment screws above 30 Ncm can be beneficial for abutment-implant stability and to decrease screw loosening.<sup>22</sup>

Some limitations of the study were that the 10 Ncm increase over 30 Ncm recommended for EH was a 33% increase, while the increase of 10 Ncm over 20 Ncm for MT was a 50% increase. However, as the loosening of prosthetic screws is a clinical problem, and the purpose of this comparison was to carry out as it happens clinically, the authors understand that when a clinician adds torque on the component above manufacturer recommendations this increase does not occur through percentages but through the addition of simple numbers. Bone simulation around the implant wasn't simulated in this study due to evidence that during the preload there's minimal transfer of stresses to it.<sup>24,26</sup> Beyond this limitations, the use of prosthetic crown and different abutments, the use of multiple implants, different size and width of the implants and the application of external load are factors that could alter the results found.

Finite element method is the instrument with better ability to analyze implants today,<sup>9</sup> but some factors may produce inaccuracies in these results as inadequate choice of simplifications, inappropriate element or very simplified mesh.<sup>29</sup> As it is a mathematical study, the results should be confirmed by in vitro studies and clinical studies.<sup>9,29</sup> By observing the stress values found in this study it is concluded that it is important that studies that simulate implant-abutment screw joint with FEA take account of the preload force as it causes high stresses in the implant complex and it shouldn't be neglected.<sup>16</sup>

Within the limitations of this FEA, the use of torque recommended by the manufacturer on external hexagon abutment screw caused tension below the optimal preload, but on morse taper screw it stood within the optimal margin. Torque loads 10 Ncm higher than manufacturer recommendations on EH screw can be used to gain higher preload force keeping the stress below the yield strength. However, the application of higher torque on morse taper implant can cause plastic deformation in the abutment screw threads.

Macedo et al.,<sup>30</sup> conducted a study with the objective of evaluating the distribution of stresses, and consequent bone volume affected surrounding external hexagon or morse taper dental implant systems by finite element analysis.

The authors conclude that Morse taper implant joints revealed a proper biomechanical behavior when compared to external hexagon systems concerning a significant volume of surrounding peri-implant bone subjected to lower stresses values. Results were different from those found by Carvalho et al.,<sup>31</sup> which noted greater stress concentrations were observed in internal connections. Our research is according to Carvalho et al., 2014,<sup>31</sup> which revealed that the screws of morse taper implant could be more sensitive to higher loads than external hexagon implant.

## CONCLUSION

With based on the methodology studied, it can be concluded that the screws of morse taper implant can be more sensitive to higher loads than external hexagon implant.

## CLINICAL SIGNIFICANCE

The adequate torque can result in screw loosening, while fracture may occur if torque is excessive. Abutment screw suffers many screwing cycles in its lifetime in a way that some tightening forces are above manufacturer recommendations.

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