Short Implant to Support Maxillary Restorations: Bone Stress Analysis Using Regular and Switching Platform

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Purpose: The aim of this study was to evaluate stress distribution on peri-implant bone simulating the influence of implants with different lengths on regular and switching platforms in the anterior maxilla by means of three-dimensional finite element analysis.

Materials and Methods: Four mathematical models of a central incisor supported by an external hexagon implant (diameter, 5.0 mm) were created, varying the length (15.0 mm for long implants [L] and 7.0 mm for short implants [S]) and the diameter of the abutment platform (5.0 mm for regular models [R] and 4.1 mm for switching models [S]). The models were created using the Mimics 11.11 (Materialise) and SolidWorks 2010 (Inovarti) software. Numerical analysis was performed using ANSYS Workbench 10.0 (Swanson Analysis System). Oblique forces (100 N) were applied to the palatine surface of the central incisor. The bone/implant interface was considered perfectly integrated. Maximum (σ_{max}) and minimum (σ_{min}) principal stress values were obtained.

Results: For the cortical bone, the highest stress values (σ_{max}) were observed in the SR (73.7 MPa) followed by LR (65.1 MPa), SS (63.6 MPa), and LS (54.2 MPa). For the trabecular bone, the highest stress values (σ_{max}) were observed in the SS (8.87 MPa) followed by the SR (8.32 MPa), LR (7.49 MPa), and LS (7.08 MPa).

Conclusions: The influence of switching platform was more evident for the cortical bone in comparison with the trabecular bone for the short and long implants. The long implants showed lower stress values in comparison to the short implants, mainly when the switching platform was used.

Key Words: Bone biology, implantology, osseointegration, prosthodontics

Although high long-term success rates with osseointegrated implants for the treatment of completely or partially edentulous patients have been reported, implant failure, marginal bone loss, and patient discomfort still occur. Bone loss usually begins at the crestal area of the cortical bone and can progress toward the apical region, jeopardizing the longevity of the implant and prosthesis. It is suggested that optimization of an implant may favor the mechanical environment for bone maintenance.

One interesting proposal suggests that a so-called platform switching protocol could ensure better bone levels, at least in the short term. According to this principle, the abutment/implant joint is moved to the center of the implant and keeps far from the peri-implant bone, which is maintained away from the inflammatory cells. Consequently, if this concept is proven to be predictable, it would certainly impact the aesthetic outcome of implants placed in the aesthetic zone and should be tested.

The maxilla may present insufficient bone quantity for insertion of long implants, which is a prosthetic-surgical challenge owing to reduced bone quality and quantity usually represented by bone types III and IV. In these conditions, the placement of short implants has been introduced as an alternative treatment strategy to deviate from advanced surgical techniques. Clinical studies have demonstrated that a short implant may be a viable long-term solution for regions with limited bone height, although the risk seems to increase if the crown-to-implant ratio exceeds the guidelines established for natural teeth.

Numerous publications have addressed the issue of implant length as a predictor of implant survival. These studies have produced conflicting results. Some studies report high failure rates with short implants, whereas other studies report high survival rates. Considering the need for additional studies to evaluate stress distribution with short implants and its association with switching platform, the aim of this study was to evaluate the influence of switching platform in short implants in the anterior region of maxilla by means of the three-dimensional finite element analysis.

MATERIALS AND METHODS

After approval by the human ethics committee (process no. 2008/01845) and signing of the informed consent, a tomographic

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This study was supported by the Sao Paulo Research Foundation (FAPESP - Brazil, no. 2008/0209-9). The authors report no conflicts of interest. Copyright © 2012 by Mutaz B. Habal, MD ISSN: 1049-2275 DOI: 10.1097/SCS.0b013e31824dab7

The Journal of Craniofacial Surgery • Volume 23, Number 3, May 2012
examination of the maxilla of a patient was conducted to obtain tomographic images in DICOM format. Four mathematical models representing the anterior segment of the maxilla were fabricated using Mimics 11.11 (Materialise, Leuven, Belgium) and SolidWorks 2010 (Inovart, São Paulo, Brazil) software.

All models were restored with a crown cemented on the abutment, varying the implant length (7.0 and 15.0 mm) and the platform diameter (4.1 and 5.0 mm), simulating 2 regular situations (short regular model [SR] and long regular model [LR]) and 2 switching situations (short switching model [SS] and long switching model [LS]).

The external hexagon implants SIN (Sistema de Implante, SP, Brazil) Revolution (5.0 × 15.0 and 5.0 × 7.0 mm) were restored with a crown IPS e-max Press (Ivoclar Vivadent, Schaan, Liechtenstein) cemented on the abutment (4.1 and 5.0 mm in diameter) with the cement Variolink II (Ivoclar Vivadent), 0.05 mm in thickness. Then, the assembly was inserted in the anterior segment of the maxilla with cortical and trabecular bone corresponding to the region of the right central incisor (Figs. 2A, B). The crown presented 13.07 mm in height, 8.8 mm in mesiodistal width, and 7.1 mm buccal-lingual width.

After fabrication, the models were transferred to the finite element software Ansys Workbench 10.0 (Swanson Analysis, Inc, Houston, PA) to determine the regions and generate the finite element mesh.

The mechanical properties of the structures were based on the specific literature (Table 1).29,30 All materials were considered isotropic, homogeneous, and linearly elastic. The bone/implant interface was considered as perfectly integrated.31,32 One oblique loading (45 degrees) was applied on the palatine surface of the crown of the right central incisor (100 N; Fig. 3A).33 The fixed support was determined in the 3 Cartesian axes (0.48 MPa for LS, * for the short regular model [SR] and long regular model [LR]) and of 2 switching situations (short switching model [SS] and long switching model [LS]; Fig. 1).

Parabolic tetrahedral elements of 0.8 mm in dimension were used for the mesh (Fig. 2C). The refinement of the mesh was established through convergence analysis (6%).29 The models presented the number of elements ranging from 230,600 to 242,353.

For analysis of the results, the maximum (σmax) and minimum (σmin) principal stress values for the cortical and trabecular bone were obtained. According to Dejak and Mlotkowski,34 these analyses criteria are appropriate for predicting failures in nonductile materials.

### RESULTS

For the cortical bone, the maximum (σmax) principal stress was highest in SR (73.7 MPa) followed by LR (65.1 MPa), SS (63.6 MPa), and LS (54.2 MPa; Fig. 6). The influence of switching platform was evident for the short and long implants. In the short switching model (SS), the σmax decreased 13.7% in comparison to the short regular model (SR), whereas in the long switching model (LS), the σmax decreased 16.7% in comparison to the long regular model (LR). The increase in implant length showed a decrease of 11.6% in the σmax for the short regular model (SR) in comparison to the long regular model (LR) and of 14.7% for the short switching model (SS) in comparison to the long switching model (LS). The minimum (σmin) principal stress was highest in SR (1.66 MPa) and the other models exhibited similar values of σmin (0.48 MPa for LS, −0.32 MPa for LR, and 0.20 for SS; Fig. 4).

For the trabecular bone, the maximum (σmax) principal stress was highest in SS (8.87 MPa) followed by SR (8.32 MPa), LR (7.49 MPa), and LS (7.08 MPa; Fig. 5). The influence of switching platform was more evident for cortical bone in comparison to the trabecular bone. In the short regular model (SR), the σmax decreased 6.2% in comparison to the short switching model (SS), whereas in the long switching model (LS), the σmax decreased 5.4% in comparison to the long regular model (LR). The influence of the implant length was more evident for trabecular bone of the switching models in comparison to the cortical models. The increase in implant length showed a decrease of 9.9% in the σmax for the short regular model (SR) in comparison to the short switching model (SS), whereas in the long switching model (LS), the σmax decreased 4.5% in comparison to the long regular model (LR). The influence of the switching platform reduced the stress in the peri-implant bone, increasing platform.

### DISCUSSION

The results of the current study demonstrated that the use of switching platform reduced the stress in the peri-implant bone, while maintaining similar stress values in the cortical bone. This suggests a potential for improved osseointegration and reduced complications associated with implant failure. Further research is needed to validate these findings and explore the clinical implications of using switching platforms in implant dentistry.
who reported that models with switching platform exhibited a decrease in stress values nearly 10% in comparison to the models with regular platform.

These findings might be explained by the biologic width formed near the implant/abutment interface, which may be caused by the microgap located at the edge of the interface. For the platform switching protocol, the biologic width extends horizontally from the abutment to the edge of the collar of the implant and the remainder extends apically to this region, which should facilitate bone preservation. This observation provides direct evidence that the biologic process resulting in the formation of the biologic dimension and position of hard and soft tissues around a dental implant has a great capacity to influence and direct the bone remodeling process than does the ability of a bone loading implant surface to resist the resorptive process of crestal bone remodeling that results from the biologic attempt to create adequate spaces for soft tissue attachment to the implants.

Similar results were confirmed by the retrospective study of Prosper et al. when observed that the switching platform reduced the bone loss for both immediate loading and conventional surgical protocol with 2 steps. Calvo-Guirado et al. radiographically observed reduced bone loss for cases with switching platform and stated that bone maintenance may result from alteration in the biologic process. Romanos and Nentwig suggested that the reduced bone loss generated by switching platform depends on the primary stability of the implant after surgery, interarch occlusal stability, and controlled diet during osseointegration.

However, other studies found similar bone loss for both switching and regular platforms. This may result from the insertion of implants immediately after exodontia in all these studies with immediate loading, which may have caused similar bone loss for all groups. Chaushu et al. and Maló et al. reported lower success rates for implant inserted immediately after exodontia (75%) in comparison to the implants inserted not immediately (100%).

In the present study, the stress was concentrated on the lingual region of the cortical bone. The same region was found by Hsu et al. in experimental and FE models, especially under lateral loading.

The current study found that a long implant and a switching platform provided biomechanical benefits for the delay-loaded implants. However, the decrease in the stress value for the trabecular bone was higher when the implant length was evaluated for the models with switching platform, with a 20.1% decrease in maximum principal stress (σ\text{max}) from model SS to model LS. The decrease in crestal bone stress induced by the increase in the implant length in the maxilla was confirmed by Otate et al., who found that short implants presented statistically significant differences, with early loss of implant in comparison to the long implant.

Moreover, other authors believe that, for long-term evaluation, the implant length could be more important than the diameter is because, before oral cavity exposure and loading, vertical osseous loss is present, and it can be close to 0.2 mm/y; in the future, the implant may lose important contact between the bone and the implant surface.

Although a linear behavior was established between the structures in the present study, it can be suggested that the switching platform or long implants improve stress distribution in the peri-implant maxillary bone. Additional studies are required to conduct an anisotropic evaluation of the properties of cortical and medullary bone using friction coefficients to simulate an immediate loading considering the influence of the switching platform in short implants in the maxilla. In addition, longitudinal clinical studies and animal studies should be conducted to complement the findings of the present study.

**CONCLUSIONS**

According to the methodology used, it was concluded that:

1. the influence of the switching platform was more evident in the cortical bone in comparison to the medullary bone,
2. the switching platform reduced the maximum principal stress (σ\text{max}) of the short and long implants, and
3. the long implant presented a lower value of maximum principal stress (σ\text{max}) than the short implant did, mainly when the switching platform was associated.

**REFERENCES**