Short Communication

A Finite Element Analysis of Tilted Versus Nontilted Implant Configurations in the Edentulous Maxilla

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The aim of this study was to evaluate stress patterns at the bone-implant interface of tilted versus nontilted implant configurations in edentulous maxillae using finite element models of two tilted and one nontilted configuration. Analysis predicted the maximum absolute value of principal compressive stress near the cervical area of the distal implant for all models. The tilted configurations showed a lower absolute value of compressive stress compared with the nontilted, indicating a possible biomechanical advantage in reducing stresses at the bone-implant interface. *Int J Prothodont 2009;22:155–157*

Implant tilting in the rehabilitation of edentulous maxillae has been suggested as an alternative to bone grafting.[1] It allows for a reduction in cantilever length and may contribute to achieving a more favorable stress distribution in the bone. Excessive stress levels at the bone-implant interface may lead to marginal bone loss, thus affecting implant survival. The aim of this study was to investigate stress patterns at the bone-implant interface through finite element (FE) analysis while considering one nontilted and two tilted implant-supported prosthesis configurations. For the nontilted model, the Toronto-Brånemark configuration was considered; for the tilted models, the All-on-4 (Nobel Biocare AB) and a tilted configuration using six implants, referred to as All-on-6, were considered.

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Materials and Methods

The three-dimensional (3-D) geometry of the maxilla was reconstructed from computed tomography (CT) scans using a commercial software (Amira, TGS). The structure symmetry allowed for the reconstruction of symmetrical models. A planar occlusal surface was obtained, simulating the surgical bone reaming. The geometric parameters assumed for the models are given in Table 1. Cylindrical implants, including a truncated cone tip and cylindrical abutments, were built. The implant-abutment interface was assumed completely bonded. In setting the All-on-4 and the All-on-6 configurations (Figs 1a and 1b), the distal implant was

Table 1 Geometric Parameters Adopted for the Models

Configuration	No. of implants*	Implant dimension (mm)		Abutment dimension (mm)		Cantilever length (mm)
		Diameter	Length	Diameter	Length	
All-on-4	4	4	15	4	4	5
All-on-6	6	4	15	4	4	5
Toronto-Brånemark	4	4	15	4	4	15
	1	4	10	4	4	

*The number of implants refers to the complete configurations.

Table 2 Material Properties Adopted for the Models

Material*	Young's modulus (GPa)	Poisson ratio
Trabecular bone	0.49	0.3
Cortical bone	14.7	0.3
Titanium grade II	109	0.32
Resin	3.52	0.35
Porcelain	68.9	0.28

*All materials were assumed to be linear elastic isotropic.

mesially inclined 30 degrees while the other implants' positions were defined by the anatomy of the maxilla. For the Toronto-Brånemark configuration (Fig 1c), the shortest implant was inserted in the most distal region. Superstructures representing implant-supported fixed prostheses with different cantilever lengths were built (Fig 1). Geometries were discretized using linear tetrahedral elements. Material properties for all models are given in Table 2.[2] An axial concentrated load equal to 100 N was applied to the distal cantilever portion of the superstructure. The nodes belonging to the upper part of the maxilla were fixed in all directions. Static analyses were carried out using the FE analysis code ABAQUS 6.6 (ABAQUS, Simulia).

Results

The maximum absolute value of compressive stress was found near the cervical area of the distal implant, similar to that found in a photoelastic stress study,[3] and was predicted to be distally located for all models (Fig 2). Specifically, it was found to be 2.3 MPa, 1.8 MPa, and 2.6 MPa, for the All-on-4, All-on-6, and Toronto-Brånemark configurations, respectively. For mesial implants of the All-on-4 and Toronto-Brånemark configurations, stress peaks were near the posterior part of the cervical area. In the All-on-6 configuration, the highest stress for the mesial implant was located near the lingual part of the cervical area, while for the intermediate implant it was near the distal part of the cervical area.

Discussion

Implant tilting can allow for an increase in the inter-implant distance and a reduction in cantilever length so that a better load distribution can be achieved. The numerical results predicted lower values of compressive stress in configurations with tilted implants. As a consequence, within the limitations of FE modeling, a possible biomechanical advantage may have been gained by using tilted implants in the rehabilitation of the completely edentulous maxilla.

Those numerical results confirm previously published data and the stress magnitudes found in this study are in agreement with other reported data.[4] For a solitary implant, compressive stress values at the bone-implant interface have been reported to increase with increasing implant inclination.[5] However, when the implant is part of a multiple implant–supported prosthesis, reduced stress values near the implant have been described.[1] Limitations of the presented models are the cylindrical shape of the implants and abutments, the linear elastic isotropic behavior of all materials, and the bonded contact condition at the bone-implant interface. Furthermore, clinical and experimental data on implant-supported prostheses show that cantilevers used in cases of infraocclusion that are designed to slightly flex come out of occlusion during clenching and thus result in a lower bending moment and lower stress in the bone. This was not the case for the models presented.

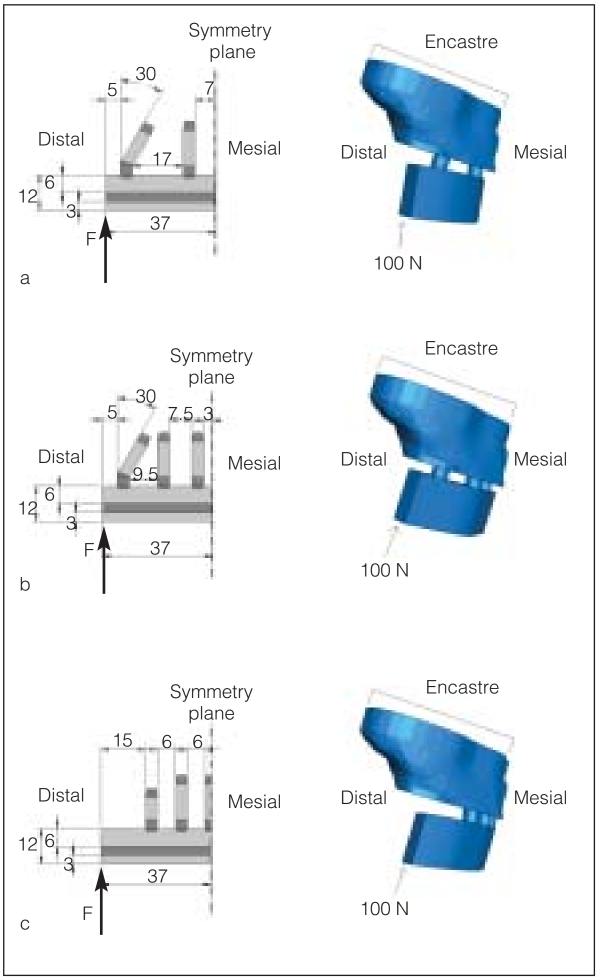

Fig 1 Schematic drawings (*left*) and 3-D models including loading and boundary conditions (*right*) of the analyzedconfigurations: (**a**) All-on-4, (**b**) All-on-6, and (**c**) Toronto-Brånemark. Arrows indicate the point of application of the load (all measurements were recorded in mm).

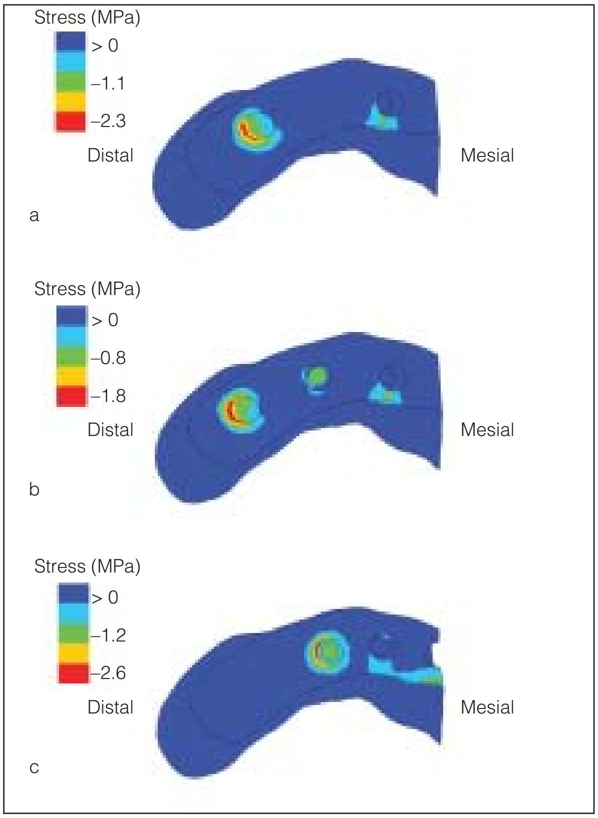

Fig 2 Compressive stress levels at the bone-implant interface predicted for the analyzed configurations: (**a**) All-on-4, (**b**) All-on-6, and (**c**) Toronto-Brånemark.

Conclusion

Current numerical predictions are a theoretical and approximate representation of the behavior of implant-supported fixed prostheses since any FE model represents only a simplification of the real structure. Within these limitations, this study suggests that tilted implant configurations may lead to a possible biomechanical advantage in reducing stress values at the bone-implant interface when compared with a non-tilted configuration.

References

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