Peri-implant Stress Analysis in Simulation Models With or Without Trabecular Bone Structure

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Most 3-dimensional (3D) finite element analyses (FEAs) simplify the cancellous bone to a block and completely ignore its trabecular structure. Thus, a 3D FEA was performed to compare the peri-implant stress distribution of a model in which the trabecular structure was accurately simulated (precise model) with that of a model with a homogenous cancellous bone component (simplified model). In contrast to the simplified model, the distribution patterns and higher stresses in the precise model may explain the overall bone resorption at the implant-bone interface in load-related implant failures. Further studies using data from the jawbone and a more detailed implant simulation are planned. *Int J Prosthodont 2006;19:40–42.*

Most 3-dimensional (3D) finite element analyses (FEAs) simplify the cancellous bone to a block, completely ignoring its trabecular structure.[1–3] These analyses have reported that the highest bone stresses occur in the cortical bone around the implant neck. Analyses of cancellous bone stress/strain[1,2] have found the highest stresses/strains concentrated near the implant apex or near the interface with the cortical bone, depending on the load direction and type of stress/strain. However, most clinical studies that have reported on failure of initially osseointegrated implants in the absence of inflammatory signs describe implant mobility sometimes associated with peri-implant radiolucency.[4,5] A biomechanical etiology was suggested for this overall breakdown pattern of the bone-implant interface.[5] Because this pattern cannot be predicted from the above-mentioned analyses, there is a need for a model that can more appropriately describe the stress state in the cancellous bone. As a first step in this quest, a 3D FEA was performed to compare the peri-implant stress distribution of a model in which the trabecular structure was accurately simulated (precise model) with that of a model with a homogenous cancellous bone component (simplified model).

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Materials and Methods

A 3D image of a bone structure from a monkey radius was reconstructed from microcomputed tomographic data (51 slices with 50-µm pitch between slices) by using a computer program for 3D bone structure analysis (TRI/3D-Bon, RATOC System Engineering). In the

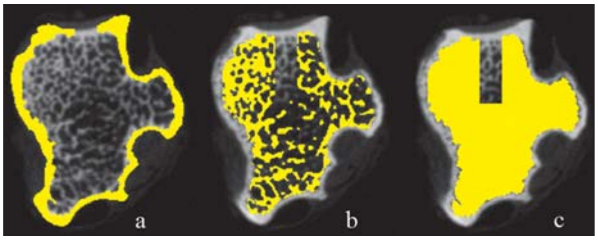

Fig 1 **(a)** Cortical bone in both models, **(b)** cancellous bone in the precise model, and **(c)** cancellous bone in the simplified model.

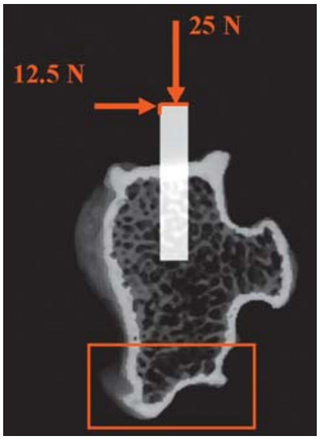

Fig 2 Constraint areas and loads.

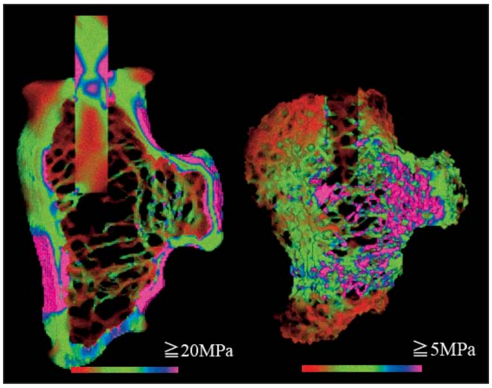

Fig 3 Von Mises stress under lateral loading in the precise model as a whole (maximum = 185 MPa) and in the cancellous bone only. (Sections differ.)

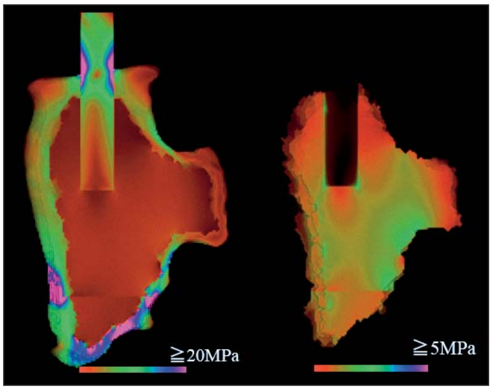

Fig 4 Von Mises stress under lateral loading in the simplified model as a whole (maximum = 76 MPa) and in the cancellous bone only. (Sections differ.)

precise model, after the images of the cortical and cancellous bone components were separated, their binarized image was edited to accommodate the binarized image of a simplified implant between the 11th and the 41st slices (Figs 1a and 1b). In the simplified model, the binarized image of the cancellous bone as a homogenous material was used (Figs 1a and 1c).

All materials in the models were considered to be isotropic, homogeneous, and linearly elastic. Young's moduli of 110, 14.4, and 0.48 GPa and Poisson's ratios of 0.35, 0.309, and 0.225 were used for the titanium implant, cortical bone, and cancellous bone, respectively.[2]

Forces of 25 N and 12.5 N were separately applied axially and laterally, respectively, to the top of the implant in each model. The lower one fifth of the model was constrained in the vertical and horizontal directions under axial and lateral loads, respectively (Fig 2). The von Mises stresses were calculated with a FEA program (TRI/3D-FEM, RATOC System Engineering).

Results

At the bone-implant interface, increases of the maximum bone stresses (approximately threefold and 2.5-fold) were found in the precise model as compared with the simplified model under axial and lateral forces, respectively. In both models, stresses under lateral loads were over 4 times higher than under axial loads. Figures 3 and 4 show the sections with highest stresses in each model as a whole and in the cancellous bone. In the cortical bone around the implant, although remarkable differences were found between the stress values of the models, stress distributions were similar, showing concentration of stresses around the implant neck. However, in the cancellous bone, differences in both stress values and distributions were found. While in the simplified model, high stress was concentrated mainly around the apical edges of the implant, in the precise model, it was distributed over wide areas at the implant-bone interface and its vicinity.

Discussion

This study simulated bone as an isotropic material. However, to create a reference for further studies of anisotropic bone models, the elastic moduli of the cancellous bone were chosen to correspond to the average values of anisotropic bone, as reported in the literature.[2] Thus, in this first step toward a more realistic bone model, focus was placed on a comparison of the stress distributions in the models, rather than on absolute stress values.

Higher cancellous bone stress at and around the implant-bone interface of the precise model can be explained by a decrease of the bone substance as compared with the simplified model. The porous bone structure also allowed a greater displacement of the implant, which triggered a greater deformation of the cortical bone and thus a higher cortical bone stress.

Conclusion

In contrast to the simplified model, the distribution patterns and higher stresses in the precise model may explain the overall distribution of bone resorption at the implant-bone interface in load-related implant failures. Further studies using data from the jawbone and a more detailed implant simulation are planned.

Acknowledgments

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Literature Abstract

Knowledge of oral cancer risk factors and diagnostic concepts among North Carolina dentists. Implication for diagnosis and referral

The purpose of this survey was to assess the knowledge level regarding oral cancer risk factors and diagnostic concepts, as well as factors associated with knowledge levels among North Carolina dentists. A 38-item pre-tested survey was mailed to a random sample of 1,115 (out of 3,303) licensed dentists practicing in North Carolina. The survey questions included 16 questions in the Risk Factor Knowledge Index and 14 questions in the Diagnostic Knowledge Index. The Cochran-Mantel Haenszel statistic was used to test for associations between the 2 knowledge indexes. The Wald statistic was used to determine which variables were to be included in the logistic regression model. Odds ratios and a 95% confidence interval were also calculated. A response rate of 52% was obtained, with 82% of respondents were male, 63% in solo practice and 80% general dentists. Knowledge levels were significantly associated with each other ($P < .0001$). Dentists who had higher risk factor and diagnostic knowledge scores were significantly ($P < .05$) more likely than less-knowledgeable respondents to: *(1)* have heard of a diagnostic aid (OR = 2.7), *(2)* graduated from dental school within the previous 20 years (OR = 1.8), *(3)* have performed biopsies (OR = 1.7), and *(4)* referred 5 or more patients with suspicious lesions per year (OR = 1.5). Results indicate that dental students and dentists need more education regarding risk factors and diagnostic concepts of oral and pharyngeal cancer.

Patton LL, Elter JR, Southerland JH, Strauss RP. *J Am Dent Assoc* 2005;136:602–609. **References:** 28. **Reprints:** Dr Lauren Patton, Department of Dental Ecology, University of North Carolina School of Dentistry, CB #7450, Chapel Hill, NC 27599-7450. Email: lauren_patton@dentistry.unc.edu—*Alvin G. Wee, OSU College of Dentistry, Columbus, OH*