Short Communication

Numerical Investigation of the Mechanical Loading of Supporting Soft Tissue for Partial Dentures

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The aim of this research was to study the impact of loading on partial dentures within the supporting soft tissue with respect to different attachment techniques. A finite element model was developed to calculate the stress and strain distribution in this tissue. The model consisted of the left half of a mandible with three remaining teeth that had suffered an atrophy in the anterior region, and a partial denture over the toothless area that was connected at the left mandibular canine using an attachment system. Resulting stress/strain distributions are presented for different load cases using a commercially available prefabricated attachment system. *Int J Prosthodont 2009;22:201–203*

Loading of the supporting soft tissue below partial dentures can have a crucial influence on both the clinical success and retention period of these devices. Cyclic loading of the mucosa and underlying bone within a physiologic range can counteract ongoing atrophy and in turn, support the clinical success. Overloading may damage the supporting structures such as the abutment tooth and its surrounding periodontal ligament (PDL), which may in extreme cases cause a loss of the abutment tooth.

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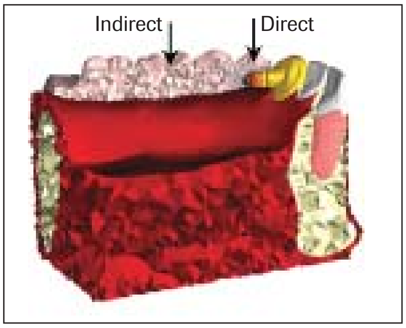
A numerical model was developed to determine stresses and strains within the relevant soft tissue and to allow the systematic investigation of various parameters (attachment technique, point of force application, etc) on the load distribution in the mucosa below the partial denture and the PDL of the abutment tooth.

Materials and Methods

Based on a commercially available three-dimensional (3-D) surface dataset (teeth with roots and gum, Digimation) a finite element (FE) model of the left half of the mandible was created. All but the left mandibular central incisor, lateral incisor, and canine were removed. The PDL (constant thickness of 0.2 mm) was modeled around the remaining teeth. In the anterior region, bone resorption due to atrophy was modeled with a mucosa thickness of 1.0 to 2.4 mm.[1] In this area, a perfect fit denture was modeled to replace the missing teeth (Fig 1). Connection between the denture and the left mandibular canine was accomplished using the computer-aided design data of a prefabricated commercial system[2] (Mini-SG PLUS, Cendres + Métaux) (Fig 2a) by following the clinical procedure. To investigate the influence of design variations in the attachment system on stresses and strains in the soft tissue, an additional model was created using a variant of the above system[3] (M-SG Star 2) (Fig 2b). The guide notch of this variant was



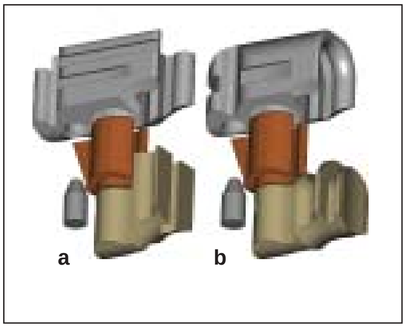
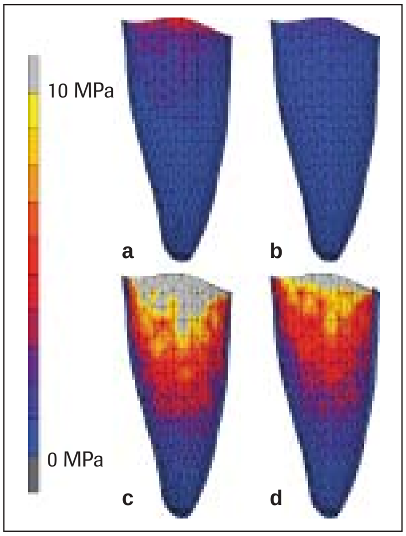


Fig 1 *(left)* Cut through of the developed FE model.

Fig 2 *(right)* Detailed view of the FE model of the **(a)** Mini-SG PLUS and **(b)** MSG STAR.

Table 1 Young's Modulus and Poisson Ratio of Materials Used in the FE Simulations

Material	Young's Modulus	Poisson ratio
Bone (not differentiated)	2.0 GPa	0.30
Teeth (not differentiated)	20.0 GPa	0.30
Mucosa	1.0 MPa	0.37
Periodontal ligament	50.0 MPa	0.30
Denture (PalaPress)	2.5 GPa	0.36
Male part and crown (Ceramicor)	136.0 GPa	0.36
Female part (Ti grade 2)	94.4 GPa	0.36
Activation screw (Ti grade 4)	100.0 GPa	0.36
Retention element (Resin)	2.9 GPa	0.33



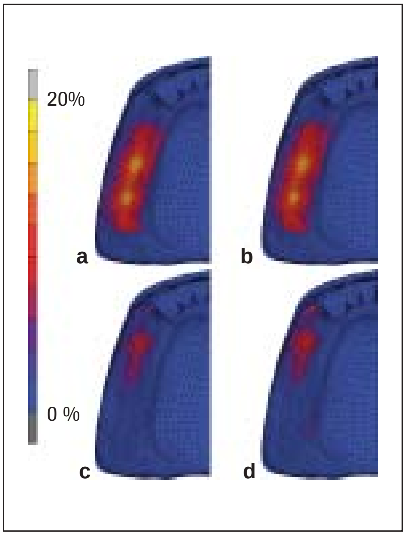


Fig 3 *(left)* Color coded stress distribution in the PDL for the indirect method with **(a)** Mini-SG PLUS and **(b)** MSG STAR, and for the direct method with **(c)** Mini-SG PLUS and **(d)** MSG STAR. The bar on the left indicates the color scheme used. Blue indicates zero stress while yellow indicates stresses of 10 MPa.

Fig 4 *(right)* Color coded strain distribution in the mucosa for the indirect method with **(a)** Mini-SG PLUS and **(b)** MSG STAR, and the direct method with **(c)** Mini-SG PLUS and **(d)** MSG STAR. Blue indicates zero strain while yellow indicates strains of 20%.

changed to optimize the load transfer between prosthesis (female part) and the abutment tooth (male part). Material parameters used in the simulations are presented in Table 1. According to the clinical situation, sliding contact (using the Coulomb Stick-Slip approach of the utilized FE system MSC.Marc/Mentat) was assumed between all parts of the attachment, between prosthesis base and mucosa, and between the remaining teeth.

To simulate different loading situations, two different load cases were defined for these two models (Fig 1): *(1)* direct: load applied on the left mandibular first premolar directly above the attachment (biting), and *(2)* indirect: load applied in the left mandibular first molar region at the end of the denture (chewing).

In both cases, vertical forces of 100 N were applied.[4,5] In all simulations the models were anchored at the posterior end of the mandible bone.

Results

The stresses in the PDL (Figs 3a to 3d) clearly showed the additional support of the denture on the mucosa. For the load case indirect, the FE system delivered stresses of 6 MPa. Stresses increased to up to 25 MPa in direct loading. The optimized design showed slightly lower stresses than the original design (indirect: 17 versus 25 MPa, direct: 4 versus 6 MPa).

Strains in the mucosa underneath the denture (Figs 4a to 4d) showed no significant differences between the two designs for each load case but differed significantly in distribution and amount between indirect (widespread, up to 20%) and direct (localized below point of load application, 12%) models.

Discussion

Stresses and strains in the soft tissue differed significantly for the two load cases, but only showed minor differences between the two designs. Thus, it can be concluded that the improved load distribution in the new design does not result in an additional loading in the soft tissue. Using the optimized design, stresses in the PDL could be reduced by 30%.

Using the presented model it is possible to determine the load distribution in the surrounding soft tissue with respect to points of force application and anchoring technique. Further studies should be performed to investigate the influence of denture fitting and anchorage location. Clinically, the assumed perfect fit of the denture is highly idealized. An insufficient fit will surely influence the stress and strain distributions in the PDL of the abutment tooth; the influence of the quality of fit between prosthesis and mucosa to loading of the soft tissue is the focus of an ongoing study. The same holds for different attachment positions in relation to the crown. Both intra- and extracoronal placement of the attachment will be analyzed using the presented method.

Acknowledgment

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Literature Abstract

Accuracy of two impression techniques with angulated implants

This study measured the accuracy of the closed- and open-tray impression techniques in vitro, using seven definitive casts, each with three implants (3i external-hex) at various angulations. The middle implant of each cast was placed perpendicular to the cast base while the angulations of the outer implants had 0 (control), 5, 10, or 15 degrees convergence toward or away from the center implant. Five open and five closed trays were made of each cast. VPS was used as the impression material and type IV dental stone was used to make the duplicate casts. A measuring stylus was used to record the coordinates on the top of the implants' hexes. Computer software was used to align the data sets, and to measure the vectors to determine the difference in degrees between the implant angles in the definitive cast and the duplicate casts. ANOVA ($P = .05$) with post-hoc tests were used for the statistical analysis. The interaction of impression technique, implant angulation, and number had no effect on the accuracy. There was a significant difference when isolating the effect of the implant's number and its angulation, or their combined effect, but with no interpretable pattern. According to this study, both closed- and open-tray techniques can produce an accurate cast when used on three implants angled no more than 15 degrees.

Conrad HJ, Pesun IJ, DeLong R, Hodges JS. *J Prosthet Dent* 2007;97:349-356. **References:** 31. **Reprints:** Dr Heather J. Conard, Division of Prosthodontics, Department of Restorative Dentistry, University of Minnesota, School of Dentistry, 9-450a Moos Tower, 515 Delaware St SE, Minneapolis, MN 55455. Fax: 612-626-1496. E-mail: conr0094@umn.edu—*Majd Al Mardini, Hamilton, Ontario, Canada*