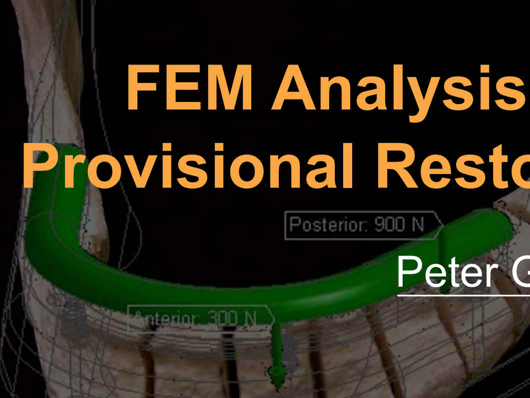

FEM Analysis on Strain Reduction in Titanium Reinforced Provisional Restorations of Immediately Loaded Implants - Part I

Peter Gehrke [1], Andre Spanel [2], Marco Degidi [3], Günter Dhom [1]

[1] Ludwigshafen/ Germany, [2] Mannheim/ Germany, [3] Bologna/ Italy

Introduction

Although initial considerations in implant dentistry have claimed that the process of osseointegration requires on average an undisturbed healing of three months in the mandible and six months in the maxilla, an increasing interest has been noticed with regard to early and immediate loading of implants to expedite the restorative outcome. In spite of the lack of a consistent terminology on the definition of micro- and macromovements of immediately loaded implants, it has been suggested that a movement of 30 µm or less has no adverse effect on integration, while a movement of 150 µm or more results in soft connective tissue apposition to the implant. A successful, accelerated protocol for implant rehabilitation depends upon several interactive factors: Beside accurate pre-surgical diagnostics and treatment planning, implant macro- and microdesign, the adequate fixation and immobility of the implant are of utmost importance to prevent the risk of micromovements related to the surrounding bone. Prosthetic concepts for immediate loading of multiple implants in the edentulous or partially edentulous mandible and maxilla reported in the literature involve bar-supported overdentures in the mandible, retrofitting of pre-existing prostheses to implants, or fabricating acrylic resin provisional restorations. A high predictability of immediate implant loading with fixed provisional restorations has been shown in several reports. All previously described techniques for reinforcement of acrylic resin provisional restorations involve either the use of a thin wire or fibers throughout the span, or a time consuming fabrication of a cast metal framework in the laboratory that covers the facial and/ or lingual surfaces of the provisional restoration. The objective of this poster was to evaluate the biomechanical effect of bite forces on strain reduction in titanium reinforced, acrylic provisional restorations. The relative deformations and stress distributions in metal-reinforced and non-metal-reinforced acrylic resin provisional restorations in the edentulous mandible were analyzed by a three-dimensional finite element model (FEM).

Material and Methods

A mandibular three-dimensional (3D) Finite Element Model (FEM) was created by sequential sectioning, scanning and imaging of a solid-foam edentulous mandible (SAWBONES, Pacific Research Laboratories, Inc., Washington, USA). The mandibular section profiles were collected at 8 mm increments. The intercondylar dimension was 8 mm. The height of the mandibular bone in the symphysis was 30 mm, and 18 mm in the left, respectively 15 mm in the right first molar region. Al traces were assembled into a 3D wireframe model by means of an ordinary 3D CAD. Four threaded cylindrical titanium implants (XiVE®, DENTSPLY Friadent, Germany) with a total length of 13 mm and a diameter of 3.8 mm were incorporated into the model. Each implant was fully inserted into the bone and temporary titanium abutments (TempBase, DENTSPLY Friadent, Germany) were mounted. Two implants were placed in each quadrant of the mandible in the center of the mandibular crest, symmetrically to the midsagittal plane, within the region of the canine and second premolar. Three-dimensional mandible models of an implant-supported, cross-arch provisional restoration on four implants with, and without metal-reinforcement was analyzed and compared. Both prosthetic superstructures were conceived as fixed, acrylic resin, symmetrical bridges with a section of 7 by 9 mm. One model was additionally reinforced by a metal framework fabricated of titanium implant abutments, intraoraly welded to a titanium bar of 2 mm in diameter. In accordance to FEM accuracy requirements of using a model over 30,000 degrees of freedom, the final FEM model was designed linearly, using 90,000 solid elements. Subsequently, a virtual masticatory load was chosen according to clinical conditions in the oral cavity. Masticatory forces in the present FEM analysis were simulated using average external loads of 300 N in the anterior region (incisors to canines), and 900 N in the posterior region (premolars to molars). FEM was carried out by Ansys 8.0 software (ANSYS Inc., Canonsburg, USA) comparing van-der-Mises and maximum stress levels obtained from the calculation.

Results

In comparison to mere acrylic superstructures, a significant reduction of deformation and strain within metal-reinforced acrylic resin provisional restorations could be detected in FEM analysis. The titanium framework reinforced provisional restorations investigated in the current study exhibited a reduction of maximum von-Mises strain values of 300 to 500 % at external loads of 300 N in the anterior, and 900 N in the posterior region. The reduction of strain and deformation in titanium-framework reinforced acrylic resin provisional restorations are given in table 1. With regards to the relationship between stress distribution and implant location along the mandibular arch, maximum stress values were located at the level of the most distal implants.

Summary

An optimal biomechanical stress distribution, both at the level of the provisional superstructure and at the level of the implant infrastructure, is the primary aim of the rigid temporization of multiple immediately loaded implants. Stress distribution in mandibular, fixed, implant-supported restorations is greatly influenced by many variables, including prosthetic design and material, occlusal scheme, bone structure, shape and activity of masticatory muscles, implant location, as well as design and material of implants and implant abutments. Although the present FEM analysis revealed a high decrease of deformation and maximum strain in titanium framework reinforced acrylic resin restorations, caution must be given when extrapolating FEM data to clinical situations, since multiple in vivo variables are excluded from a controlled computer analysis. The tendency of strain reduction was, however, obvious. Research in fixed implant prosthodontics on osseointegrated implants has advised to section the superstructure in multiple free-standing bridges, rather than designing one cross-arch rigid restoration. A rigid restorative system could not follow the flexure of the mandibular bone, generating high stress concentrations and increasing the rate of screw loosening and fractures. In the treatment concept of immediate implant loading, however, an adequate fixation and immobility of implants in the early stages of bone healing is a prerequisite to prevent micromovements in relation to the surrounding bone. After successful osseointegration of immediately loaded implants, splitting the final superstructure into multiple free-standing bridges should be taken into account, thereby allowing an adequate stress distribution and a better prosthetic fit as a result of fewer connected abutments.

Literature

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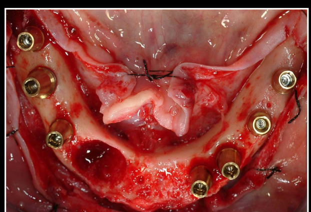
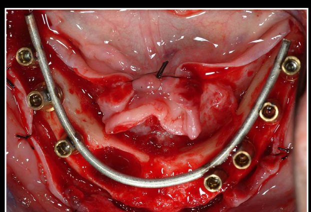
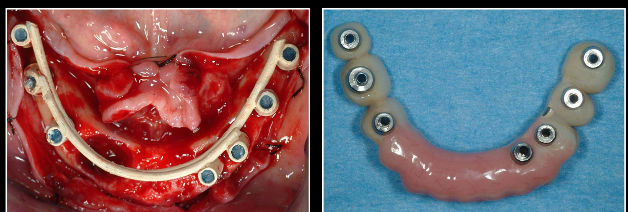

Occlusal view of mandible after extraction and implant placement

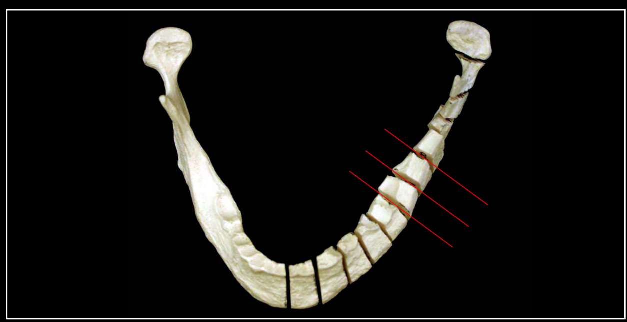

Situation after intra-oral welding of titanium bar to temporary titanium implant abutments

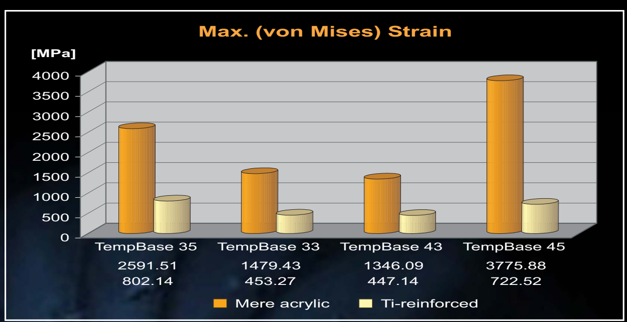

Try-in of unit after grit-blasting and opaque appliance - Basal view of provisional titanium bar re-inforced acrylic rerstoration


Occlusal and labial view of screw-retained restoration

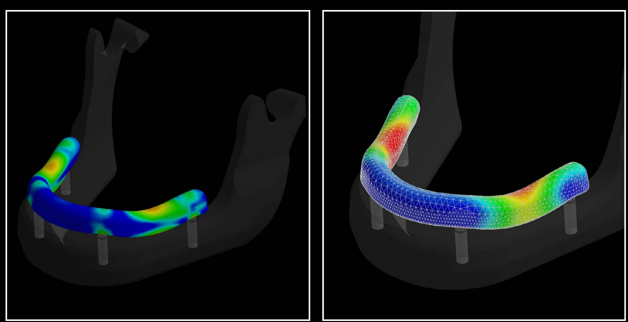

Sequential sectioning at 8 mm increments of sawbones

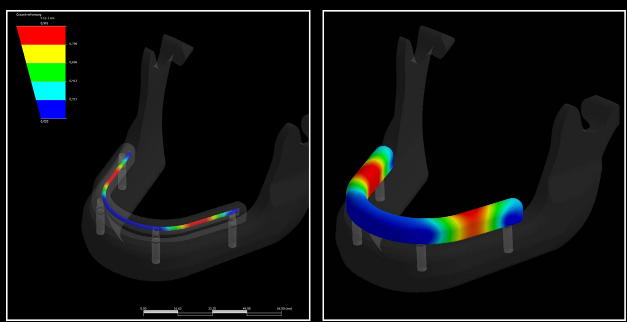
Sequential sectioning at 8 mm increments of sawbones


Sawbones for scanning



Tab. 1: Reduction of strain and deformation in titanium-framework reinforced acrylic resin provisional restorations in %. Non-metal reinforced/ Titanium-framework reinforced


Case A: Acrylic resin provisional


Case B: Titanium-bar reinforced acrylic provisional

Dr. Peter Gehrke
Bismarckstraße 27
D - 67059 Ludwigshafen
E-mail: dr-gehrke@dr-dhom.de

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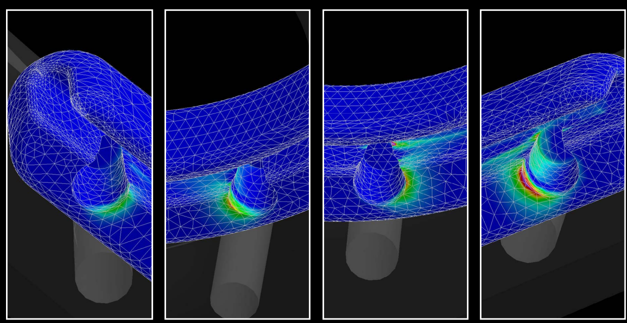
Case B: Occlusal view of XiVE® TempBases with titanium-bar reinforced acrylic provisional