Three-Dimensional Contact Shape Optimization and Free-Form Fabrication for Removable Partial Dentures: A New Paradigm for Prosthetic CAD/CAM

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Abstract

This study aims to develop a fully automatic procedure for shape optimization of a removable partial denture (RPD) base, to minimize the contact pressure on the mucosa and avoid associated clinical complications. The optimized denture was prototyped by 3D printers and evaluated with *in vitro test*. A 3D heterogeneous finite element (FE) model was reconstructed from a patient's cone beam computerized tomography (CBCT) images with virtual denture insertion. The oral mucosa was modeled as a hyperelastic material derived from *in vivo* clinical data. A contact optimization algorithm was developed based on the bi-directional evolutionary structural optimization (BESO) technique, where the relative deviation of contact pressure on the denture-mucosa interface was the determinant. After prototype fabrication by 3D printing, both initial and optimized dentures were tested with fitting silicone and pressure sensitive film. Through shape optimization, the maximum contact pressure was reduced by nearly 70%, and the uniformity was improved by 63%. The adaptive modification rate technique provided the best combination of efficiency and robustness. Both *in vitro* tests of prototyped samples well demonstrated the effectiveness of this algorithm in re-distributing the contact pressure. Despite the commonality of clinical complications induced by dentures, there has, as yet, been no quantitative method available for denture base adaptation. Our procedure provides a novel CAD-CAM method for denture adjustment. The integration of digitalized modeling, optimization, and free-form fabrication enables more efficient clinical adaptation. The customized optimal denture design is expected to minimize pain/discomfort and potentially reduce long-term residual ridge resorption.