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Original article

A digital image correlation analysis on the influence of crown material in implant-supported prostheses on bone strain distribution

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Abstract

Purpose: A digital image correlation (DIC) method for full-field surface strain measurement was used to analyze the effect of two veneering materials for implant supported crowns on the strain distribution within the surrounding bone.
Methods: An epoxy resin model of a bone block was made by housing acrylic resin replicas of a mandibular first premolar and second molar together with threaded implants replacing the second premolar and first molar. Porcelain-veneered (G1 and G3) and resin-veneered (G2 and G4) screw-retained splinted crowns were fabricated and loaded with (G1 and G2) and without (G3 and G4) the presence of the second molar replica. A 2-dimensional DIC measuring system was used to record surface deformation of the bone block model at a frequency of 1.0 Hz during application of a 250-N load.
Results: Maximum compressive strains (ε_{XX}, %) were found for the following regions: between molars, G1 (−0.21), G2 (−0.18), G3 (−0.26), and G4 (−0.25); between implants, G1 (−0.19), G2 (−0.13), G3 (−0.19), and G4 (−0.14). The magnitude of strains in the simulated bone block with the resin-veneered crowns was lower than that with porcelain-veneered crowns, irrespective of the presence or absence of the second molar.
Conclusions: The softer resin veneer helped to spread the load more evenly amongst the supporting teeth and implants, thus reducing the strains in the simulant bone block. Conversely, using the harder porcelain veneer resulted in the load being concentrated within one or two teeth or implants, thus leading to higher strain values in the bone block.

Keywords: Image correlation; Dental implants; Load transfer; Dental materials; Fixed partial denture

1. Introduction

The successful osseointegration and long-term survival of oral implants depend on several biomechanical factors. The selection of appropriate implant position, prosthesis design, biocompatibility and mechanical and physical properties of the materials is critical for the longevity, stability and proper function of the implant prosthesis [1–6]. Since no micromovement is provided by a fully osseointegrated dental implant, all stresses and impact forces applied to the implant-supported prosthesis are directly transmitted to the surrounding bone through the implant–bone interface. Consequently, overstressing the implants may cause bone microfractures [7] and lead to the occurrence of an increased rate of marginal bone loss [8]. Since the nature and magnitude of loads necessary to cause implant loosening is unknown, it is recommended that occlusal forces be kept to a minimum [6].

The design and material of dental superstructures influence the loading of dental implants and, hence, the deformation of the bone [9]. Ceramic materials are commonly used for veneering implant-supported prostheses as they provide great improvements to the esthetics of implant restorations [10].

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However, porcelain is not a shock-absorbing material, and forces developed at the occlusal surface will be directly transmitted to the prosthesis, the implant, or the bone interface, unless they are interrupted in some way [6,11]. One of the concepts developed to distribute the stresses more evenly around dental implants is to dampen the occlusal forces with the use of shock-absorbing materials, such as acrylic and microfilled resins [5,7,12]. Studies comparing the shock-absorbing behavior of different veneering materials found that, when harder and stiffer materials were used, a higher impact force was transmitted to the fixture and with a shorter rise time. Conversely, the more resilient the material, the longer was the rise time and the smaller was the stress [12,13].

Finite element (FE) modeling has proven to be a useful tool for analyzing the mechanical behavior of dental implants with different prosthetic designs. Still, FE studies would benefit from the use of an accurate experimental tool to validate their results. However, experimental studies involving direct strain measurement of dental restorations to date have only provided limited local measurements [14–16], which are not sufficient to fully demonstrate the mechanical behavior of the restorations or to validate the 2- or even 3-dmensional strain distributions predicted by FE modeling [17,18]. Digital image correlation (DIC) is an optical method initially developed to measure the flow of fluid and later the surface strain distribution in materials under mechanical testing. The method works by taking a series of images of a specimen during loading and then tracking the displacement of individual speckles on the surface of the specimen. Subsequent analysis with specialist software derives the strains on the surface from the displacement fields, providing a full-field strain measurement [19].

Using the DIC method, this *in vitro* study measured strains generated by implants of 2 different veneering materials (ceramic and resin) in simulated supporting bone under 2 clinical situations (presence or absence of a distal proximal contact to the restoration). The load transfer characteristics of the different prosthetic solutions were analyzed and compared. The null hypothesis was that there would be no differences in the strains generated in the supporting bone between the cases with different veneering materials and between those with different proximal contact conditions.

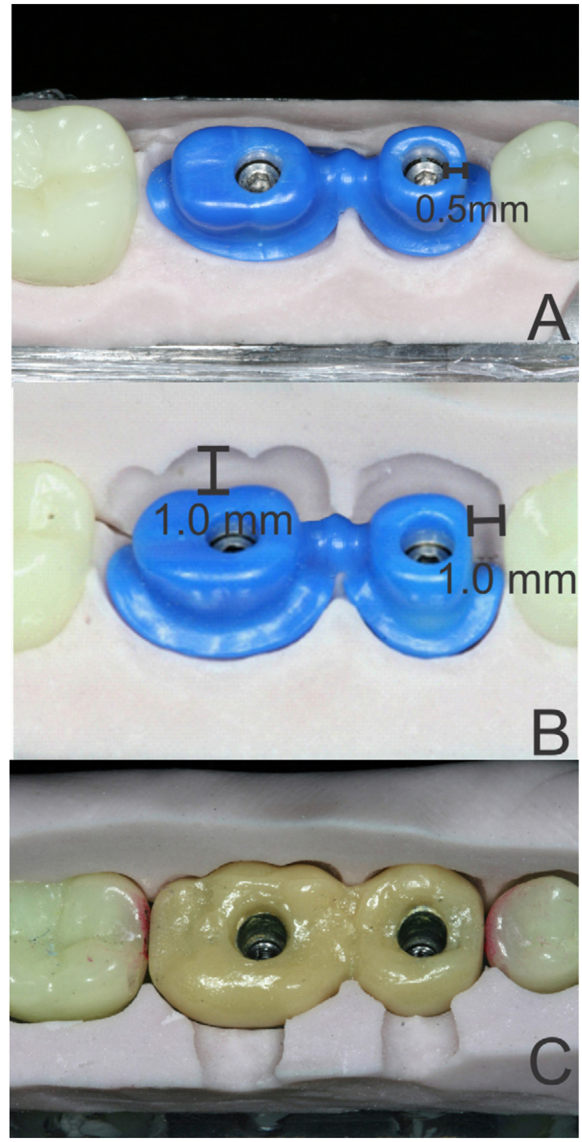

Fig. 1. Fabrication of the frameworks used in the study. (A) Waxing of the frameworks with thickness of the metal framework of at least 0.5 mm; (B) silicone wall to standardize the esthetic veneers with 1 mm thickness all-around the metal framework; and (C) connector design and finished morphology of the fixed partial dentures with standardized veneer thicknesses.

2. Materials and methods

A polymethylmethacrylate model (Plexiglas®, Altuglas International, Philadelphia, USA) with dimensions of 68 mm × 25 mm × 15 mm (length, height and depth, respectively) was fabricated to represent a bone block. The model was made with socket spaces for teeth and implants to simulate part of the arch of a partially edentulous patient. Two Ø3.75 mm × 11 mm threaded implants (Titamax GT, Neodent, Curitiba, PR, Brazil) were embedded into the bone block model in the second premolar and first molar positions with cyanoacrylate adhesive (Super Bonder; Loctite Brasil Ltd., Itapevi, SP, Brazil) applied on their surface to represent complete integration [20]. The model was completed with the placement of acrylic replicas of a first premolar and a second molar (Odontofix, Ribeirão Preto, SP, Brazil) using the same method as that for the implants.

Accepted clinical and laboratory procedures were used to fabricate 2 sets of implant-supported 2-unit splinted fixed partial denture (FPD) (Fig. 1) by an experienced dental technician with thickness of the metal framework of at least 0.5 mm and with a 1 mm cutback to allow for the addition of the veneering materials (Fig. 1A and B). Framework design was identical for both veneering materials. However, retentive beads were added on the surface of the resin veneered crowns to allow better retention of the esthetic veneer. A silicone wall was made to standardize the esthetic veneering of each crown with a 1 mm thickness all-around the metal framework (Fig. 1B and C). The spruing, investment, burnout, and casting techniques were standardized and frameworks were cast in Ni–Cr–Ti alloy