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An attempt to create a standardized (reference) model for experimental investigations on implant's sample

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ABSTRACT

The aim of this study was to determine, evaluate and measure strain of vertically loaded implant using the digital image correlation method. The Straumann® dental implant system with the SLActive® surface was used in this study. Implant was immersed in poly-methyl-methacrylate during his hardening process. After preparation procedure a sample of implant and poly-methyl-methacrylate was obtained. This sample was loaded using external load from 0 to 400 N. Maximum strain in the 4 mm surface layer was 0.30% whereas maximum strain in the 6 mm surface layer (opposite side) was 0.20%, detected in the marginal and apical part of implant-poly-methyl-methacrylate sample. Minimum strain measured by Aramis software was 0.01%, detected in the 4 mm surface layer. According to results obtained by Aramis data processing, the 4 mm surface layer indicated higher overall strain in apical direction with the strains of 0.18–0.21%. Increasing the load did not affect the value of maximum strain however, higher load influenced the overall strain concentration increased especially in marginal and apical part of the sample surfaces that surrounded lateral sides of implant body.

1. Introduction

Several previous studies have shown that the Digital Image Correlation method (DIC) can be used for investigations in the field of dental biomechanics [1–3]. In current dentistry, the DIC can be utilized for the stress and strain measuring of different biomaterials, as a power tool for improving biomechanical properties of dental biomaterials [4]. The DIC is a fully automated highly precise strain/displacement analysis system, capable to provide accurate full field analysis of the dynamics of the strains generated on the surface of a model [5]. Based on analysis of colored images obtained during occlusal loading, the DIC is usually employed when performing *in vitro* experimental analysis [6]. Investigations performed in this way exclude invasive clinical approaches that could compromise patient's condition. By using the DIC, the surfaces strains generated around dental implants can be detected and evaluated using simple *in vitro* set up conditions [1]. Considering the fact that there is no standard design of samples of different biomaterials used for the DIC *in vitro* experiments [7], the researchers should try to test different forms of models in order to create the best one for biomechanical investigations. For example, the biomechanical properties

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of different implants can also be investigated using a number of various cubic samples exposed to the vertical loading conditions and photographed by the DIC cameras. Vertically loaded dental implants induced strains in the abutment and implant body as well as in the medium where implant is positioned [2]. The ideal design of a sample used for the DIC investigations in implant biomechanics has not been represented, yet. Thus, every single attempt to perform an experiment using atypical samples can better explain the implant behavior under vertical loading conditions.

Following experiment was performed in order to represent an example for creating good, representative model and a method for analyzing implant behavior in dental biomechanics. The aim of this *in vitro* study was to determine, evaluate and measure strain of vertically loaded implant using the digital image correlation method.

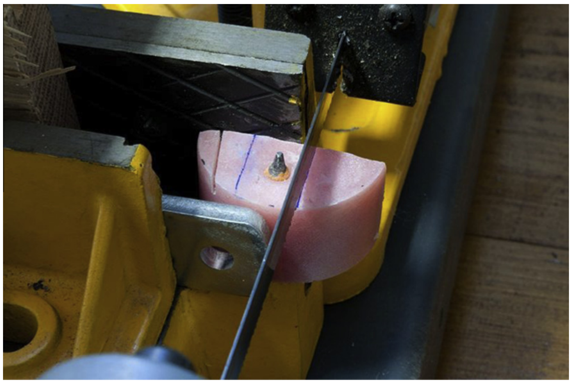

Fig. 1. Preparation of the implant–PMMA sample with two different surfaces layer.

Fig. 2. An implant-PMMA sample prepared for testing in the Tinius Olsen equipment.

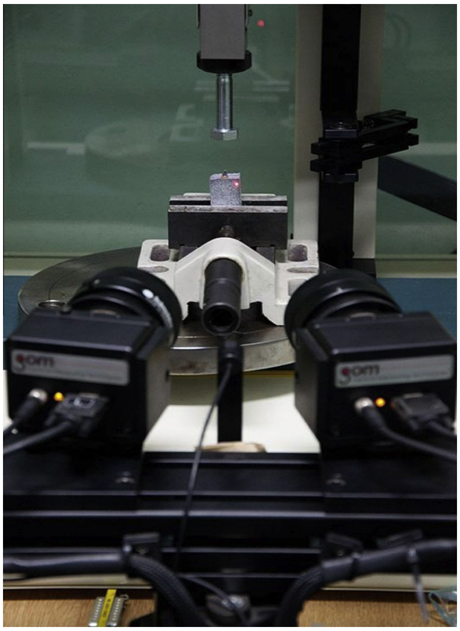

Fig. 3. Vertical load of the Tinius Olsen testing machine directed on the occlusal abutment surface.

2. Material and method

Prior to experiment was performed the preparation of sample (specimen) design had to be done. The Straumann® cylindrical dental implant system (4 × 10 mm) with the SLActive® surface was used in this study. It was placed in cylinder shaped poly-methyl-methacrylate (PMMA), with diameter of 44 mm, and height of 27.5 mm. Implant was immersed in PMMA during his hardening process, on the opposite side of the base of the cylinder. Sample was then reduced to approximately rectangular shape with dimensions 22.36 mm × 14.1 mm × 27.5 mm (l × w × h). This was done on table saw Quantum S91G, manufacturer Optimum (Germany). During this preparation, there was concern to place the proximal surfaces of abutment 4 mm from one side of the sample edge, and 6 mm from another, so the abutment to edge distance parameter could be related with deformations that occur during loading (Fig. 1). In the further context will be used the terms “4 mm surface layer” and “6 mm surface layer”.

For strain analysis, digital image correlation system was used manufacturer GOM [8]. The optical deformation measurement system consists of special set of stereo cameras and lenses, and Aramis software (6.2.0, Braunschweig, Germany). The system also includes a stand, providing the stability of the sensors, a power control and image recording unit, as well as the data processing system [9]. The surfaces of the sample to be examined were sprayed with a dense layer of white paint, and afterwards with fine layer of black paint to produce irregular-shaped speckles for tracking of the points and calculating the strains generated on the surface of the model (Fig. 2).

Prior to the starting three-dimensional (3D) strain measuring, two digital cameras were positioned manually and adjusted in accordance with the measuring volume of the calibration object, according to the manufacturer instructions. Sample was then placed in H10K-S UTM Testing machine with 5 kN load cell, by manufacturer Tinius Olsen. During loading process, sample had to be fixed to the bottom section of Testing Machine. This was done using machine clamp BMS 85, by manufacturer