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# Holographic Stress Analysis in a Distal Extension Removable Partial Denture

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**Abstract** - *This study examines tress analysis of the mandible when submitted to mastication simulated forces over a distal extension removable partial denture. Two situations were analyzed upon loading: small pins had been placed over the bone crest and under the denture; low amplitude loads were applied over tooth 34-37. Holographic interferometry techniques were used to assess mandible's deformation. Results indicate that a correct adaptation of the denture base is critical to reduce stresses in the mandible. High stress levels in the second molar region suggest its non-inclusion in these prosthetic rehabilitations.*

KEY WORDS: dental stress analysis, removable partial denture, dental prosthesis design, biomechanics, mandible

## INTRODUCTION

The rehabilitation of a partial edentulous arch, Kennedy type I and II, can be done with a dental prostheses supported by dental implants, or with removable partial dentures (RPD). The steps needed to restore the natural dentition of the patient should consider a number of factors regarding his quality of life, such as aesthetics and functional activity, without interfering with the health of the oral tissues. By using dental materials with different mechanical properties, comparing to the living tissues of the oral cavity, we are promoting physiological responses in search of a new equilibrium[1]

The principles of mandible biomechanics should be considered in order to establish a correct diagnosis and treatment plan[2-6]. During mastication, the mandible is submitted to different stresses that are important in the stability, support and retention of a removable denture[2]. A denture stability is related to adequate support from the teeth and residual ridge[7]. If the support to withstand vertical forces, achieved by the bone, mucosa and teeth, leads to excessive stress, it can trigger bone resorption mechanisms on the residual ridge[7]. The selection and design of the clasps is very important for the retention of the RPD, and also to minimize stress over abutment teeth[8,9] and denture base, but the main factor to reduce this stress is the properly fit of the base[7,10-13]. The tissue surface of the base should cover the distal extensions at the most relaxed state to minimize movement of the RPD base, although some movement always occurs due to movable living tissues[7].

The distal extension RPD is one of the most complex prosthetic rehabilitation. The longitudinal study of Vanzeveren[14], about treatment with removable partial dentures, states that most of the failures occur in RPD with free-end saddles, especially in the mandible.

The main objective of this research is to make a stress analysis of the distal extension RPD and mandible bone, when submitted to mastication simulated forces. Holographic interferometry techniques were used to assess the mandible deformation in different loading conditions.

## MATERIAL AND METHODS

An in vitro edentulous mandible of a Caucasian male was used with six anterior (acrylic) teeth artificially inserted to simulate a Kennedy Class I situation. A removable partial denture was designed and constructed in Cr-Co, with retentive clasps in the canines. The metal infra-structure of the RPD was conceived with tooth size hollows, supported by metallic pins connected to the acrylic, in order to permit the replacement of different teeth for the study. The stabilization of the mandible was achieved by an acrylic base. (Figure 1)

The stress analysis for different support conditions was performed with the Holographic Interferometry techniques available in the Laboratory of Optics and Experimental Mechanics in the Engineering School of Porto University. Holographic Interferometry is an experimental method which allows the assessment of the displacement field on the surface of diffuse objects by correlation of pairs of light wave fronts emitted in different load conditions[15,16]. With these techniques non contact global measurements could be carried out with high resolution, the same order of magnitude of the laser wavelength. In the present work a solid state laser Verdi 2W, was used to illuminate the object and double-exposure correlation was performed to obtain the interference pattern between two reconstructed images of the same object, before and after a specific load has been applied[15,16]. The set-up was prepared to allow measurements of out-of-plane displacement. This way the results shown correspond to displacements perpendicular to the image plane[15,16].

The Holographic Interferometry technique used was the ESPI (Electronic Speckle Pattern Interferometry). In this

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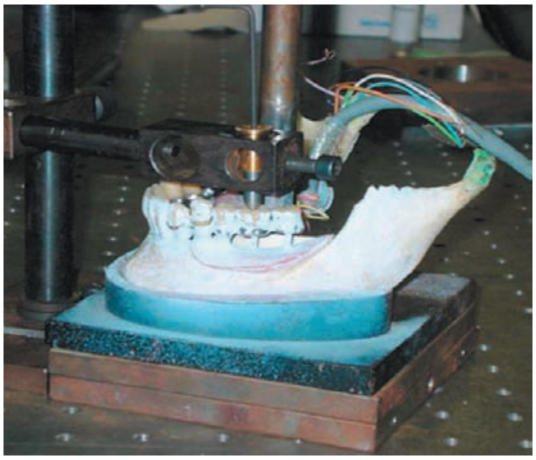

**Figure 1.** *Mandible and removable partial denture used in the study.*

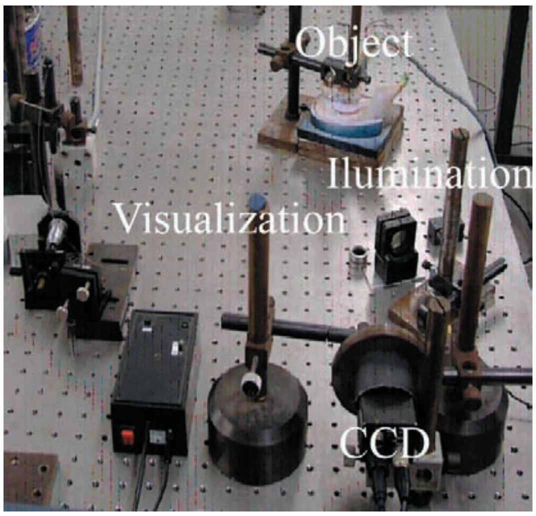


**Figure 2.** *Holographic set-up used in the research and detail of the inspection region.*

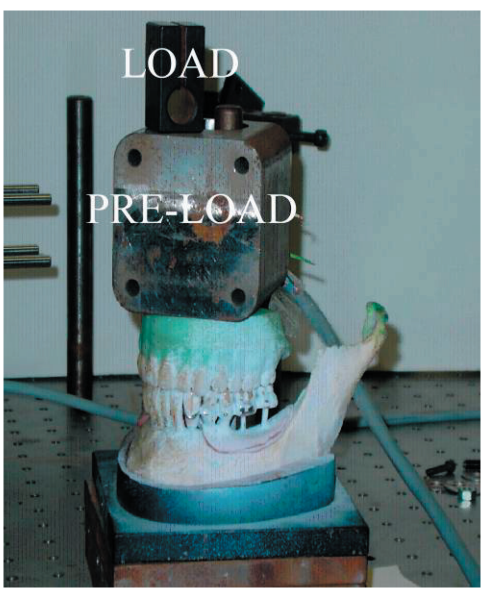


**Figure 3.** *Loading set-up*

technique the recording media is the target of a CCD video camera (Figure 2), which replaces the conventional photographic emulsions used in classical holography[15,16]. A phase shift device and an image processing package were also available for phase calculation[15,16].

This technique had been used in Dentistry by several authors along the last two decades, to study mandible biomechanics, stresses produced by RPD with different clasp designs, prosthetic devices and restorative materials[5,17-26]. The test rig was designed to be simple and mechanically stable. The loads were applied by dead weight using metallic masses with 19,62N and 0,981N. To achieve a good mechanical stability of the set-up, the mandible was subjected to a constant pre-load, over which low amplitude loads where applied to perform the tests (Figure 3).

Using the previously described set-up two types of tests have been performed for two different purposes:

1. To study the influence of the RPD base over the mandible support area in the stress distribution on the mandible;
2. To evaluate how the position of the load (different teeth) alters the behavior of the mandible in the region under the denture.

To perform the first test, two small metallic pieces where inserted in different locations between the partial denture base and the in vitro mandible bone (Figure 4). This way, different support conditions were simulated and the corresponding stress distribution was assessed in various locations in the surface of the mandible bone. As so, an overstress due to a small contact was simulated.

The second test was performed with a different loading system. In this case a metallic pin was used to apply a specific load over each teeth of the denture. The 0,981N mass was applied on top of the pin to generate a force on top of each teeth (Figure 1). The bone displacement was then measured.

## RESULTS

### 1st Test

In the first measurement a punctual contact between the mandible and denture was simulated by placing a small metallic part under the denture and aligned with the tooth 36 and 37. The results shown on figures 5 and 6 correspond to the out-of-plane displacements obtained. As can be seen in the figures the vertical load applied in a region of the bone with a small inclination generates displacements which move the bone away from the observer. This effect is detected by the dark regions near the metallic pin. In both situations, it appears a concentrated deflection patterns in the area where the removable partial denture base is contacting the metallic pins.

### 2nd Test

In the second tests the load was applied directly on the crown of each one of the four teeth placed on the denture left side. The results obtained with teeth 34, 35, 36 and 37 can be seen in figures 7-10. In Figure 7 and 8 a deflection pattern near the bottom of the loaded tooth is evident. The RPD seems to move in a horizontal axis, approaching to the

**Figure 4.** *Metallic pieces inserted in the area of tooth 18 and 19, to simulate a specific stress concentration area due to an "incorrect" partial denture base.*

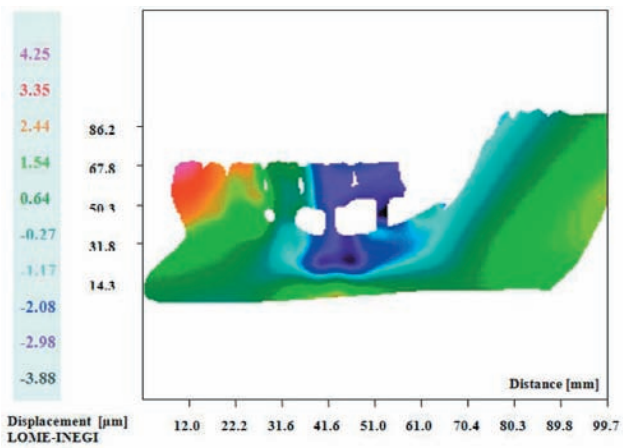


**Figure 5.** *Removable partial denture with a metallic pin in tooth 36 area.*

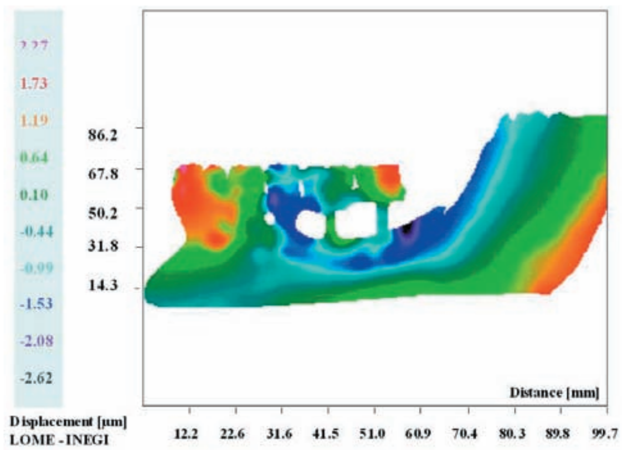


**Figure 6.** *Removable partial denture with a metallic pin in tooth 37 area.*

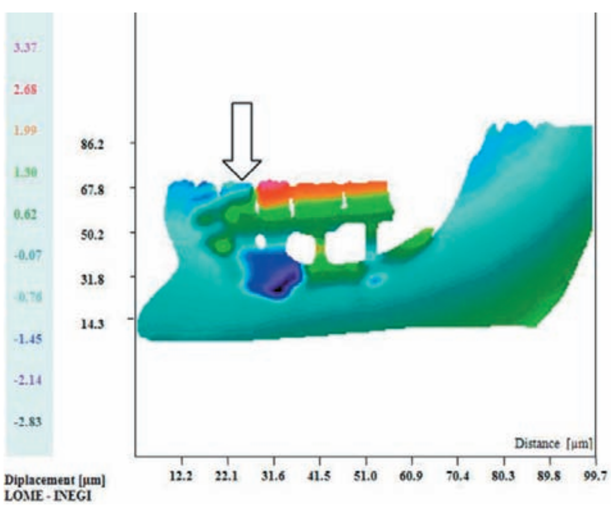


**Figure 7.** *Load applied over tooth 34.*

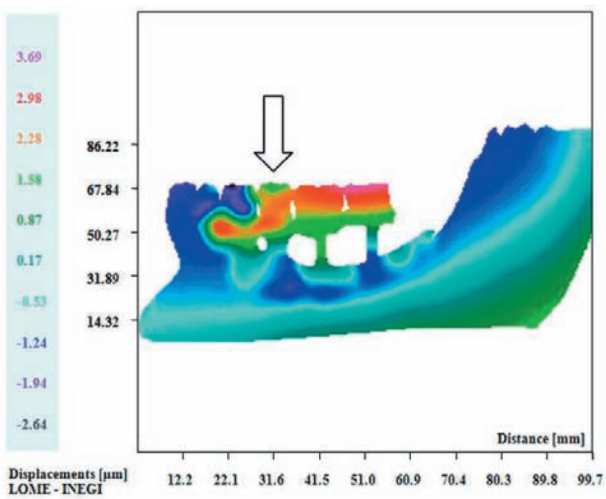


**Figure 8.** *Load applied over tooth 35.*

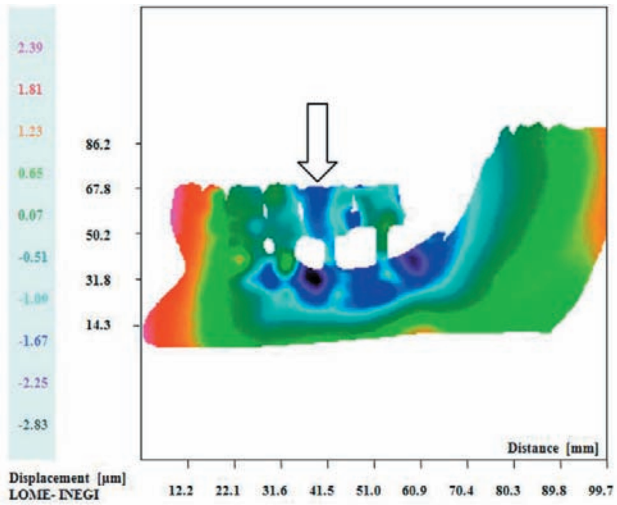


**Figure 9.** *Load applied over tooth 36.*

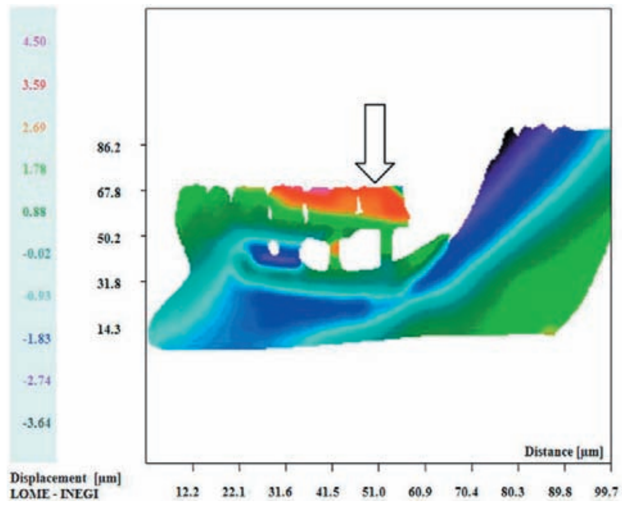


**Figure 10.** *Load applied over tooth 37.*

observer, with the retention clasp rotating as a rigid body. In Figure 9 it can be observed instead a stronger deflection pattern in a vertical axis, rather than a horizontal. In Figure 10 it's perfectly observed that the removable partial denture acts as a rigid body rotating along its fulcrum. The deflection patterns observed extends over the entire mandible body, instead of specific areas as in Figures 7-9. Of all tests executed, this one has performed the greatest stress loads in the mandible support area.

## DISCUSSION

The stress patterns related to the displacements observed in our research seem to have the capacity to affect the physiological process of bone remodelation, and may produce a change in the mandible shape due to a continuous applying of a small amount of load. This process, known as mechanical histeris has been described by Ferre, in 1985[17].

First test's results of the study showed the importance of the RPD base in minimizing stress over the mandible body. The contact surface of the RPD base should be properly fitted in order to promote a better stress distribution and, as so, minimize bone resorption in high stress areas. The results obtained in the second test, with loads over teeth 34 and 35 showed the importance of the retention clasp in the stability and retention of the removable partial denture, as it tries to rotate along a horizontal axis. Instead, the stress verified in the area of tooth 36 suggests mostly a vertical movement, due to the deflections on the mandible body. In another way, the load applied over tooth 37 shows a very high load transmission, with high deformation levels along the mandible's body. This might suggests that the second molar may not be needed in this type of rehabilitation.

Studies about the importance of different retainers[8-11] shows their importance in the retention and stability of the RPD, and as a consequence, in minimizing stress distribution over the abutment teeth and the supporting base, but they also conclude that a properly fitted base is the most important factor in this matter. Our research corroborates these studies and also suggests the elimination of the second molar as a factor to minimize high stress in the mandible.

## CONCLUSIONS

We can conclude that the multidisciplinary approach used seems to adapt perfectly to this type of study. The movement exerted by the RPD is related to the movement of the mandible but is independent, as it functions as a rigid body with the fulcrum situated in the retention clasps. The stresses verified in the distal free-saddles are related to the correct adaptation of the denture base and also to the number of teeth present, and the high stresses verified in the second molar region may raise the question of the insertion of this tooth in this kind of prosthetic rehabilitations.

## MANUFACTURERS DETAILS

Verdi 2W (Coherent Inc., Santa Clara CA, U.S.A.).

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