Digital flow and mechanical devices innovating photoelastic methodology: technique description

Fluxo digital e dispositivos mecânicos inovando a metodologia fotoelástica: descrição de técnica

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Resumo

The technique describes the development and production of photoelastic models used in dentistry, which simulate structures subject to the action of forces. It proposes to standardize, with more accuracy, the assessment of stresses generated by the stomatognathic system when dental arches are rehabilitated using implants and prosthetic devices. The technique details the insertion of digital flow and new mechanical devices, such as vacuum mixers and bubble-eliminating pan, in addition to describing the necessary precautions to avoid frequent problems in its creation, obtaining more reliable results when using the photoelastic method.

Descritores: Dental stress analysis; Dental prosthesis, Implant-supported; Polymers; Dental Materials; CAD-CAM

Abstract

A técnica descreve o desenvolvimento e a produção de modelos fotoelásticos empregados em odontologia, que simulam estruturas sujeitas à ação de forças. Propõe padronizar, com mais acertividade, a avaliação das tensões geradas pelo sistema estomatognático quando os arcos dentários são reabilitados utilizando implantes e dispositivos protéticos. A técnica detalha a inserção do fluxo digital e novos dispositivos mecânicos, como misturadores a vácuo e panela eliminadora de bolha, além de descrever os cuidados necessários para evitar problemas frequentes na sua criação, obtendo resultados mais confiáveis na utilização do método fotoelástico.

Descriptors: Análise do estresse dentário; Prótese dentária fixada por implante; Polímeros; Materiais dentários; CAD-CAM

Introduction

The photoelastic method is widely used in stress analysis in various fields, such as dentistry, engineering, and physics. However, this methodology presents some difficulties, mainly related to its transparency and bubble formation. Photoelastic analysis in dentistry is essential for understanding the masticatory forces on the supporting bone structures. It allows quantitative and qualitative observation of the distribution of loads in relation to the different components involved[1-3]. The photoelastic model is a simplification of the original models and allows stresses to be visualized in the form of colored fringes the main advantage of the method[2,4-8]. However, resin selection and the production process should generate models as close as possible to reality[8]. Peri-implant bone stability may vary, and it is possible to evaluate the stress pattern using this method[5]. The development of digital tools has been creating alternatives for more predictable and accurate treatments and planning, as well as enabling more sophisticated research with more accurate methodologies[9-14].

The scientific validation of the photoelastic method with photoelastic models that reproduce the anatomical structures of the region to be treated, can assist in diagnosis, planning and execution of treatments[1-8]. This study aims to describe the steps to obtain a standardized photoelastic model, from virtual models, with the least possible distortion.

Methods

The construction of the photoelastic model requires a careful technique. There are several steps to its construction, to which others have been added, following the development of technological advances. The sequence is described below.

1 – Create a reference model and objects that will be used for the development of the technique, using 3D design software (CAD, Fusion 360; Autodesk), followed by printing them on an FDM 3D printer (GTMax3D Core A3; GTMax3D.) (Fig.1).

2 – Install the implant (ArcsysCM; FGM) in the reference model according to the virtual planning and using the devices created for this purpose (Fig.2).

3 – Promote impression taking of the reference model with blue silicone (Redelease Blue; Redelease), wait for the impression material to fully polymerize according to the manufacturer's recommendations, then remove the reference model from the tray and install the implant (ArcsysCM; FGM) in the impression tray (Fig.3).

4 – Pre-mix the photoelastic resin and its hardener (Rigid Epoxy Resin; POLIPOX) in the proportion according to the manufacturer's recommendations in a gentle manner, always avoiding excessive bubble formation.

5 – Place the resin under a vacuum of 20Hg (-), mixing at a speed between 60 and 80RPM for 5 minutes, to promote its homogenization and to eliminate eventual bubbles (Fig.4).

Figure 1. Reference model and objects designed in 3D design software (CAD) and manufactured in a 3D printer (CAM)

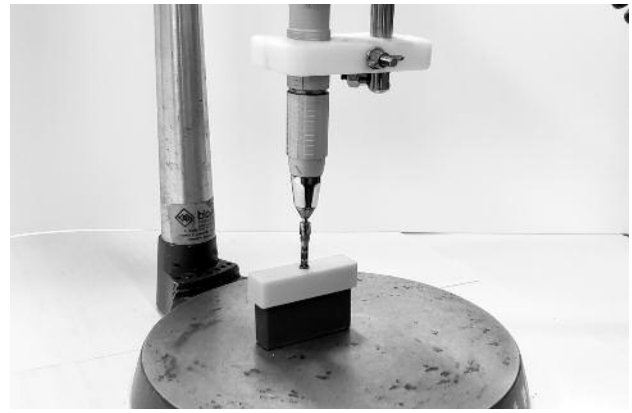

Figure 2. Implant installation in the reference model, as per the virtual planning, with the individualized surgical guide

Figure 3. Blue silicone impression of the reference model with the implant installed

Figure 4. Manipulation of the photoelastic resin in a vacuum mixer

6 - Pour the mixture into the mould in small amounts (Fig. 5) and then place the mould in the bubble eliminator pan under 20Bar (+) pressure to eliminate any bubbles entirely, waiting for the resin to polymerize completely for 72 hours, then remove the photoelastic model from the mould (Fig. 6).

7 – Finish and polish the photoelastic model using sandpaper (600-2500), White of Spain (K-Dent; Quimidrol) and cotton brush (OGP; Val) until glassy surfaces are achieved (Fig 7).

8 – Analyze the photoelastic model created observing that it should not present residual stresses resulting from the fabrication process (Fig 8).

Discussion

The production process of the photoelastic model should generate pieces that come as close as possible to a real situation.

The colored fringes observed in studies using the photoelastic method show that it is possible to evaluate the stress behavior in photoelastic models according to the stress pattern applied[1-8].

Several techniques have been developed to achieve the ideal photoelastic model, according to the methodology of each study and the resources available[1-4,7,8]. However, they observed that some problems persist: inhomogeneity and bubble formation[8].

The resin selection and the production process should generate models that are faithful to what is intended to be studied. Therefore, several factors must be evaluated and circumvented, such as loss of transparency, which can occur due to the lack of homogeneity of the resin and the presence of residual bubbles; changes in model dimensions, caused by water absorption and evaporation. Failure to do so can compromise the photoelastic analysis[8].

The ideal photoelastic model has a homogeneous appearance (no veins) and no residual bubbles, which promotes the reliability of the method[8].

The use of digital flow, with 3D design programs and 3D printers make it possible to create millimeter-perfect and reproducible reference models, as well as individualized tools and devices for all stages of the process, virtual planning programs for the ideal positioning of the implant, the prosthesis and the surgical guide[9-14]; and new equipment, such as the use of vacuum mixers that allow a more adequate homogenization of the photoelastic resin and the eventual formation of bubbles at this moment, and bubble elimination pans that have the purpose of totally eliminating the formation of bubbles at the moment of the final polymerization of the photoelastic resin, propose alternatives to help in the production process, creating final models with higher quality and standardizing methodologies with more accuracy.

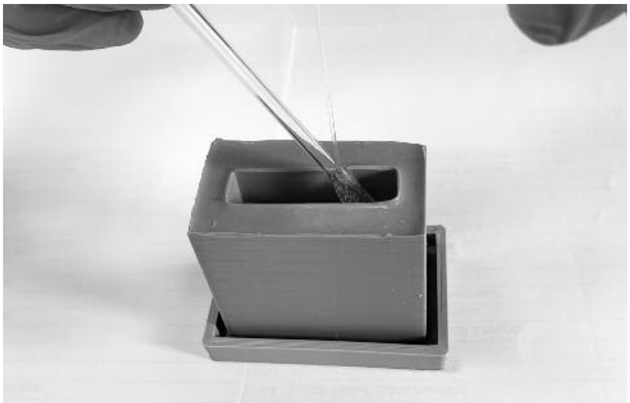

Figure 5. Photoelastic resin inserted into the impression tray with the implant in place

Figure 6. Impression tray inserted in bubble eliminator pan

Figure 7. Ready photoelastic model

Figure 8. Photoelastic analysis of the model without residual stresses

Conclusion

The technique describes a laboratory workflow using 3D design computer program (Computer Aided Design - CAD), which enable the creation in a digital environment of reference models and objects such as molding forms, fasteners, positioners, which are materialized in 3D printer (Computer Aided Manufactured - CAM), giving more quality to the method and standardizing the stages of the process with more accuracy. The use of vacuum mixer and bubble eliminator pan allow better homogeneity and elimination of any bubbles respectively at the time of manipulation of photoelastic resin, which are frequent problems and can compromise the quality of photoelastic models and, consequently, the proposed analysis.

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