Photoelastic Analysis of Two Maxillary Protocols Using Zygomatic Implants

Análisis Fotoelástico de Dos Protocolos Maxilares con Uso de Implantes Cigomáticos


ABSTRACT: The aim of this study was to analyse the in vitro the stress distribution in craniofacial structures around zygomatic implants. Synthetic polyurethane skulls replicas were used as templates for installation of standard and zygomatic implants performing two techniques using rehabilitation with using one zygomatic implant in the right and left side in combination with 2 and 4 standard implants in the anterior maxilla (group 1 and group 2). The skull replicas of photoelastic resin were subjected to photoelastic analysis after linear loading using an Instron 4411 servohydraulic mechanical testing, with a 2 mm displacement. The stress distribution showed the fringes with concentration in the body and the frontal process of zygomatic bone. In the case of model 1, higher concentrations of stress were found around the standard and zygomatic implants and surrounding bone. Under this condition, the rehabilitation with 2 zygomatics implants and 4 standard implants (group 2) provided the most favorable behavior.

KEY WORDS: photoelastic analysis, maxillary atrophy, zygomatic implants.

INTRODUCTION

In many patients, standard implant treatment cannot be performed in the edentulous maxilla because of extensive bone resorption and the presence of extensive maxillary sinuses. Patients with extreme resorption of the maxilla, or defects after tumor resection are complex problems for oral rehabilitation. In the treatment of these patients, bone grafts have been used to reestablish osseous contours providing possibilities for a tooth anchorage system. The maxillary autogenous graft are demanding for the patients and usually require hospitalization (Aparicio et al., 2008; Aghabeiji & Bousdras, 2007).

Introducing the zygoma implant concept, Brånemark presented a nongrafting alternative for the treatment of this group of patients (Ujigawa et al., 2007). Treatment with zygoma implant does not require hospitalization and usually allows the patients to use their maxillary dentures immediately after surgery. In general, zygomatic fixtures can be used in patients with totally and partially edentulous maxillary which have insufficient bone volume for placement of regular implants. The zygomatic implants with standard implants in the anterior region, offers anchorage for a fixed bridge using less invasive surgery compared with bone-augmentation procedures (Ujigawa et al.; Malevez et al., 2004).

Clinically, the response of zygomatic implant, in the long-term, presents good results when prosthetic conditions are correct (Aparicio et al., 2014). However, these results can be failed when the final position of the zygomatic implants is not correct in relation to maxillary sinus and cervical position (Rodriguez-Chessa et al., 2014) that allow sinus pathology, bone resorption, infection and loss of osseointegration. When protocols of installation are correct, the success rate is over than 95% (Aparicio et al., 2014; Duarte et al., 2007).
The mechanical condition, on the other hand, is an important question in zygomatic implants and the response to this question is not enough. The aim of this study was to investigate mechanical stress in supporting bones around zygomatic implants using photoelastic analysis.

**MATERIAL AND METHOD**

**Polyurethane Skulls.** Were used identical synthetic polyurethane skulls replicas (Nacional, Jaú, São Paulo, Brazil). Synthetic replicas were chosen to eliminate many of the variables associated with human cadaveric skulls and bone from animal sources. From these replicas, was established guidelines to perform the implants obtaining parallelism and similar angulation. Finally, the model skulls were made in photoelastic resin reproducing the angulation of implants obtained in the models of polyurethane.

**Dental Implants.** The INP System Implants (Sistema de Implantes Nacionais e Próteses) was used. The standard implants were used (Conus®) with cylindrical body and conical apex, external hexagon 3.5 x 10 mm. The zygomatic implants were used (JTR®) cylindrical body and external hexagon 4.0 x 50.0 mm.

**Implant Superstructures.** To make the prosthetic structure we used metal abutment UCLA type titanium INP System Implants (Sistema de Implantes Nacionais e Próteses) and cylindrical bars pre-fabricated in Ti-6Al-4V with 3.0 mm diameter. For the union of the bars we used laser welder (Desktop Laser-Dentaurum - Germany), programmed at 365V, with a focus 9ms pulse and frequency set at zero.

The structure was made using laser welding of titanium components prefabricated because in addition to excellent passive and adaptation on the implants and mechanical strength, it is a fast method, low cost and thus also widely used in clinical practice, especially in immediate loading.

**Photoelastic Models.** Two models performed with different rehabilitation protocols using zygomatic implants were evaluated.

Model 1 - Two zygomatic implants associated with 2 standard implants in the anterior maxilla (Fig. 1).

For fabrication of the photoelastic skulls it was necessary to manufacture tooling for latter injection of photoelastic resin. From the polyurethane skull models with implants already installed, the manufacture of the tooling was made from rigid and external structures lined with a flexible surface, superimposed on the lid and bottom.

Thus, obtaining the components of the flexible resin Polipox III®, A (resin) and B (reagent) these were weighed using a balance of precision with the ratio recommended by the manufacturer, then mixed to become homogeneous and placed in a desiccator attached to a vacuum pump. This process removed all micro-bubbles from the resin and the end of this procedure was performed on resin injection tooling. After the injection, tooling goes through two processes: 1) deposited in a hyperbaric chamber at a pressure of 30 lbs for a period of 12 hours and 2) twenty-four hours drying environment.
Photoelastic Test. The photoelastic models were taken to a plane polariscope (Eikonal Instrumentos®, Ópticos Comércio e Serviço, São Paulo, SP, Brazil) attached to the Instron 4411 test machine and submitted to loading at the first molar region for up to a 2-mm displacement, at a 1-mm/minute speed. This was the speed that presented the best distribution of isochromatic fringes during the pilot tests for the stress distribution. The photoelastic models were photographed before load input to check for absence of residual stress over the models. They were also filmed and photographed after the desired displacement (2 mm). For this task, the qualitative method of analysis was applied.

RESULTS

After the 2 mm displacement with application of unilateral load on the zygomatic region implant, a photographic record was taken to analyze the stress fringes. It was possible to see that the stress zones were located especially around body and frontal process of zygomatic bone. Also, the cervical area in both models did not show load distribution.

Model 1: The fringes are present in the apical area of the zygomatic implant in the load side; stress distribution is present in the frontal process and infraorbital rim; all zygomatic body is included in the load distribution. The non-load side showed a zygomatic implant without distribution in the zygomatic body with distribution in the infraorbital rim and frontal process. Standard implant showed distribution in the apical area; the piriform area is not involved in stress distribution (Fig. 3).

Model 2: Lesser stress than in model 1 is observed. The zygomatic body in the load side showed less stress than model 1; stress distribution is present in the frontal process with a little distribution in the infraorbital rim. The non-load side with zygomatic implant showed stress distribution close to the apical area, without distribution in the frontal process and zygomatic body. The standard implant showed a minor distribution than model 1 with a poor stress in the apical area (Fig. 4).

DISCUSSION

Mechanical parameters are excellent indicators of the mechanical risk because they are objective and can be measured.
Photoelastic analysis has been extensively used in different fields of biomechanics and several reviews dealing with the technique may be found in the literature. Several studies related to implant dentistry have used photoelastic analysis to investigate the effect of implant abutment angulation (Clelland et al., 1993; Ochiai et al., 2003), implant-abutment interface design/retention mechanisms and the performance of implant-tooth supported fixed partial dentures upon load transfer (Ochiai et al.).

Some authors (Parel et al., 2001; Penarrocha et al., 2007) suggest that zygomatic implants offer an especially powerful treatment in prosthetic rehabilitation for edentulous patients with maxillary atrophy, and virtually eliminate the need for bone grafts on the floor of the maxillary sinus. Also, they suggested that zygomatic implants should be installed in combination with at least two standard implants in order to distribute the functional load and to prevent rotational loads (Aparicio et al., 2008). In studies on multiple implants splinted together on a superstructure, no difference was observed in stress on cortical bone between angled and non-angled implants (Zampelis et al., 2007); our result show clear difference in stress distribution, first between the zygomatic implant and second in the standard implants.

The cervical area is not subjected to load in this model and this situation is very important because clinically, this bone is very small and shows a low quality (Branemark et al., 2004). The presence of a zygomatic implant can be result in exclusively load in the apical area and not in the cervical area. Complications in this area are related to sinus pathology, drainage and mucositis (Rodriguez-Chessa et al.); with the absence of the load in this area, some adjunctive procedures can be realized to better condition in the long-time.

On other hand, zygomatic implant position is not unique and show relation with the maxillary sinus. Aparicio (2011) observed that some implants are laterally to the maxillary sinus and others are into the maxillary sinus. In load terms, this position is not relevant because the middle area of the zygomatic implant is not used in the stress distribution.

The photoelastic test suggested that, in Model 1, all stress is concentrated around the attachment system showing a greater concentration of loads on the body and frontal process of zygomatic bone when compared to Model 2. In addition, the Model 2 had a better distribution of loads in the anterior maxilla. Considering the limitations of the methodology applied, the stress distribution was similar to Ujigawa et al. Regular implants used in the anterior area are very important for stress distribution. However, the response of this implant in the mechanical behavior shows differences when compared with other standard systems, like all on tilted system (de Faria Almeida et al., 2014); with zygomatic implants, the anterior implants show load mainly in the apical area but with standard implants, the load shows distribution in all of the implant.

However, there are limitations to the photoelastic analysis, mainly in biologic simulations that need studies to assume some simplifications. Bone is a complex living structure without a defined pattern; its characteristics vary among individuals. Because of individual differences in the morphology of the jaw bone, the results obtained do not apply to all individuals.

Under the conditions tested, both rehabilitation techniques using zygomatic implants were biomechanically efficient. However, the rehabilitation with 2 zygomatics implants and 4 standard implants (Model 2) provided the most favorable behavior.


RESUMEN: El objetivo de este estudio fue analizar el estrés in vitro y la distribución de tensiones en la estructura craneofacial a partir de los implantes cigomáticos. Réplicas de cráneo de poliuretano fueron usados como modelos para la instalación de implantes cigomáticos estándar utilizando dos modelos de distribución de implantes. Estos modelos fueron usados como modelos utilizando 1 implante en cada lado con dos o cuatro implantes convencionales en la región anterior maxilar (grupo 1 y grupo 2); posteriormente, se realizó una carga compresiva unilateral en la máquina Instrom 4411 utilizando 2 mm de desplazamiento máximo. La distribución de estrés se concentró principalmente en la región de cuerpo de hueso cigomático y en la región frontal del proceso cigomático; el modelo 1, con dos implantes convencionales, mostró mayor distribución de estrés en la región cigomática al compararse con el grupo 2; bajo estas condiciones, se concluye que la distribución con cuatro implantes convencionales entrega mejores condiciones de distribución de tensiones.

PALABRAS CLAVE: análisis fotoelástico, atrofia maxilar, implante cigomático.
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