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Cirurgião-Dentista

ANÁLISE FOTOELÁSTICA EM DIFERENTES PROTOCOLOS DE REABILITAÇÃO UTILIZANDO IMPLANTES DENTAIS EM MAXILAS EDÊNTULAS ATRÓFICAS

Dissertação apresentada a Faculdade de Odontologia de Piracicaba, da Universidade Estadual de Campinas, para obtenção do titulo de Mestre em Clínica Odontológica, área de Concentração em Cirurgia e Traumatologia Buco-Maxilo-Faciais

Orientador: Prof. Dr. José Ricardo de Albergaria Barbosa

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"Dedico este feito a meus pais pelo todo empenho que realizam desde sempre e pelo suporte familiar propiciando obter minhas metas"

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“O que mais me impressiona nos fracos,
é que eles precisam humilhar os outros,
para se sentirem fortes”

Mahatma Gandhi

RESUMO

Com o avanço da implantodontia, as maxilas edêntulas atróficas que anteriormente eram indicações de enxertos ósseos para viabilizar a reabilitação com implantes dentais, atualmente é possível contornar a maioria destes quadros clínicos sem a necessidade de enxertos ósseos utilizando técnicas como implantes zigomáticos. No entanto, visando a manutenção destes tratamentos aplicados, torna-se essencial o conhecimento do comportamento biomecânico destas modalidades de tratamentos. Diante do exposto, a presente pesquisa apresenta 3 estudos biomecânicos "*in vitro*" descritos nos capítulos a seguir. **CAPÍTULO I**: O objetivo deste estudo foi analisar as tensões mecânicas ao redor dos implantes e ossos adjacentes por meio de análise fotoelástica simulando três combinações de reabilitações com implantes zigomáticos. Cargas oclusais na região do primeiro molar foram simuladas, e a distribuição de tensões sobres os implantes e ossos adjacentes foram examinados. A distribuição das cargas foi observada predominantemente nas regiões de corpo e processo frontal do osso zigomático para ambos os modelos analisados. A distribuição de tensões analisadas pela análise fotoelástica concentrou-se no corpo e processo frontal do osso zigomático. No modelo 1 (2 implantes zigomáticos + 2 implantes convencionais), maiores concentrações foram encontradas ao redor dos implantes e osso adjacente. Diante dos testes realizados, a reabilitação com 2 implantes zigomáticos com 4 implantes convencionais (Modelo 2) são mais favoráveis mecanicamente. **CAPÍTULO II**: O objetivo deste estudo foi analisar a distribuição de tensões em estruturas craniofaciais e regiões adjacentes aos implantes de dois tipos de reabilitação com conceito All-on-Four utilizando implantes zigomáticos. Os testes fotoelásticos mostraram concentração de carga no corpo e processo frontal do osso zigomático. A partir das análises obtidas, ambos os modelos apresentam satisfatório comportamento mecânico.

Palavras Chave: implantes dentários; biomecânica; maxila; próteses e implantes

ABSTRACT

With the advancement of implantology, atrophic edentulous jaws that previously were indications of bone grafts to enable rehabilitation with dental implants, actually is possible to circumvent most of these clinical situations without the need for bone grafts using techniques such as the zygomatic implants. However, for the maintenance of these treatments, becomes essential knowledge of the biomechanical behavior of these treatment modalities. Given the above, this research presents three biomechanical studies in vitro described in the following chapters. **CHAPTER I**: The aim of this study was to analyze the mechanical stresses around the implants and surrounding bone by photoelastic analysis simulating combinations of three rehabilitations with zygomatic implants. Occlusal loads in first molar region were simulated, and the stress distribution on the implants and surrounding bone were examined. The load distribution was observed predominantly in the body and frontal process of zygomatic bone for both models analyzed. The stress distribution analyzed by photoelastic analysis concentrated on the body and frontal process of zygomatic bone. Model 1 (2 + 2 zygomatic implants conventional implants), higher concentrations were found around the implants and surrounding bone. Before the tests, rehabilitation with two zygomatic implants with conventional implants 4 (Model 2) are better mechanically. **CHAPTER II**: The aim of this study was to analyze the stress distribution in craniofacial structures and regions adjacent to implants of two types of rehabilitation with All-on-Four concept using zygomatic implants. The photoelastic tests showed load concentration in the body and frontal process of zygomatic bone. From the analysis obtained, both models have satisfactory mechanical properties.

Key-words: dental implants; biomechanics; maxilla; prostheses and implants

SUMÁRIO

INTRODUÇÃO

A reabilitação oral com implantes dentários osseointegrados melhorou a qualidade de vida de milhares de pacientes nas últimas três décadas. Estima-se que os implantes dentais atinjam atualmente taxas de sucesso próximas de 95%. Os trabalhos de Adell *et al.(*1990) e Albrektsson *et al.* (1998), confirmaram esses altos indíces de sucesso a longo prazo com a utilização de implantes osseointegráveis no tratamento de pacientes totalmente edêntulos.

No entanto, têm-se observado que fatores como o planejamento cirúrgico, a execução de uma técnica cirúrgica atraumática, a biocompatibilidade, o desenho do implante e suas caracteristicas de superfície, assim como as condições do leito receptor, podem interferir no sucesso da osseointegração.

Um sistema de implante é caracterizado por suas macro e microestruturas, propriedades intrínsecas, tipo de conexão implante-intermediário, presença ou ausência de espiras, desenho de espirais, micro arquitetura da superfície e composição química. Estes são desenhados visando conseguir o sucesso clínico e, para que se obtenha um protótipo ideal de implante, devem responder as dúvidas existentes sobre qual é a intensidade de transferência de estresse aos tecidos biológicos e as respostas destes tecidos frente a este estresse. Por tal motivo, os princípios biomecânicos são relevantes no desenho e padronização dos implantes.

A biomecânica de um implante é diferente daquela de um dente natural, pois este último é circundado por ligamentos periodontais. A possibilidade de transferir carga excessiva ao implante e deste ao osso adjacente pode acabar ultrapassando o limite fisiológico e provocar a perda da osseointegração. Devido a esta função dos implantes de transferir cargas oclusais aos tecidos biológicos, o objetivo deste é direcionar estas cargas através de uma melhor distribuição dessas forças, otimizando a função das próteses suportadas por estes implantes. Entretanto, não é fácil quantificar a intensidade de força que pode levar a sobrecarga, pois a capacidade óssea individual de suportar forças apresenta uma grande variabilidade.

Fatores como a concentração e magnitude do estresse estão sujeitos a algumas variáveis como: dente antagonista, força oclusal, parafunção, número de implantes para distribuir as cargas, posição do implante, rigidez da prótese e geometria do implante.

A oclusão é um fator importante na determinação da direção da carga. Forças compressivas devem ser as predominantes na oclusão das próteses sobre implantes, pois são menos nocivas que as forças de tensão. O osso cortical é mais resistente a compressão (Bidez & Misch, 1992).

Em maxilas severamente absorvidas podem ser utilizados os implantes dentais osseointegráveis convencionais. Todavia, nestas situações, estão presentes obstáculos para a instalação dos implantes como: quantidade insuficiente e qualidade inadequada do osso encontrado na maxila, como também por pneumatização do seio maxilar (Cawood & Howell, 1991). Historicamente, nestas situações, anteriormente a instalação destes tipos de implantes, eram necessárias cirurgias reconstruitivas para restabelecer as dimensões do rebordo em espessura e altura possibilitando assim a instalação adequada destes implantes. Geralmente, essas reconstruções utilizam osso autógeno retirado de algum sitio doador do paciente, como a calota craniana, costela e crista do ilíaco, o que faz deste procedimento, ser considerado um tratamento mórbido e de menor aceitação por parte do paciente (Rawashdeh, 2008). Além disso, em diversos estudos publicados sobre instalações de implantes em maxilas severamente absorvidas, a média de sucesso é maior para implantes instalados em osso residual maduro junto às áreas que receberam enxerto ósseo, encontrando faixas de 13% a 25% de falha após dois anos de acompanhamento (Widmark *et al.*, 2001; Lekholm *et al.*, 1999).

Como alternativa de tratamento, os implantes zigomáticos e a técnica "All-on-Four" podem ser utilizadas em maxilas severamente absorvidas com presença de pneumatização de seio maxilar em região posterior sem a necessidade de procedimentos reconstrutivos com enxertos ósseos. A técnica All-on-Four foi desenvolvida para maximizar a utilização do osso disponível e permitir a função imediata. Originalmente, utiliza-se 4 implantes convencionais em maxilares edêntulos, a solução é favorável pelas vantagens de inclinação dos implantes posteriores com variação de (15º a 45º), fornecendo um suporte protético satisfatório e seguro para uma prótese fixa, mesmo com volume ósseo mínimo. Desta forma, estes tipos de implantes além de oferecerem menor tempo de tratamento comparados aos procedimentos associados com enxertos ósseos, oferecem redução nos periodos de hospitalização, dos riscos, da morbidade e dos custos (Ahlgren, 2006).

No entanto, é necessário o conhecimento biomecânico desta modalidade de reabilitação utilizando o conceito All-on-Four, seja apenas com implantes convencionais ou associados a implantes zigomáticos.

Na reabilitação utilizando os implantes zigomáticos, esta modalidade de tratamento é sugerida em combinação com no mínimo dois implantes convencionais na região anterior da maxila (Brånemark, 2000; Parel *et al.*,2001). São utilizados desta forma com o intuíto de distribuir a carga funcional prevenindo forças rotacionais sugestivas de falha biomecânica (Ujigawa *et al.*, 2007). Todavia, na literatura científica, não existe um consenso em relação ao número ideal de implantes zigomáticos e tipos de implantes convecionais para que se desenvolva uma distribuição de cargas para se obter um adequado funcionamento biomecânico a longo prazo. Desta forma, são encontradas vários protocolos de implantes zigomáticos, entretanto, sem apresentar estudos especificos em relação a sua eficácia biomecânica (Zwahlen, 2006; Peñarrocha, 2007; Ahlgren, 2006).

A fotoelasticidade é uma técnica experimental para análise e determinação do campo de tensões/deformações em peças e/ou estruturas de engenharia utilizada, principalmente, em modelos complexos, sendo portanto um eficiente método para análise de campo completo de tensões no estado plano ou tridimensional. Diferentes estudos relatam o uso da análise fotoelástica aplicados para análise dos componentes biomecânicos na implantodontia (Cehreli *et al.* 2004; Ochiai *et al.* 2003; Guichet *et al.* 2000; Clelland *et al.* 1993). Na fotoelasticidade de transmissão é necessária a confecção de modelos transparentes com características de birrefringência ou anisotropia ótica quando submetidos a esforços mecânicos.

Para a aplicação desta técnica, é necessário utilizar um aparelho ótico denominado polariscópio, cuja característica principal é trabalhar com luz polarizada. O polariscópio possibilita a visualização dos parâmetros fotoelásticos, em forma de franjas coloridas, quando utilizada a luz branca, e franjas pretas e brancas quando se utiliza luz monocromática. Esta ordem de franjas está associada com o estado de tensão no modelo.

Desta forma, esta dissertação apresenta 2 estudos mecânicos realizados "*in vitro*", subdividida em capítulos, objetivando avaliar o comportamento mecânico dos diferentes protocolos de reabilitação para maxilas edêntulas atróficas através de ensaios com análise fotoelástica.

CAPITULO 1

Photoelastic Analysis of Two Protocols for Zygomatic Implants

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Keywords: photoelastic analysis; maxillary atrophy; zygomatic implants

Purpose: The objective of this study was to analyse in vitro the stress distribution in craniofacial structures around zygomatic osseointegrated implants.

Material and Methods: Synthetic polyurethane skulls replicas were used as templates for installation of standard and zygomatic implants performing two techniques using rehabilitation with zygomatic implants. These models were used as templates for the manufacture of photoelastic models keeping the same arrangement of implants. Were performed using variations of 1 zygomatic implants in each one zygomatic bone in combination with 2 and 4 standard implants in the anterior maxilla (Models 1 and 2). The skulls replicas of photoelastic resin were subjected to photoelastic analysis after linear loading using an Instron 4411 servohydraulic mechanical testing unit with a 2-mm displacement.

Results: The stress distribution in the photoelastic analysis, the fringes were concentrated body and frontal process zygomatic bone. In the case of the model 1, higher concentrations of stress were found around the standard and zygomatic implants and surrounding bone.

Conclusions: Under the conditions tested, the rehabilitation with 2 zygomatics implants with 4 standard implants (Model2) provided the most favorable behavior.

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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, leading to inadequate amounts of bone tissue for anchorage of the implants. Patients with extreme resorption of the maxilla, or defects after tumor resection present complex problems for the restorative dentist. In the treatment of these patients, bone grafts have been used to reestablish osseous contours providing possibilities for a tooth anchorage system. The grafting procedures are demanding for the patients and usually require hospitalization[3,4]. Many patients are unable or unwilling to undergo the rigors of these procedures.

By introducing the zygoma implant concept, Brånemark presented a nongrafting alternative for the treatment of this group of patients.[1] 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 who have insufficient bone volume for placement of regular implants posterior to the canines. The zygomatic implants together with standard implants in the anterior region, the zygomatic fixture offers anchorage for a fixed bridge using less invasive surgery compared with bone-augmentation procedures[1,2].

Brånemark[8] 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.

The aim of this study was a investigate mechanical stresses in supporting bones around implants using photoelastic stress analysis, simulating two combinations of rehabilitation using zygomatic implants. Occlusal loads were simulated, and stresses on the implants, superstructures and surrounding osseous structure were examined.

MATERIALS AND METHODS / METHODOLOGY

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® of 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 infrastructure 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 were used laser welder (Desktop Laser-Dentaurum - Germany), programmed at 365V, with a focus 9ms pulse and frequency set at zero.

The infrastructure prosthetics were 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.

Groups

Two models were performed with different rehabilitation protocols used zygomatic implants.

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

Model 2 - Two zygomatic implants associated with 4 standard implants in the anterior maxilla. (Figure 2)

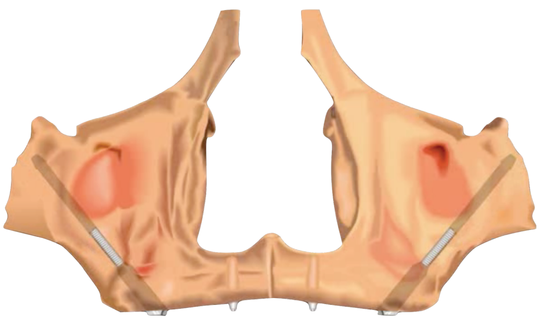

Figure 1 – Two zygomatics with 2 standard implants

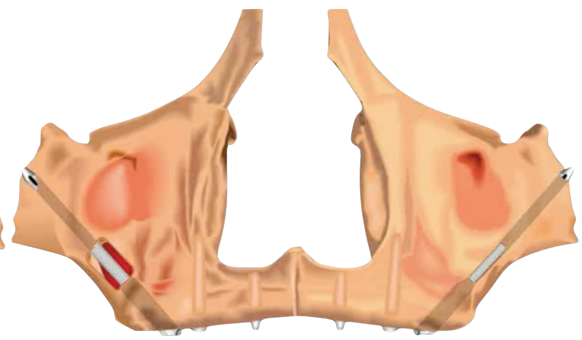

Figure 2 – Two zygomatics with 4 standard implants

Photoelastic Models

For fabrication of the photoelastic skulls 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) were weighed using a balance of precision in the ratio recommended by the manufacturer, then mixed to become homogeneous and placed in a desiccator attached a vacuum pump. This process will remove 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.
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 evaluation. The photoelastic models were photographed before load input to check for the absence of residual stress over the models. They were also filmed and photographed after the desired displacement (2 mm) was reached. For this task, the qualitative method of analysis was applied.

RESULTS

After the 2-mm displacement with application of unilateral load on the region zygomatic implant, a photographic record was taken to analyze the stress fringes. Was possible to see that the stress zones were located especially around body and frontal process of zygomatic bone. Also, the stress forces were dissipated along of anterior region maxilla (Figure 3 and 4).

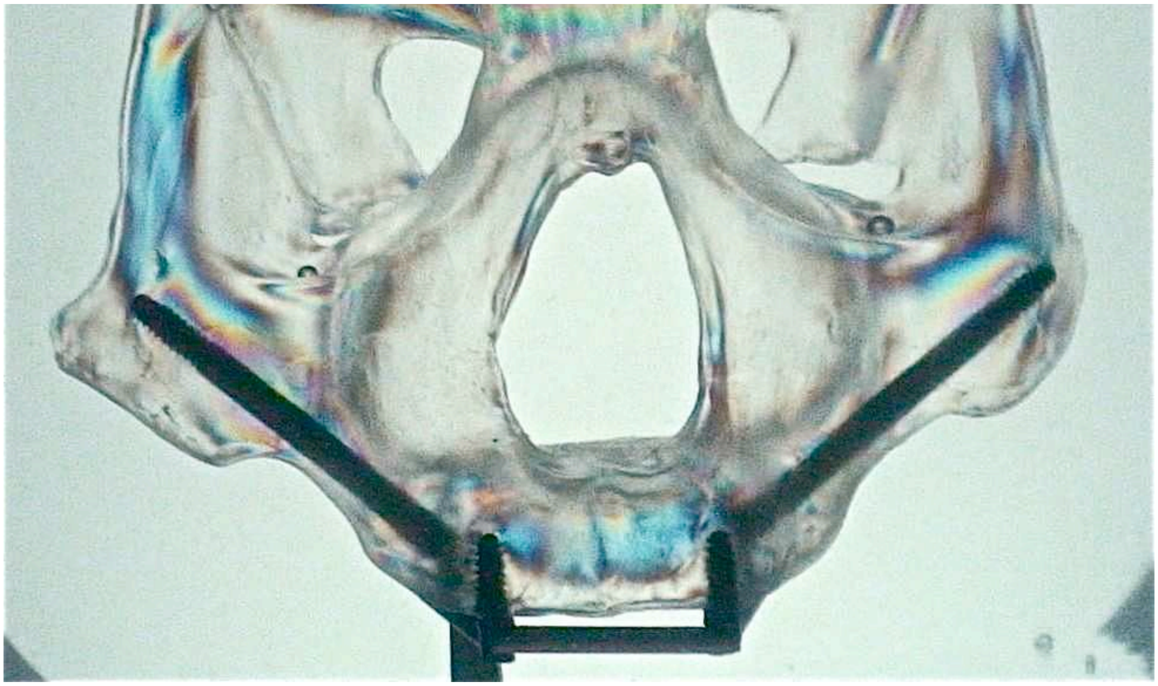

Figure 3 – Photoelastic test with application of loading in first molar right region (Model 1)

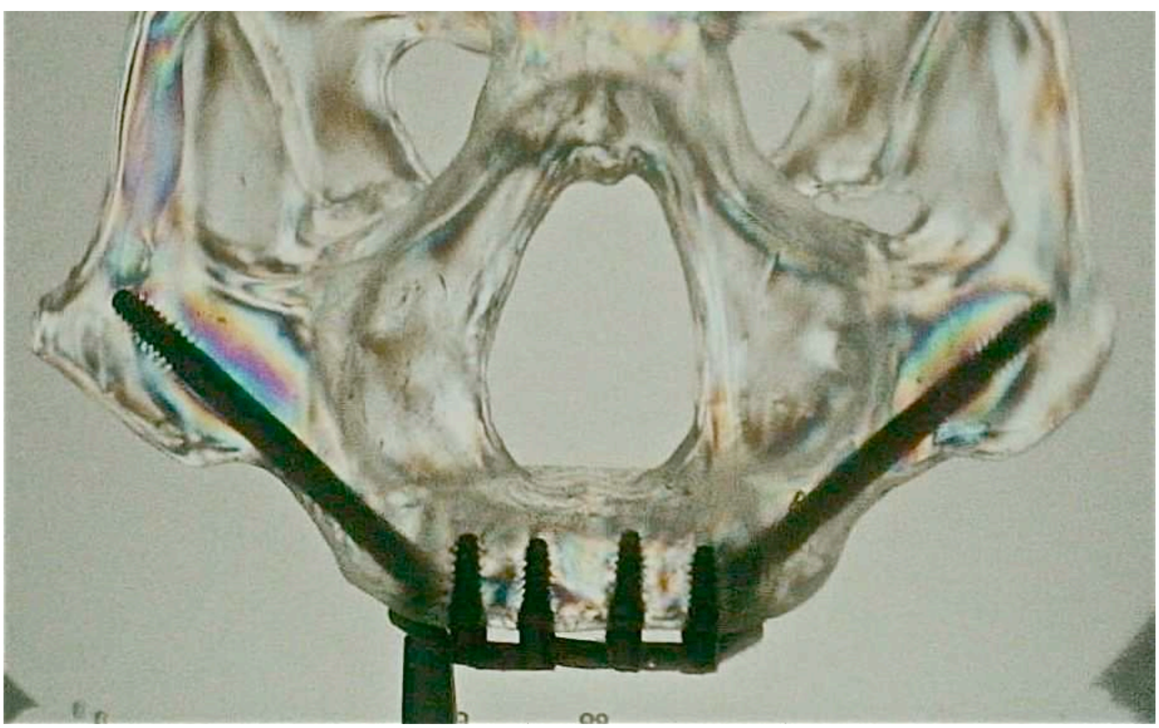

Figure 4 – Photoelastic test with application of loading in first molar right region (Model 2)

DISCUSSION

Mechanical parameters are excellent indicators of the increased risk because they are objective and can be measured. One may determine which condition presents greater risk, and by how much the risk is increased.

The application of loads was carried out in the region corresponding to the first molar. Studies show that higher loads are found in the occlusal region of molar teeth[18]. Importantly, the photoelastic analysis reveals the stress distribution independent of the amount of force applied. The force applied in this test is determined by the mechanical specification of the resin used.

From theoretical models, actually in vivo measurements found that the bite force varies along the dental arch, being largest corresponding to the posterior teeth (molars and premolars), intermediate in the canine area, and least in an incisal clench[11, 12,13,14,15,16,17].

Thus, this study evaluated the distribution of loads aimed at analyzing the mechanical behavior by means of loads distribution in photoelastic resin skulls simulating the two types of rehabilitation using zygomatic implants.

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[5,6], implant-abutment interface design\retention mechanisms and the performance of implant-tooth supported fixed partial dentures upon load transfer[6].

Some authors[8,9] suggests 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 in 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[3].

Studies on multiple implants splinted together on a superstructure, no difference was observed in stress on cortical bone between angled and non-angled implants[10].

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.*, 2007.

From the data obtained using photoelastic analysis, the rehabilitation related to the Model 2 had a better mechanical behavior than Model 1. Thus, this study showed that the stress was higher when the number of implants was lower in anterior maxilla. Possibly because of the higher number of implants in the anterior maxilla promotes better distribution of stresses.

However, there are limitations to the photoelastic analysis, mainly in biologic simulations that oblige studies to assume some simplifications. Bone is a complex living structure without a defined pattern; its characteristics vary among individuals, and its actual mechanical properties are not precisely established. Because of individual differences in the morphology of the jaw bone, the results obtained do not apply to all individuals. Also, the model in this study simulated one of the various stresses situations that implants are submitted in mouth.

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CAPITULO 2

Photoelastic Analysis on Different *All-on-Four* Concepts Using Zygomatic Implants

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Keywords: photoelastic analysis; all-on-four; zygomatic implants

Purpose: The objective of this study was to analyse stress distribution in craniofacial structures around of 2 concepts of rehabilitation using All-on-Four with zygomatic implants.

Material and Methods: Two photoelastic resin skulls replicas, each with four implants simulating the All-on-Four configuration, were prepared. Two models used concept All-on-Four with zygomatic implants. Were performed using variations of 1 zygomatic implants in each one zygomatic bone in combination with 2 standard implants in the anterior maxilla and another group with only four zygomatic implants (Models 1 and 2, respectively). The four implants were splinted by means of a cast metal bar. The skulls replicas of photoelastic resin were subjected to photoelastic analysis after linear loading using an Instron 4411 servohydraulic mechanical testing unit with a 2-mm displacement. The fringe patterns produced in the photoelastic resin for each implant and load were photographed with a digital camera.

Results: The stress distribution in the photoelastic analysis, the fringes were concentrated body and frontal process of zygomatic bone.

Conclusions: Under the conditions tested, Both models showed satisfactory biomechanical behavior

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INTRODUCTION

During the past decades, rehabilitation of maxillary defects still poses a significant challenge for both surgeons and prosthodontists[1]. The aim of rehabilitation is not only to provide a cosmetically acceptable appearance, but also to restore oral functions such as deglutition, mastication and phonation[1,3,4]. The technique of free bone grafts combined with dental implants, especially, zygoma implants (Zygomaticus fixture; Nobel Biocare, Gothenburg, Sweden) developed by Brånemark, proposes a new treatment for functional reconstruction of maxillary defects[2–5,6]. With their specific design, these implants have been successfully used to support prostheses in the atrophic edentulous maxilla, as well as in patients who have undergone maxillectomy.[5–7]

The advantages with the zygomatic implant procedure compared with bone grafting techniques include interventions, as is customary for standard 2-stage implant treatment. However, the zygoma implant has to be combined with standard implants to secure stability for the restorations. The ideal cases for zygoma implants are patients with a sufficient remaining bone volume in the anterior region but severely resorbed posterior parts with pneumatization of the crestal bone by the sinus allowing implant stability marginally. However, clinical situations of maxilla severely absorbed jaws that prevent the installation of implants in the anterior maxilla[8]. For these situations, can be applied to rehabilitation using the All-on-Four concept with only four zygomatic implants.

About 10 years ago, further biomechanical analysis and technical advancement led to the introduction of the All-on-Four full-arch restoration strategy, which evolved from the 6 implant–supported fixed detachable bridge. Biomechanical analysis determined that a fifth or sixth implant was unnecessary in terms of mechanical support.

Although the use of only four implants for a complete fixed rehabilitation of the maxilla has been supported by clinical studies, mainly over short evaluation periods.

The aim of this study was to investigate mechanical stresses supported by the bones around implants using photoelastic stress analysis, simulating 2 combinations of rehabilitation using All-on-Four concept. Occlusal loads were simulated, and stresses on the implants, superstructures and surrounding osseous structure were examined.

MATERIALS AND METHODS / METHODOLOGY

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

We used the INP System Implants (Sistema de Implantes Nacionais e Próteses). The standard implants were used Conus® of cylindrical body and conical apex, external hexagon 3.5 x 10 mm in the anterior maxilla associated with zygomatic implants (ZI) were used JTR® cylindrical body and external hexagon 4.0 x 47.5 mm (ZI anterior) e 4.0 x 50.0 mm (ZI posterior).

Implant Superstructures

To make the infrastructure 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.

The titanium bars were previously split disc with carborundum (Dentorium-NYU-USA) and maintained by the juxtaposition of the abutments. For the union of the bars were used laser welder (Desktop Laser-Dentaurum - Germany), programmed at 365V, with a focus 9ms pulse and frequency set at zero.

The infrastructure prosthetics were 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.

Groups

Two models were performed with rehabilitation protocols used zygomatic implants using the All-on-Four concept.

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

Model 2 – Only 4 zygomatic implants. (Figure 2)

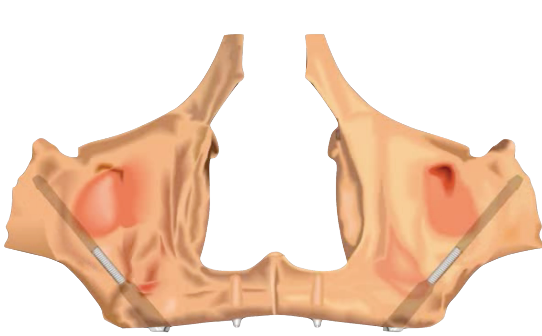
Figure 1 – Two zygomatics with 2 standard implants

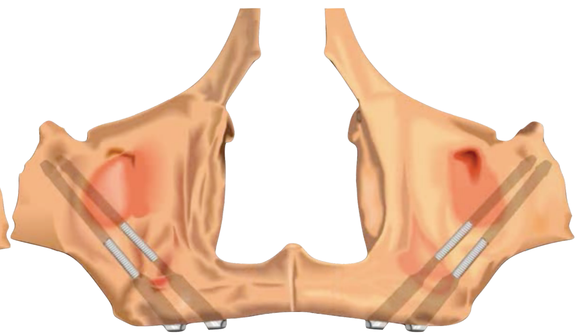
Figure 2 – Four zygomatic implants

Photoelastic Models

For fabrication of the photoelastic skulls will be needed to manufacture tooling for latter infection of photoelastic resin. From the polyurethane skull models with implants already installed, the manufacture of the tooling is 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) were weighed in the balance of precision in the ratio recommended by the manufacturer, then mixed them well to become homogeneous and then placed in a desiccator attached a vacuum pump. This process will remove all micro-bubbles from the resin, 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.
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 evaluation. The photoelastic models were photographed before load input to check for the absence of residual stress over the models. They were also filmed and photographed after the desired displacement (2 mm) was reached. For this task, the qualitative method of analysis was applied.

RESULTS

The maximum stress levels were always located in the zygomatic implants, on the side of load application. In the two models, very similar patterns of stress location and stress concentration located especially around body and frontal process of zygomatic bone (Figure 3 and 4). However, in model 2, by the absence of standard implants in anterior maxilla, there were no tensions in the anterior maxilla. Moreover, higher concentrations were found in more anterior zygomatic implants.

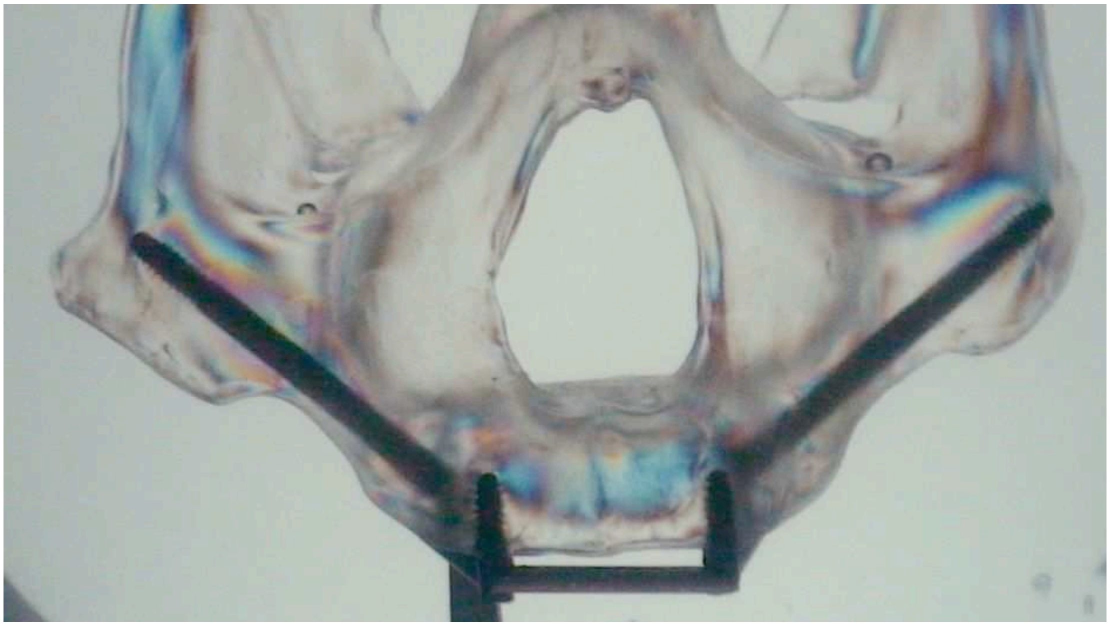

Figure 3 – Photoelastic test with application of loading in first molar right region (Model 1)

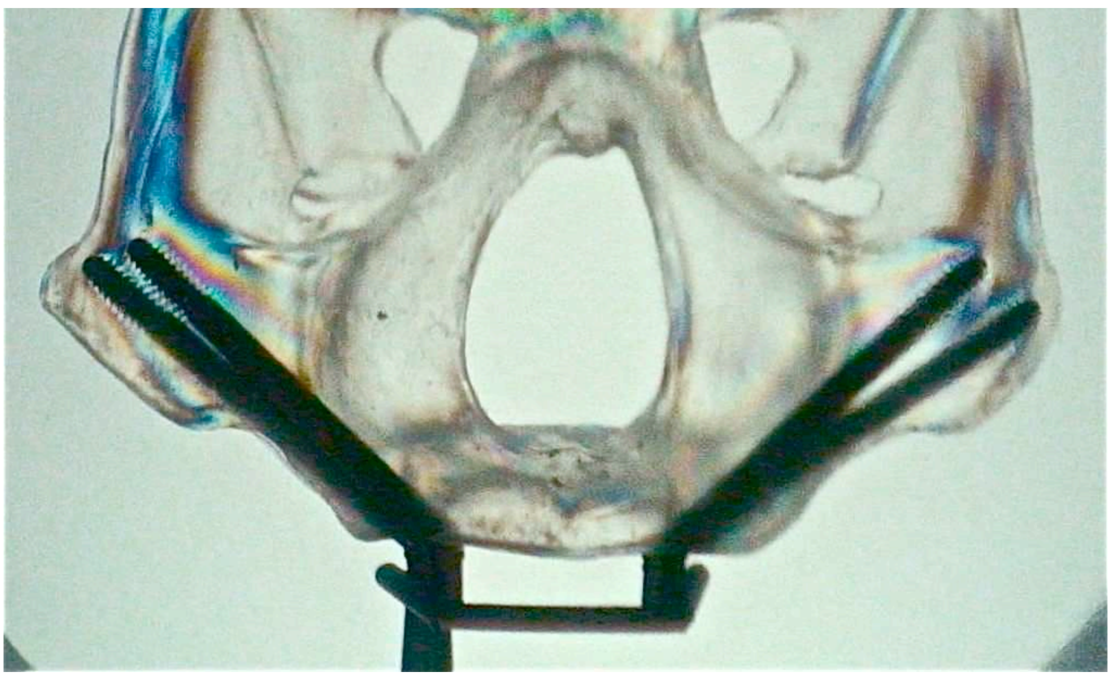

Figure 4 – Photoelastic test with application of loading in first molar right region (Model 2)

DISCUSSION

Standard protocol with implant-supported prostheses establishes insertion of multiple parallel implants in the anterior maxilla and mandible.[11] Some studies have shown that the large amount of force applied to the distal extension of the prostheses is absorbed by the distal implant and the total load absorbed by this implant is not related to the number of fixtures.[12] The insertion of four implants was enough biomechanically, so the all-on-four concept[13] was introduced to permit the insertion of four implants in adequate positions and correct inclination for the distribution of forces.

Study of biomechanics is critical to medical and dentistry materials sciences. Understanding how living tissue reacts to and interacts with external forces or artificial devices requires particular scientific research techniques. This requisite is a considerable challenge for existing measurement technologies.

When applying photoelastic analysis, the specific disadvantages of the technique have to be considered. The need for photoelastic resin limits its application to *in vitro* investigations of plain models. Small objects like dental implants or the anatomy of a root canal cannot easily be reproduced with a sufficient degree of accuracy. Furthermore, internal stresses inside photo elastic replications often lead to fringe patterns, residual stresses in the model material could be observed. Thus, the photoelastic analysis has the advantages: Easy to use and inexpensive; Provides a general idea of a mechanical problem; Displays loading conditions within an object. The disadvantages of mechanical test are: Internal residual stresses may falsify measurement results; Quantitative measurements can hardly be conducted[14], specifically three-dimensional models.

However, photoelastic analysis is an inexpensive and easy-to-use visual technique that produces contours of principal stress differences. A polariscope is employed to view an object consisting of photoelastic resin under a certain load. The emerging isochromatic fringe patterns in the material are photographed and interpreted.

The present study compared the mechanical behavior of the two models All-on-Four concepts.

Maximum stress levels were always located in the zygomatic implants, on the side of load application. This was expected because the higher loads were applied at a location close to these implants. When the load was applied unilaterally, the implants on the opposite side were subjected to less stress, which was also observed by other authors[12].

In Model 2 (Figure 4) with only four zygomatic implants with the absence of standard implants in the anterior region, the implant that plays this role is theoretically the most anterior zygomatic implants. Thus, it is expected to present a greater concentration of loads when compared with more posterior by the absence of standard implants in anterior maxilla. However, even with higher stress in zygomatic bone, the biomechanical behavior of the model was sufficient to distribute the loads by the zygomatic body an process frontal of the bone zygomatic similar to model 1 (Figure 3).

However, when available bone in the maxilla, this research suggests the application of the All-on-Four as shown in the model 1 exhibited lower stress concentrations (Figure 1).

According to this analysis of the effects of zygomatic implants in a photoelastic analysis of the craniofacial skeleton, stress due to occlusal forces was mainly supported by the zygomatic bone, and it was not significantly influenced by the anatomical structure of the maxilla.

Experimental analysis of biological specimens has already led to valuable findings that have improved medical and dental devices and techniques. Nevertheless, the complexities inherent in materials like bone, and demanding test settings such as multi-axial loading experiments preclude the use of only one technique. Additionally, the structures of biomechanical samples are often quite complex so that solely theoretical models cannot regard all aspects of a sample. Only by combining results from different analytical methods can statistical material properties be established, local effects analyzed, and resultant models verified. The combination of techniques (Photoelastic analysis, Strain gauges, Finite element analysis and Full-field three-dimensional optical inspection) will, in the future provide a much more reliable basis for interpretation of results and for application *in vivo*.

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CONCLUSÃO:

No presente estudo de acordo com a metodologia empregada podemos concluir que:

1- As diferentes combinações de reabilitação utilizando implantes zigomáticos analisados em modelos de resina fotoelástica são opções viáveis para reabilitações de maxilas atróficas permitindo a transmissão de tensões de forma eficaz mecanicamente, principalmente quando associado a 4 implantes convencionais na região anterior de maxila.

2- As diferentes combinações de implantes zigomáticos apresentaram-se semelhantes na distribuição de tensões direcionadas para a região do corpo e processo frontal do osso zigomático nos modelos em resina fotoelástica.

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