INFLUÊNCIA DAS VARIÁVEIS MORFOLÓGICAS EM MODELOS FOTOELÁSTICOS COM IMPLANTES, SUBMETIDOS A CARGA AXIAL

*A*INFLUENCE OF MORPHOLOGICAL VARIABLES IN PHOTOELASTIC MODELS WITH IMPLANTS SUBMITTED TO AXIAL LOADING

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RESUMO

Purpose: This study used 12 photoelastics models with different height and thickness to evaluate if the axial loading of 100N on implants changes the morphology of the photoelastic reflection. *Methods*: For the photoelastic analysis, the models were placed in a reflection polariscope for observation of the isochromatic fringes patterns. The formation of these fringes resulted from an axial load of 100N applied to the midpoint of the healing abutment attached to the implant with 10.0mm x 3.75mm (Conexão, Sistemas de Próteses, Brazil). The tension in each photoelastic model was monitored, photographed and observed using the software Phothoshop 7.0. For qualitative analysis, the area under the implant apex was measured including the green band of the second order fringe of each model using the software Image Tool. After comparison of the areas, the performance generated by each specimen was defined regarding the axial loading. *Results*: There were alterations in area with different height and thickness of the photoelastic models. It was observed that the group III (30mm in height) presented the smallest area. *Conclusion*: There was variation in the size of the areas analyzed for different height and thickness of the models and the morphology of the replica may directly influence the result in researches with photoelastic models.

UNITERMS: Dental Implantation; Dental Prosthesis, Dental Stress Analysis.

INTRODUCTION

Recently, studies using photoelasticity [1], finite element method [2] or strain gauges [3] to evaluate the effect of forces on implants have been conducted to clarify the resistance or fragility of some planning with implant-supported prostheses. It has been suggested that no method is superior to other since the researchers agree that the different analyses are complementary [3].

Photoelasticity is based on the property of some colorless materials that exhibit patterns of chromatic fringes under polarized light. These patterns result from alteration of the polarized light due to the internal stress of waves that cross with different speed. The internal stress in the model is generated by loading and the loads are visualized in the models with polarized filters [4]. In general, photoelasticity demonstrates the quality, quantity and distribution of the loads in some object through fringes that look like a successive series of adjacent bands. Considering the different colors, each band represents a different degree of birefringence corresponding to a tension subjacent to the tested area [5].

This technique is widely used to evaluate the forces distribution since it was already tested and represents a simple method to construct the models and interpret the results [6]. However, the variables to obtain the models, such as linear dimensions and thickness of the photoelastic material, should be carefully controlled since they may influence the final result and the composition of the spectrum. The forces applied generate internal stress that is distributed according to the direction, form and mode of support of the patterns [7]. So, the supporting base and the fixation of the patterns should be carefully observed to allow practical extrapolations closest to the real situation.

In the last years, photoelasticity has been progressively used in Dentistry [4] to evaluate the interactions between tissue behavior and physical characteristics of the prostheses and implants [8]. Although this technique does not allow differentiation between cortical and medullary bone, the stress generated by different types of prostheses can be observed and the concentration area is accurately indicated even when the magnitude of the stress is probably different from the real situation [8].

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This method has been used only in *in vitro* studies to evaluate stress distribution [9] in fixed dentures [8,10,11], removable dentures [12], different designs of implants [5], angulated implants [1], angulated attachments [13], and others. However, Fernandes *et al.* [9] demonstrated the effectiveness of the reflective photoelasticity as a technique to monitor the stress/tension distribution in prostheses in *in vivo* study.

Several techniques have been applied in researches focusing on the stress generated by axial loading or not in photoelastic models. These researches simulate a clinical situation of patients treated with implant-supported prostheses. Considering that the models do not exhibit the same volume or size, the photoelastic reflection may be altered regardless the force applied.

The aim of this study was to use 12 photoelastic models with different height and thickness to evaluate if the axial loading of 100N applied on implants of 3.75mm x 10.0mm alters the photoelastic reflection due to the variation of the samples size.

MATERIAL AND METHOD

The replicas were fabricated according to a pattern in pink wax n.07 with 30.0mm in length, 30.0mm in height and 14.0mm in thickness corresponding to the largest replica. This pattern was molded in silicone (Zetalabor, Zhermack S.A., Rovigo, Italy) to reproduce 12 plaster casts with similar dimensions.

These casts were grinded with 280- and 400-grit sandpapers (3M do Brasil, Sumaré, São Paulo, Brazil) in a polishing machine (Arotec S.A. Ind e Com, Cotia, São Paulo, Brazil). All models presented the same length (30.0mm) but different height and thickness (Table 1).

Table 1. Distribution of the groups

Groups	Length (mm)	Height (mm)	Thickness (mm)
I	30	20	14
	30	20	12
	30	20	10
	30	20	8
II	30	25	14
	30	25	12
	30	25	10
	30	25	8
III	30	30	14
	30	30	12
	30	30	10
	30	30	8

After obtaining the casts, perforations were made in the geometric center of the implantation base with spherical and tapered burs using a low-speed handpiece (Kavo do Brasil Ind e Com Ltda, Joinville, Santa Catarina, Brazil) until the penetration of the implant at the cervical platform. The implants with 10.0mm x 3.75mm (Conexão – Sistemas de Prótese Ltda, Arujá, São Paulo, Brazil) were inserted in the perforated casts using a dental surveyor (DFL Indústria e Comércio S.A., Jacarepaguá, Rio de Janeiro, Brazil) and fixed with extra-hard wax to maintain the same axial position perpendicular to the implantation platform (figure 1,2 and 3).

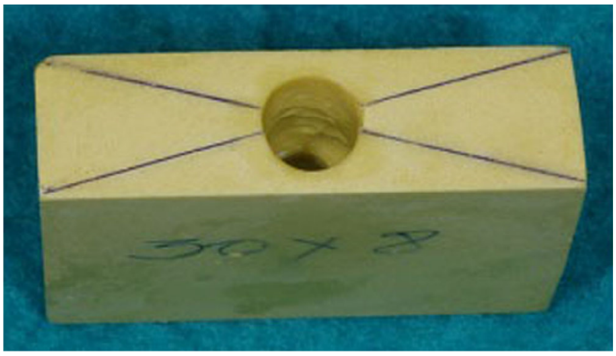


Figure - 1

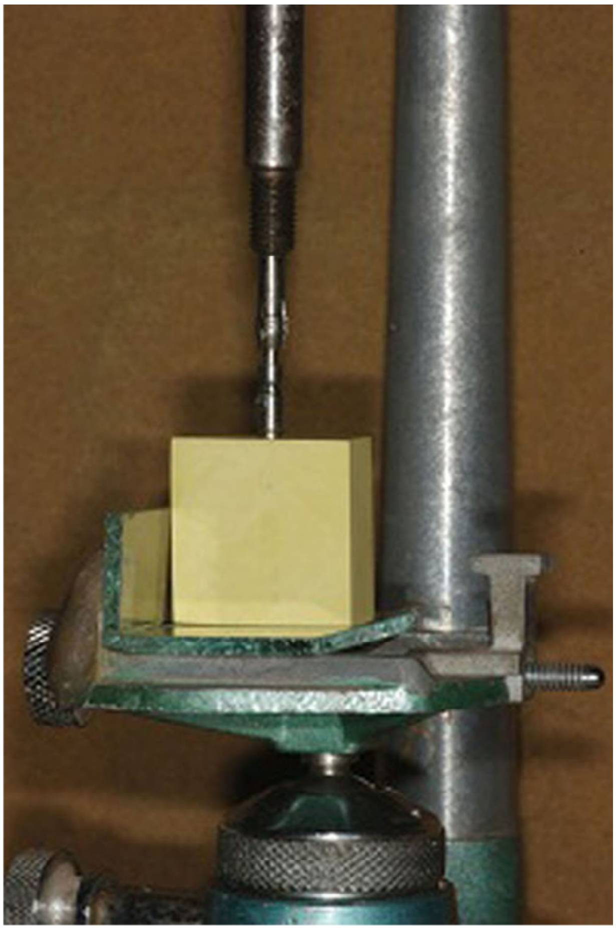


Figure - 2

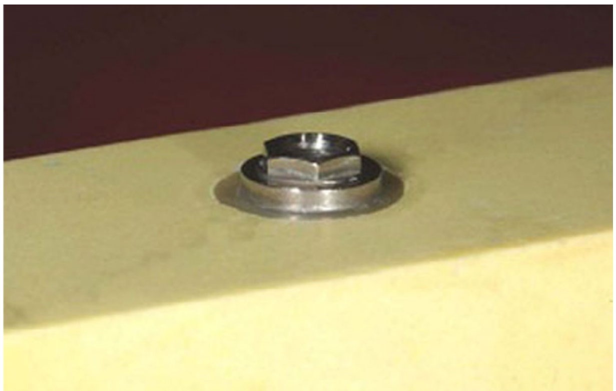


Figure - 3

All casts/implant were duplicated with silicone (Sapeca Artesanato, Bauru, São Paulo, Brazil) to obtain the photoelastic models (Figure 4). The photoelastic resin (PL-2, Vishay Micro-Measurements, Raleigh, NC, USA) was manipulated at once to avoid variation in the models, poured into the space of the mold and stored in a hermetically sealed recipient under 40 pounds of pressure during 24 hours to avoid bubbles into the models (figure 5). After this period, the surface of the photoelastic models were regularized in a polishing machine with 1200-grit sandpaper at 300rpm to avoid tension and, then, polished in a lathe (Nevoni, Lapa, São Paulo, Brazil) (Figure 6).

Figure - 4

Figure - 5

Figure - 6

A healing abutment was attached to the implant (Conexão – Sistemas de Prótese Ltda, Arujá, São Paulo, Brazil) for axial loading of 100Newton (N) in the midpoint. The load was compatible with the photoelastic resin to allow better reading of the fringes order. Afterwards, the photoelastic model was immersed in a recipient with mineral oil to minimize the refraction of light of the surface and facilitate the observation of the isochromatic fringes, according to Federick and Caputo, 1996 [14]. Each model was observed through the digital camera Nikon D70 (Nikon Americas Inc., Melville, NY, USA) to identify the initial stress generated by the fabrication of the models. After that, the axial loads of 100N were applied to the models. The stress generated in all areas of the photoelastic model was monitored, photographed and observed in the graphic software Phothoshop 7.0 (Adobe System – San Jose, California, USA) (Figure 7).

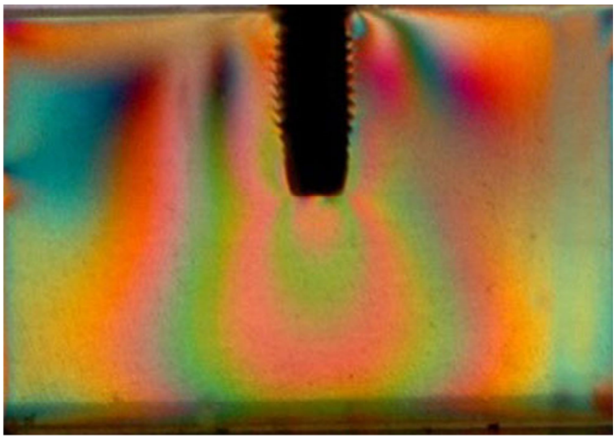


Figure - 7

The area between the implant apex and the green band of the second order fringe was delimited for the qualitative analysis of the stress area generated under the implant apex in each photoelastic model (figure 8). The green band was determined as reference due to better visualization and delimitation since it was present in all models. This analysis was conducted through the software UTHSCSA Image Tool (IT) and the numerical results were tabled and compared to asses if the variation of the model altered the morphology of the photoelastic reflection (Table 2).

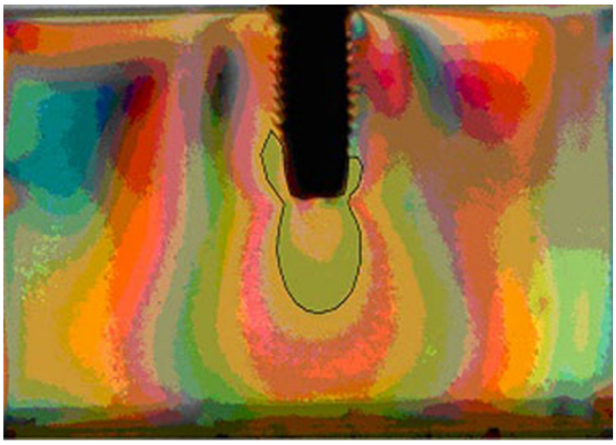


Figure - 8

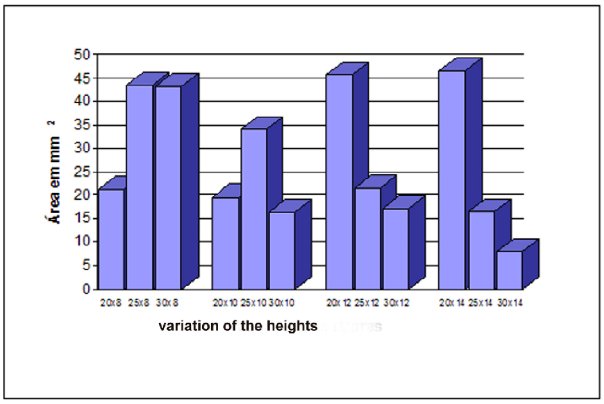
Table 2. Mean values of the areas generated under the second order fringe in each photoelastic model

Groups		reading	reading	reading	Área
		1	2	3	(mm^2)
I	20x8	21.49	21.21	21.11	**21.27**
	20x10	19.43	19.82	19.57	**19.61**
	20x12	45.77	45.07	45.95	**45.60**
	20x14	47.32	46.03	46.48	**46.61**
II	25x8	43.69	43.19	43.58	**43.49**
	25x10	33.4	34.39	34.15	**33.98**
	25x12	22.23	21.36	21.23	**21.61**
	25x14	16.89	16.63	16.21	**16.58**
III	30x8	43.13	43.44	43.09	**43.22**
	30x10	16.18	16.3	16.69	**16.39**
	30x12	16.95	17.17	16.98	**17.03**
	30x14	7.98	7.9	8.35	**8.08**

RESULT

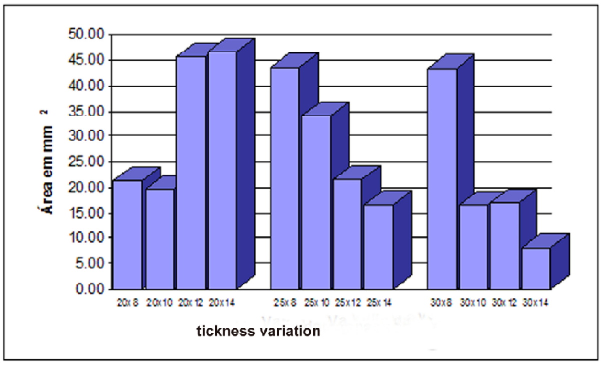
The axial loading of 100N generated stress in the apical region of the implant with similar pattern of fringes order.

The comparison of the photoelastic analysis among the models with same thickness and different height (20.0, 25.0 and 30.0mm) showed that the lower the height, the minor the representation of the selected area in the models with 8.0 and 10.0mm in thickness while inverse situation was observed for the models with 12.0 and 14.0mm in thickness (Graph 1).



Graph 1. Mean values of the areas generated under the second order fringe in each photoelastic model for same thickness and different height.

The same comparison among the models with same height and different thickness (8.0, 10.0, 12.0 and 14.0mm) revealed that, the thinner the model, the greater the representation of the selected area for the models with 25.0 and 30.0mm in height. A contrary tendency was observed in the models with 20.0mm in height (Graph 2). The evaluation of the mean values of the representation of the selected areas for each group regarding the height (20.0, 25.0 and 30.0mm) demonstrated that the greater the height, the minor the area. However, the models with 8.0 and 12.0 in thickness presented higher values in area. Table 2 shows the values of each reading and the mean values of each photoelastic model evaluated.



Graph 2. Mean values of the areas generated under the second order fringe in each photoelastic model for same height and different thickness

DISCUSSION

The results obtained in the present study demonstrate the applicability of the reflection photoelasticity for *in vitro* analyses. The method revealed the tension areas and the stress localization with loading of 100N. Recently, the planning for implant insertion results in situations similar to the axial load, which may reduce the marginal bone resorption.

The load applied to the photoelastic models generated internal stress that spreads according to the direction of the forces. The form and mode of support [7] were confirmed in the present study since the loading axial to the implant exhibited uniform stress distribution in the implant apex in all replicas regardless the dimensions.

Considering the areas measured in the group I with 20.0mm in height, the thicker photoelastic models presented the highest values in comparison to the thinner models. Contrary results were observed in the groups II and III with 25.0 and 30.0mm in height, respectively, as shown in Table 2.

The largest photoelastic model exhibited the minor area. This result is in agreement with the theory that states that the higher the volume of the photoelastic resin, the minor the plastic deformation of the material; which may influence the formation of the isochromatic fringes. Considering that the same load was applied to all replicas, the deformation in this thicker model was less intense and generated fringes representing less stress in the model tested. This phenomenon is also useful for the biomechanical analysis of the implant with the bone tissue. The extrapolation of the *in vivo* results indicates that the higher the volume of the bone tissue surrounding the implant, the better the biological performance; which guarantees that such load is tolerable.

The comparison among the models with 14.0mm in thickness demonstrated that the fringes areas gradually reduced when the height of the photoelastic model increased. Similar result was observed for the models with 12.0mm in thickness. However, the same observation was not supported by the other two thickness values evaluated in this study. So, it can be suggested that studies with thickness values lower than 12.0mm may compromise the validation of the results obtained with blocks of photoelastic models depending on the height. Thus, it was not established a direct relation between the area and the height of the photoelastic model since the thickness should be also considered.

The qualitative analysis revealed sharper isochromatic fringes in the smallest photoelastic models. This result demonstrated that smaller models can be used for analysis of stress generated by loading in implants through photoelastic studies. These smaller models allow more accurate evaluation of the real situation for the stress transmitted throughout the implant to the bone tissue.

However, the comparison between the smallest model (20x8mm) and the largest model (30x14mm), regardless the groups, showed significant difference between the areas selected in these photoelastic models. The models with 30.0x14.0mm exhibited an area three times smaller in comparison to the models with 20.0x8.0mm. This result represents an important clinical significance for *in vivo* analysis considering that implantation in reduced bone dimensions may generate higher stress.

There were significant variations between the largest and the smallest dimensions in each group, as shown in Table 2. This result has clinical significance to define values for the fringes. Besides, it should be considered the influence of the supporting base of the photoelastic models [7] that, under loading, exerts stress in the contrary direction and may influence the formation of the fringes, masking the visual analysis of the morphology of the photoelastic reflection. However, this does not occur *in vivo* since there is no supporting base but the muscular action in mandibular studies that may generate different stress regardless the presence of the implant.

So, although this study confirmed the applicability of the technique of photoelastic analysis that has been widely used in dentistry, this methodology should be carefully applied for the affirmation of its results.

CONCLUSION

According to the limitations of the present study, it was concluded that:

1. There was variation in the size of the areas analyzed for different height and thickness of the models;
2. It was observed that the smaller the photoelastic model, the smaller the area generated;
3. There is no direct relation between the height of the model and the area generated;
4. The morphology of the replica may directly influence the result in researches with photoelastic models.

RESUMO

Este estudo utilizou 12 modelos fotoelásticos com diferentes alturas e espessuras para avaliar se cargas axiais de 100N sobre os implantes alteram a reflexão fotoelástica. Para a análise fotoelástica os modelos foram colocados em um polariscópio de reflexão para a observação de franjas isocromáticas. A formação dessas franjas foi resultante de cargas axiais de 100N aplicadas no ponto médio dos pilares dos implantes com 10.0mm x 3,75mm (conexão, Sistemas de Prótese, Brasil). A tensão em cada modelo fotoelástico foi monitorado, fotografado e analisado com a utilização do software Photoshop 7.0. Para a análise qualitativa, a área sob o ápice dos implantes foi mensurada incluindo a banda verde da segunda ordem de franja de cada modelo utilizando o software Image Tool. Após a comparação das áreas, o desempenho gerado por cada espécime foi definida de acordo com a carga alxial. Houve alterações nas áreas com diferentes alturas e espessuras dos modelos fotoelásticos. Foi observado que o grupo III (30 mm em altura) apresentou a maior área. Houve variações no tamanho das áreas analisadas para diferentes alturas e espessuras dos modelos e a morfologia da réplica pode influenciar diretamente o resultado nas pesquisas com modelos fotoelásticos.

UNITERMOS: Implante dental, Prótese dental, Análise do stress dentário.

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