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ANALYSIS OF STRESS PRODUCED BY SPLINTED IMPLANTS WITH SOLDERED BAR

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Abstract. *Procedures in the construction of dental prostheses are associated with difficulties in fitting of the piece which are essential to long-term function. The inappropriate fit leads to stress causing micro-movements of the prosthesis components, breakage or screw loosening and osseointegration breakdown. The misfit can result from one or several steps followed in the metal framework casting. An usual method in Dentistry in order to minimize distortions and promote fitting is the cut and solder process. The purpose of the present investigation is to study, by the photoelasticity technique, the stress distribution generated by implants connected with a cast metallic bar that was later sectioned and soldered by a brazing torch. Six photoelastic models were built and two implants connected by a bar were fixed in each model simulating an overdenture framework. The models were evaluated in 25 points distributed along the fixtures and inter-fixtures space in two situations: under 20 Ncm torque and under l kgf loading. Despite greater gradients of strain have been consistently observed in the implant's apices, there was not uniformity in the fringes patterns developed in the six models, suggesting a lack of symmetry in the components fitting over the implants. It confirms literature statements which say that the brazing process can influence on strain levels becoming a procedure affected by the technique. Stress patterns can be accumulative under external loading.*

Keywords*: implants, soldering, fitting, photoelasticity.*

1. Introduction

The recognizing of the biocompatible union between bone and aloplastic materials generated a great number of new procedures to Dentistry. The use of implants to support and retain dental prosthesis has been demonstrated to be an effective clinical procedure.

Despite the implant/bone be today a trustfully reality, clinical complications could and have been occurred in the prosthetic level. The rigid union between bone, implant and prosthesis results in the formation of a structure behaving like one, then any misfit between the system components generates internal stresses on the prostheses, implant and/or bone (Skalak, 1983). The superposition of masticatory functional loads creates additional stresses which affects the entire group (Carlsson, 1994; Hussaini and Wong, 1991; Sahin and Cehreli, 2001; Wee, Aquilino and Schneider, 1999). Although the technological advance in the fabrication of the metal structure, the 'ideal seating', free of stress, is considered one of the most important requirement to the bone/implant interface maintenance, could not be reached yet.

Technical problems during the prosthesis fabrication process still have not been resolved, frustrating clinics and patients. The literature suggest that dental prostheses, especially the implants supported, show passive seating to prevent prosthetics complications such as implant fracture and/or the components, screw lose, bone loss, osseointegration failure (Hussaini and Wong, 1997; Kan *et al*., 1999; Romero *et al*., 2000; Sahin and Cehreli, 2001; Wee, Aquilino and Schneider, 1999), and misfit could be associated to biological complications like discomfort and pain (Kan *et al*., 1999; Wee, Aquilino and Schneider, 1999).

From the practical point of view, the prostheses confection by lost wax, witch completely passive seat is impossible to be reached (Carlsson, 1994; Goll, 1991; Huling and Clark, 1977; Hussaini and Wong, 1997; Kan *et al*., 1999; Romero *et al*., 2000; Sahin and Cehreli, 1999; Schiffleger *et al*., 1985).

The sequence of technical, clinical and laboratorial procedures to develop the prosthesis obtainment adds risks of distortions in each stage. Then, the implants alignment, the dimensional alterations of the molding materials, the waxing, the inclusion and casting, the materials, indexing and soldering procedures, the extension and configuration of the prostheses and even the experience of the involved professionals influence at the precision of the piece seating (Goll, 1991; Kan *et al*., 1999; Romero *et al*., 2000; Saito, 1972; Wee, Aquilino and Schneider, 1999). Many methods have been used trying to get a better possible seating of the prosthetic framework being the cutting and soldering procedure the most usual.

The purpose of the present work was to evaluate the stress gradient generated in a prosthetic systems called overdenture supported by Dolder type bars. In this case, the stress generated after the cutting and soldering process of the bars, using the experimental technique of the plane transmission photoelasticity. To this work, six Dolder type bars were screwed, one by one, over two implants included in blocks of photoelastic material. Externals loads were applied to the bars, simulating masticatory loads, looking to verify the contribution of the residual stress of the brazing process over the final stress gradient. The laboratorial model chosen (implants connected by bars) to quantify and qualify the distortions caused because of the soldering technique, usually used in prosthetic laboratories and taught in the Dentistry schools, intend to collaborate with knowledge to a better patient health rehabilitation, when the prosthetic option are included in the Implantodontology area.

2. Material and methods

Six models of acrylic resin were made with the dimensions of 58.0mm (length) x 20.0mm (height) x 8.00mm (thickness). Two perforations were made on the 58.0mm surface of each, this were used to insert implants of 3.75mm diameter and 13mm length from the Conexão Sistemas de Prótese (São Paulo, Brazil), they were parallel and distant, in medium, 24.0mm each other, over the implants two abutments UCLA type connected by a circular section bar Dolder type were adapted. Three of the master models with two implants, two UCLA cast abutments and one bar, have the abutments/bar group cast in Nickel-Chrome and three acrylic master models with two implants, two UCLA abutments with metallic band and one bar, have the abutments/bar group cast in Palladium-Silver (Fig. 1). This prosthetic configuration copy an overdenture, kind of prosthesis mucosa supported and implant retained frequently used at the mandibular anterior region, which have been demonstrated an excellent functional and aesthetic resolution because of it results in retention and stability of the prosthesis, and permits removal to hygienic procedures. The abutments/bars groups were removed from the implants, the bars were sectioned with a 0.22mm thickness disc, the pieces were replaced on the models, screwed, with a torque level of 20 Ncm and indexed with autopolymerized acrylic resin (Fig. 2). Silicon models from the master model/implant/abutment/bar group were obtained (Fig. 3) containing the groups implant/abutment/bar, which served subsequently to the confection of the photoelastic models.

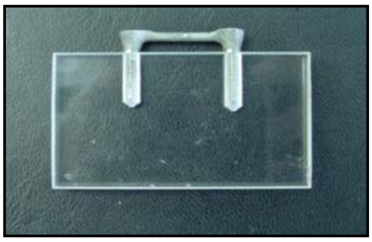

Figure 1. Acrylic master model.

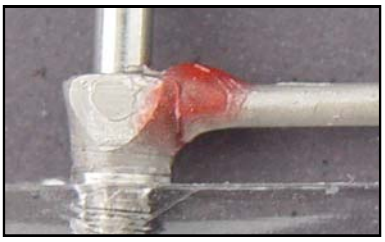

Figure 2. Sectioned and indexed bar.

Figure 3. Silicon model.

Six photoelastic models with the implants/abutments/bars were obtained from the silicon models. A circular photoelastic model was used to calculate the optical constant (K) of the resin. The used resin was commercially sold by the name Adesivo para Brinde Flexível Componente A (base) and Adesivo para Brinde Flexível Componente B (catalyst) fabricated by Polipox Indústria e Comércio LTDA, at the proportion of 2/1 (Oliveira, 2003).

The photoelasticity is an experimental technique to determine the stress field and strains, extremely useful with complex geometry bodies, complicated load situations, or both. The name photoelasticity explain the nature of this experimental method, 'photo' because of the use of the light and optical techniques, while 'elasticity' describes the stress and strain study. It permits analysis of high and low stressed areas. This technique is based on the optical anisotropy, propriety of certain transparent materials that, when under stress, show different light refraction index, different propagation velocity, which determine a relative late of the light bolts. Then, many optical phenomenons could be perceptible, and they were determined fringes, resulted from this different refractions index (Dally and Riley, 1978).

Before they were removed from the silicon models, the photoelastic models with the implants/abutments/bar group were numbered from 1 to 6 and marked on the indexed side for future soldering. Any stress that, eventually, could be from the dimensional alteration promoted by the acrylic resin polymerization to the indexing of the bars were eliminated, this because the photoelastic models were obtained after the cutting and indexing procedure. When those models were brought to the polariscope, no stresses were observed in the models, because of the lack of fringes during the observation. Before all those procedures, the bars were taken to the prosthetic laboratory to soldering.

At the prosthetic laboratory, the working screws of the implants/abutments/bar group were unscrewed, the bars were removed and include in specific compound (Heat Shock – Polidental Indústria e Comércio LTDA) to casting and with total expansion near of 2.0%. The compound manipulation was made adding powder and water in the proportion indicated by the fabricant, small blocks of 40.0mm length and 15.0mm extent, in medium, in which the bars were included. Before ready, the compound blocks were reduced, getting rectangular form.

Small channels were made under the indexed regions, to permit a free 'running' of the solder (Fig. 4). After the compound tusk, the bars were taken to the door of a furnace Bravac pre-heated to 300°C during 20 minutes, permitting the thermal expansion of the compound, and after that the door was closed and the temperature was elevated to 700°C during 30 minutes, to volatizing of the acrylic resin used at the indexing of the parts. During the wait time of the resin burn, the propane-oxygen blowtorch was prepared, adjusting it with the reducing flame to avoid oxidation of the metal. To the models 1, 2 and 3, cast with Ni-Cr alloy, Suprem Hi-fusing Pre-solder (Talladium) was selected, specific to soldering of ceramic metals non precious (Ni-Cr) and to the models 4, 5 and 6, cast with Pd-Ag alloy, the used solder were Degudent U1 (Degussa Dental AG – Germany), specific to precious metals, including the Pd-Ag. The used flux for all bars was the Talladium Hi-Tech pre-flux, added simultaneous to the sold, in which stick was delicately involved. When all the index resin was volatized the bars included in the compound were removed, one by one, from the furnace and deposited in refractory blocks, under the action of the reducing flame of the blowtorch, drove in the superior direction and with little angled in relation to the soldering place, until the piece turned its color to intense flaming red (Fig. 5), when the soldering was being done, at the opposite site of the flame direction (Anusavice, 1998; Kataoka, 1991). The soldering procedure timed 30 seconds, what accords with Ryge (1958). Those technical procedures obeyed the used protocol of the laboratory.

The bars were removed after cooling to ambient temperature, receiving finishing and polishing.

Figure 4. Channels under index region.

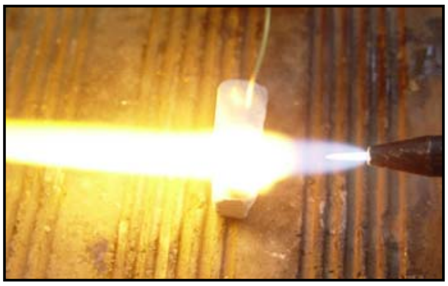

Figure 5. Soldering process.

2.1. Plane transmission photoelasticity

The photoelasticity have been used as a research technique in situations where there is necessary knowledge about a stress field. The methodology consists in build, with a specific material, a bi or three-dimensional reproduction of the model to be studied. This model, being submitted to external loads and passed throw by a polarized light presents fringes that could be quality and quantity analyzed. The number of those fringes multiplied by a calibrated factor, result the internal stresses with correspond to the original prototype, if it is submitted to proportional loads (Dally and Riley, 1978). According to Caputo e Standlee, in 1987, the photoelastic effect is the generated image by the difference between the light velocities, when passing throws a solid object under stress. Such authors established the proportionality between fringe numbers and intensity, as well as proximity of the fringes and stress concentration. The most important characteristic of the photoelastic materials, according to Oliveira e Gomide (1990) is the result to stress/strain by the changing of the refraction index, in the direction of the main stress. Those materials, when under stress/strain conditions, passed throw by polarized light and observed in an apparatus called polariscope, permit the verification of the stress by the interpretation of the optical photoelastic parameters observed. In situation that the used light is the common, the optical effects evidence like color fringes (isochromatics) and when the used light is monochromatic, there is an alternate sequence of white and black fringes which have an order number at a point, depending of the load intensity (isoclinic).

After the soldering of the bars, they were screwed on their receptive models, at a torque level of 20 Ncm and took to the circular polariscope to do the reading of fringes and obtainment of the results. Considering that the used polariscope increased the image 10x, and purposing to establish and standard a way of analyses, a reading rail with the compatible increase was made (Fig 6). The rail was placed over the polarizing filter of the polariscope and perfectly adjusted over the analyzed image, establishing, then, a protocol to read the stressed points over the line which traversed the external surface of each implant, being used the field between the two implants connected by the soldered bars either (Fig. 7).

Each model was read two times, at 25 points, being 10 of them over the implant A body (left), 10 over the implant B body (right), and 5 between the two implants.

With the aim of make easy the analysis and discussion of the results, agreed on that the external surfaces of the implants A and B would be called of distal side and the internal surfaces, turned to the inter-implants region, of medial side. The first read of the models was realized without load and, to the second read, a load of 1 Kgf with a cell load Kratos was applied over the center of the bars. Data of the direction of main stress (isoclinic) were obtained of each analyzed point, by those the full and fractioned fringe orders (N) were possible to be determined, using the Tardy compensation method (Dally; Riley, 1978).

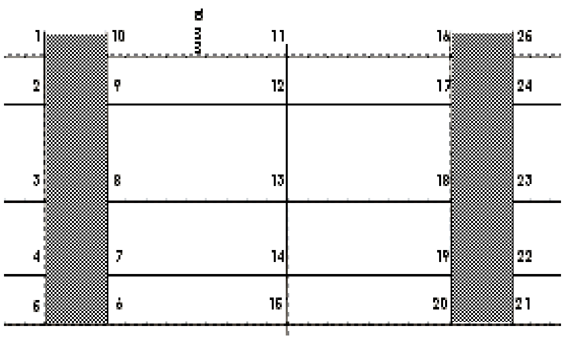

Figure 6. Reading rail.

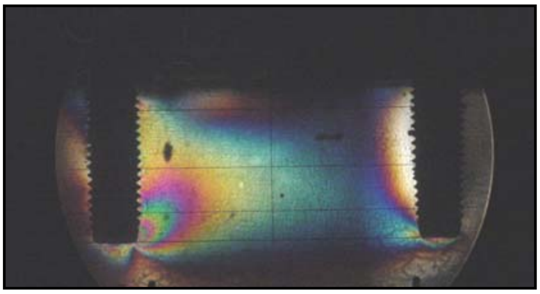

Figure 7. Reading rail over the image.

Considering that the main characteristic of the photoelastic materials is the fact that they respond to stresses/strains changing their refraction index of light at the directions of the main stresses and that the difference between the index of refraction on the two main plans is proportional to the difference of the main stresses, in any point of the model, the color combination is uniquely in function of σ_1 - σ_2. The stress optical law is given by:

$$\frac{\sigma_1 - \sigma_2}{2} = \tau = \frac{K\sigma\, N}{2h} \qquad (1)$$

where σ_1 and σ_2 → main stresses at the point;

K_σ → optical constant of strains, it is a constant established by calibration and depends of the material and the length of the wave light used;

N → fringes order at the point;

h → thickness of the model.

A calibration disc, already mentioned in this work, was submitted to a compression load P looking to obtain the K value of the resin used in the present research. The optical constant (K_σ) obtained was 0.25 Nmm. Because of the maximum shear stress depends only of the difference of the shear stress, this could be determinate in all extension of the model.

3. Results and discussion

One of the techniques most routinely used in Dentistry to correct the distortions of cast metallic frameworks and to promote highest fitting precision is the cutting and soldering. The present work evaluated the soldering laboratorial procedure of a cast metallic bar Dolder type, verifying possible dimensional alterations, by analyzing possible generated strains. A specific framework to rehabilitations with overdenture was used, and in those the bar is straight, with small metal quantity, uniform thickness and is accommodated only on two implants. To effective the analysis, the fringes comportment was verified in their most critical situations. The reading rail was positioned over the out screen of the outline project, using the neck of the implants as reference to their positioning, in the way that, by the insertions of the models, all analyzed points had the exactly same distance, for all the analyzed points. After that, the maximum shear stresses (τ) of each point were determinate, according to the techinique of plane transmission photoelasticity. The Figures 8 and 9 show the fringes patterns developed in one of the models, respectively without and with the load applications and the Fig 10 and 11, de values of (τ) were obtained from the reading of the referred model, under the same conditions; such values were analyzed and compared with the observed in the others models.

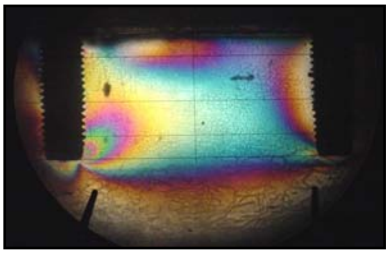

Figure 8. Model 2, without load.

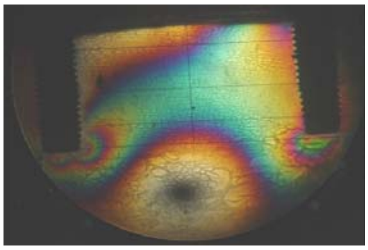

Figure 9. Model 2, with load.

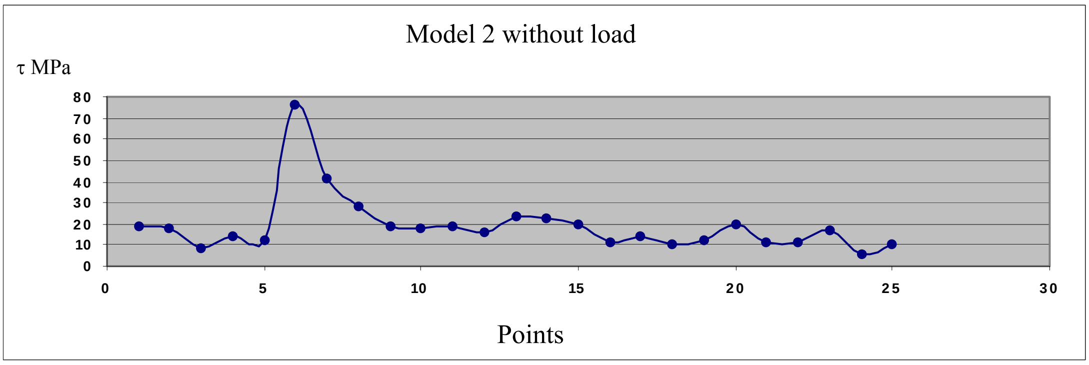

Figure 10. Maximum shear stresses values generated in model 2.

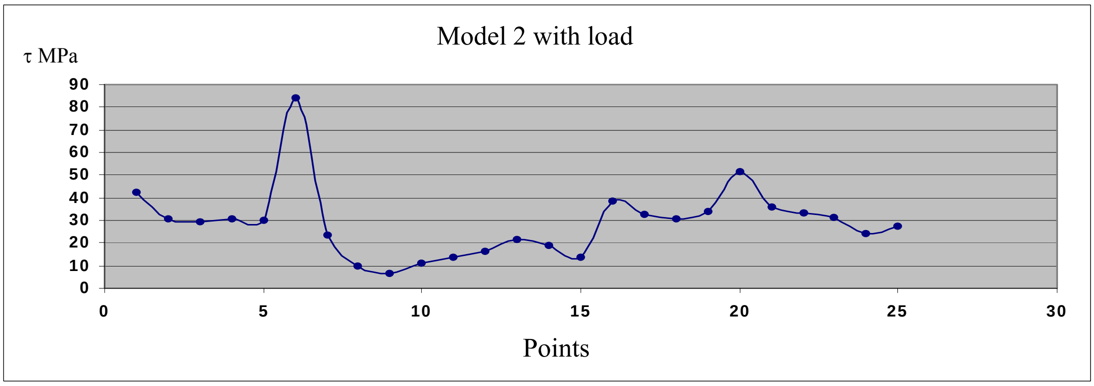

Figure 11. Maximum shear stresses values generated in model 2, with 1 Kgf load.

The point 6 presented a value of (τ) equal to 76.59 MPa. The point 13, with (τ) equal to 23.90 MPa, was localized in the inter implant region and was the second most stressed from the model 2, without load. The medial site of the implant B apex, presented either the higher value of (τ) = 20.06 MPa, but the distal side of the same implant, point 21, presented values near to zero (τ) = 10.82 MPa. When under load, the fringe pattern increased and the values of (τ) passed 80.0 MPa, being the critical points correspondent to the implant A and B apex points Then, the point 6 (medial apex of the implant A), demonstrated (τ) = 84.33 MPa; the point 16, (medial implant neck of the implant B), with (τ) = 38.73 MPa and the points 19, 20 and 21, which margin all the apex of implant B, presented values between 33.0 and 52.0 MPa. Under load, there was small reduction of the fringes at the inter implant region.

The comparison with the others models demonstrated that the models with numbers 1, 3 and 4, in a 20 Ncm torque level and not loaded, presented stress gradients near to zero, even at the around regions to the implant apex where in spite of to be significant higher, they got a maximum value of shear stress of 20 MPa. Considering that the simple screwed and torque already induce stress to the system (Carlsson, 1994; Wasckenwicz, Otrowsky and Parks, 1994; Watanabe *et al.*, 2000), there was to expected that some quantity of stress were, really, observed, even with lack of misfits. But differently, the models 2, 5 and 6 presented the higher gradient of stress, in some points near to 80 MPa, in absent of external load. The meaning of so different results was searched with many investigations, in the literature, under the same causes frequently related as promoter of misfits.

4. Conclusions

Within the limitations of the present work it could be concluded that:

•The usual soldering process with blow torch leads to dimensional alterations, it because all models presented some stress gradient;

•Fringes were observed over many places in the model, but the apex region of the implants was the most stressed, in all samples and situations;

•The lack of uniformity of the fringes localizations suggests that the dimensional alterations are random;

•The cast prosthetic framework with Ni-Cr based alloy demonstrated maximum shear stress gradient in medium between 8% and 10% higher, indicating to a higher dimensional alteration of those alloys;

•The 1 Kgf load appliance changed the stress gradient suggesting that small difference in height and/or inclination of the implants could produce unequal force distribution between the system components;

•The dimensional alteration looks to depend less from the used material, which were the same for all models, than the technique.

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