Original Article

Braz J Oral Sci.
January/March 2010 - Volume 9, Number 1

A comparative study of microstrain around three-morse taper implants with machined and plastic copings under axial loading

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Abstract

Aim: To evaluate the occurrence of microstrain around morse taper implants in straight configuration under axial load in a cast monoblock framework. **Methods:** Three implants were inserted in a polyurethane block and microunit abutments were installed on the implants with 20 Ncm torque. Plastic and machined copings were adapted on the preset waxing to fabricate the framework (n=5). Four strain gauges were attached on the upper surface of the block and then each framework was tightened on the abutments and a vertical load of 30 kg was applied to five points of the framework. **Results:** The data obtained in the strain gauge analysis were subjected to two-way ANOVA and Tukey's test (α=0.05). There was statistically significant difference (p=0.0222) for the factor application point and the mean microstrain values were: application point B 402,04µε, point A 401.21µε, point E 390.44µε , point D 341.76µε and point C 309.19 µε. **Conclusions:** There was no microstrain difference between plastic and machined copings during axial loading. Difference in the application point was observed, but remained within bone physiological limits.

Keywords: dental implant, fixed prosthesis, axial load, strain gauge, morse taper.

Introduction

The use of oral implants for rehabilitation has become a clinical routine. The abutment/implant connection must have the ability to reduce the stress peak and strain at the bone interface.

The design of morse tapered implant posts is characterized by the internal walls of the implant and the external walls of the abutment fabricated with an 8° taper. During the abutment threading in the implant body, there is an intimate contact between the two components, creating frictional lock[1]. This design promotes significant retention and resistance under lateral loads creating frictional adaptation to the internal anchorage or implant body, allowing for an extended duration of function[2].

The prudent control of biomechanical loading in dental implants is imperative for their extended success[3]; if the loading is not controlled, implant failures can occur after delivering of the prostheses. Although the mechanisms responsible for failures are not completely understood[4], a consensus exists that the localization and magnitude of occlusal loading affect the quality and amount of induced strain in all the components of the prostheses/bone/implant complex[5-7].

Received for publication: August 06, 2009
Accepted:: March 11, 2010

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The application of functional load induces stress and strain in the bone/implant complex and affects the periimplant bone remodeling[8-9]. The fraction of this occlusal load transmitted to the implants, and its induced stress, is dependent upon where the load is applied to the prostheses[7]. Excessive loading on the bone/implant interface is one of the main factors accounting for marginal loss bone, motivating this current strain study[10].

The transference of occlusal loading can be influenced by factors related to the precision of the implant/abutment and abutment/prosthesis interfaces. The coping is one of the factors responsible for the precision, and machined copings have higher precision than plastic copings[11-12]. Moreover, these authors reported that the precision of copings is associated with the distribution of stress, demonstrating the importance of comparing the precision between plastic and machined copings.

Some implant failures can be related to unfavorable stress magnitudes[13]. When pathologic overload occurs, above 4000 µå, gradients of stress and strain exceed the physiologic bone tolerance and cause micro fractures in the bone/implant interface[14]. Occlusal overload results in an increase of bone resorption around the implant and a decrease in the percentage of mineralized bone tissue[15], showing that a remodeling process occurs when the bone is subjected to stress[16-17].

The aim of this study was test the hypothesis that different application points promote similar microdeformations, but machined copings are preferred over plastic copings to reduce the occurrence of these microdeformations.

Material and methods

An aluminum matrix with internal dimensions of 95 x 45 x 30 mm was developed for this study. Identical proportions of base and catalyst of a polyurethane resin (F16 Axson, Cergy, Lle-de-France, France) were mixed until a homogeneous mixture was obtained. After resin polymerization, the surfaces were polished with wet 220- to 600-grit abrasive papers to obtain flat surfaces, free of irregularities. A second aluminum matrix was used to standardize the linear placement of three implants in the polyurethane block as well as to standardize the waxing of the frameworks (Figure 1).

The distance and places for inserting the three cone morse implants (Conexão Sistemas de Prótese, São Paulo, SP, Brazil) in the polyurethane block was standardized by fixing component 3 in the block with horizontal screws and rings identified by colors with internal diameters compatible with the diameters of the burs used: white, yellow and blue rings with diameters of 2, 3 and 3.15 mm, respectively. A handpiece with 20:1 reduction (Koncept, Kavo Ind.Com Ltda, São Paulo, SP, Brazil) connected to an electric engine (MC 101 Omega, Dentsclar, Ribeirão Preto, SP, Brazil) was used to perforate and insert the implants. Mean speed for inserting the implants was 14 rpm and torque was adjusted to 40 Ncm. Three morse taper implants (3.75 mm in diameter x 13 mm long; Conexão Sistemas de Prótese) were placed in the polyurethane block. Microunit abutments (Conexão Sistemas de Prótese) were screwed into the implants with torque of 20 Ncm as measured with a manual torque meter (Conexão Sistemas de Prótese).

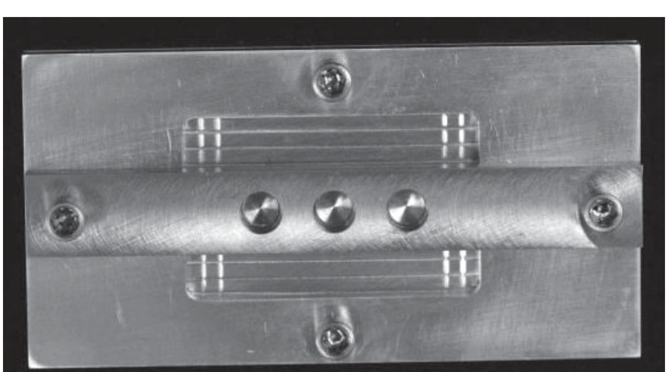

Fig. 1 – Matrix: 1- base with in line cylinders (3.75mm diameter x 4 mm height). 2: component with central opening level with the height of the cylinders. 3: rectangular bar with 3 holes coinciding with the location of the cylinders. Lateral screws to keep the three components stable.

Before adapting the waxing standardizations, the copings were reduced with the aid of a carborundum disk (Dentrium, New York, NY, USA) to a height of 10 mm in order to facilitate and level the insertion of the waxing. A heated dropper-type instrument was used to promote peripheral sealing of all copings (PK Thomas type waxing set: SS White, Rio de Janeiro, RJ, Brazil). Then, 10 waxed were cast in Co-Cr, being 5 for plastic copings (n = 5) and 5 for machined copings (n = 5). The waxings of the frameworks were standardized by using the base (component 1) and component 2 which, when fixed by vertical screws, resulted in a rectangular compartment that allowed a systematic reproduction of the waxing of all the tested specimens, especially in terms of thickness.

Cr-Co alloy (Wirobond SG, Bremen, Bremen, Germany) was used for casting. The frameworks were individually adapted to the polyurethane block, in which the stability of the set was gauged by tightening the screws. The screw tightening sequence was standardized from the center to the edges of the piece, starting with the central implant 2, followed by lateral implants 1 and 3[18].

In order to determine exactly the bonding place of four strain gauges (Kyowa Electronic Instruments Co., Ltd, Tokyo, Kanto, Japan), a line was drawn with a ruler and a 0.7 mm lead pencil. The four strain gauges were bonded along this line tangential to the abutments with a thin layer of cyanoacrylate adhesive (SuperBonder, São Paulo, SP, Brazil) under slight pressure for 3 min. After bonding, each strain gauge was measured by using a multi-meter appliance (Minida ET 2055: Minida São Paulo, SP, Brazil), and the terminal plates to which the electric connections were adapted, were bonded onto the upper surface of the polyurethane block (Figure 2).

The linear electric strain gauges were connected to an electric signal conditioning appliance (ADS 2000IP; Lynx, São Paulo, SP, Brazil), arranged in a ¼ Wheatstone bridge configuration with 120 &! resistance , which is an electric circuit appropriate for detecting minimal alterations in resistance caused by deformation. The signals were interpreted, modified and processed by using a Strain-Smart computational program.

An idealized load application device was connected to

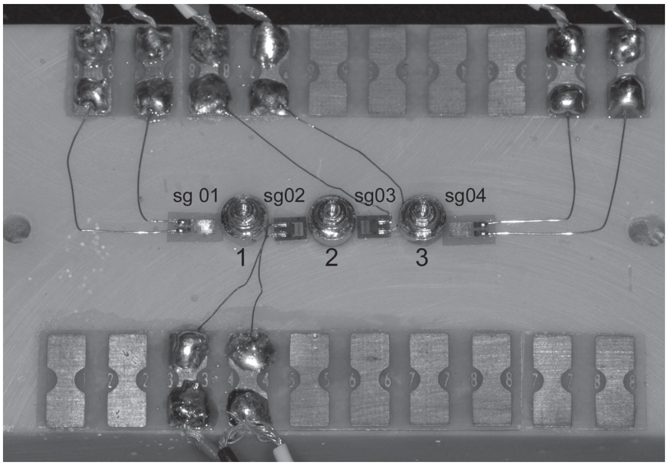

Fig. 2 - Strain gauges around the microunit abutments.

the electrical signal conditioning appliance (Model 5100B Scanner; System 5000, Raleigh, NC, USA) in order to apply the load. The experimental model was placed on the load application appliance (Figure 3) with the framework in place, on which axial loads of 30 kg[19] were applied for 10 s on the center of each implant and on the mid-point between them, totalizing 5 load application points. The points referred to were designated as: A (Center of the retention screw of implant 1), B (mid-point between the orifices of the screws of implants 1 and 2), C (center of the retention screw of implant 2), D (mid-point between the screw orifices of implants 2 and 3) and E (center of the retention screw of implant 3) (Figure 4). The measurement of points (B and D) between two implants was checked with a ruler. The microdeformations determined at the five points were recorded by four extensometers and the same procedure was performed for all the frameworks, repeating three loadings per load application point.

The data obtained in the strain gauge test were subjected to two-way (*coping* and *application point*) repeated-measures analysis of variance (ANOVA), and Tukey's multiple-comparison test was used to determine the occurrence of statistically significant differences. A significance level of 5% was adopted

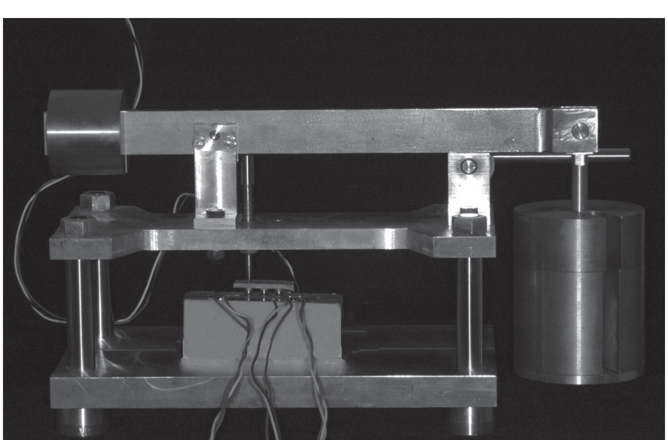

Fig. 3 - Experimental model in the loading apparatus with load applied at point A.

Results

The two-way ANOVA revealed that the interaction between factors was not significant (p = 0.0699) and the factor *coping* was not significant either (Table 1). But application point factor (p = 0.0222) show significant influence on the microstrain. Then, the Tukey's test was realized according Table 2.

The mean strain values for the interaction factor between cooping and load point are presented in Figure 5.

Discussion

Since the introduction of osseointegration, dental implants have been widely used in the rehabilitation of partially or completely edentulous patients[20], and showing the success of implantology for prosthetic treatments in modern dentistry[21]. In spite of this, implant failures might occur after delivery of prosthesis, and have been reported to be mainly due to biomechanical complications[4].

Occlusal overload has been identified as the primary cause of loss of Peri-implant bone, implants and implant supported dentures[10,22]. The extensometers used in Implant Dentistry are based on the use of electrical resistance and the association of equipment promoting measures of strain induced by static and dynamic loads both *in vivo*[23-24] and *in vitro*[7,25]. Under an applied force, the strain gauge measures the mean dimensional change[5,7].

Bone quality is one of the factors that influence in the result of the treatment with implants. The bone surrounding them does not constitute a homogeneous substratum and its physical properties vary as the age, functional state and systemic factors of the patient[13]. Moreover, *in vitro* studies have used homogeneous and isotropic materials[25-26].

In the present study, a homogeneous model with uniform elastic properties was designed[11], and a polyurethane block with similar modulus of elasticity to that of the human medullary bone was used to simulate the human bone (Polyurethane: 3.6GPa/medullary bone: 4.0 4.5Gpa)[17].

Some strain gauge studies used special devices for load application on implants[7], but others used universal testing machines[26] to apply load. The amount of load used in this experiment, 30 kg (approximately 294N), was based on the study by Merick-Stern et al.[19], who investigated the occlusal force in patients with fixed partial implant-supported dentures, and found a mean value of 30.6 kg (300N) for maximum force in the region of the second molars.

Placement of extensometers on the surface of the polyurethane block, adjacent to the cervical area of the implant is justified because in this region there is higher stress concentration after load application[25]. Other studies opt for bonding the extensometers onto the implants[22] and on the metal structures of the denture[24], but bonding on the surface simplifies the procedure.

The aim of the methodology used in this study was to eliminate steps that would promote dimensional alterations, such as those resulting from the transfer molding of implants and obtaining the plaster model. The plastic and machined copings were adapted directly onto the implants and joined

Table 1 – Results of two-way analysis of variance for conditional experiments.

Effect	df	SS	MS	F	P-value
Cooping	1	25222	25222.2	1.22	0.3014
Residue I	8	165304	20663.0		
Application Point (AP)	4	70280	17570.0	3.32	0.0222*
Interaction (cooping/ AP)	4	51013	12753.1	2.41	0.0699
Residue II	32	169575	5299.2		
Total	49	481394			

*p<0.05.

Table 2 – Results of Tukey's test for the mean microstrain values at five load points.

Application Point	Mean	Homogeneous Group
B	402.04	A
A	401.21	A
E	390.44	AB
D	341.76	AB
C	308.19	B

*Same superscript letters indicate no statistically significant differences (p>0.05).

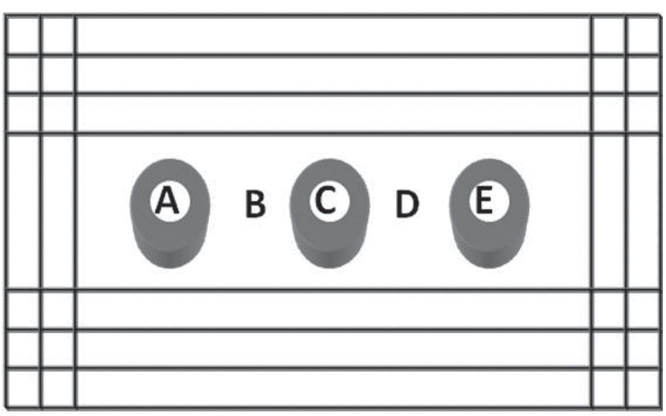

Fig. 4 - Five points of load application (A, B, C, D and E)

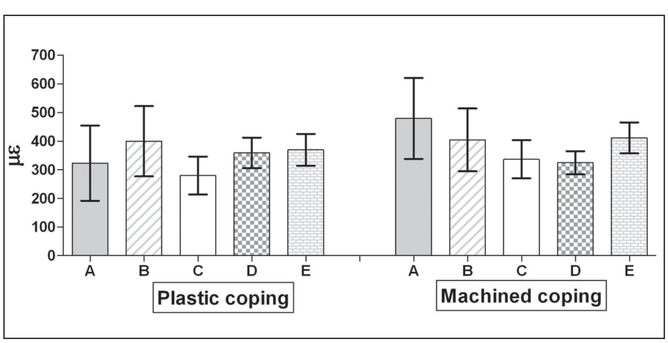

Fig. 5 - Mean values and standard deviations of the microstrain (με) for plastic and machined copings in each load point.

to the standardized waxing. This method was based on the study by Heckmann et al.[11], who recorded that metallic structures fabricated on the plaster model produced larger deformations when compared with those made without the molding procedures.

The mean microdeformation with reference to the interaction of the coping and the load application point, observed in Figure 5, showed that the copings had the same deformation pattern, and showed no significant difference. These results are in agreement with those of previous strain gauge studies, in which the fixed partial implant-supported dentures made from plastic and machined copings produced the same magnitude of microdeformation during retention screw tightening, before ceramic application[10-11].

Based on the physiological balance, clinical and laboratory studies indicate that permanent mechanical stimulation is needed[21]. Deformation intensities above 100 µå are necessary to prevent bone resorption. However, the stimulation values must not exceed the physiological limit of 4000 με[16-17].

The reason for casting the structure in a monoblock configuration is based on the study by Watanabe et al.[27], who verified that monoblock castings do not differ from those made in segments and later welded as regards the distribution of stresses on screwed implant-supported dentures. The structure in this study was made in a flat shape due to the need to evaluate axial loads, because the inclination of the cusps would generate horizontal force and the magnitude of axial loading would be altered[3].

The data on Table 1 shows significant difference (p = 0.0222) for the load application point effect and the Tukey's multiple comparison test (Table 2) verified that there was no homogeneous distribution of microdeformation among the groups[28-29], probably due to the absence of absolute passive seating, suggesting that clinical evaluation to verify passive seating allowed small distortions that were not perceived by the visual method[30]. Casting of the metal structure is a determinant step in the influence of passivity determining a non-homogeneous seating of the structure. This is because the fit obtained in implant 2 could have been different from the one achieved in implant 1 and from the one seen in implant 3, hence justifying stress generation and producing a different microdeformation distribution for the various points of load application.

The rationale for the parameters of this investigation, considering the type of coping and place of load application, is based on the idea of choosing the best option when performing a treatment with a three-element fixed partial implant supported denture, to allow long term clinical success. According to the pertinent literature, determining the best option continues to be a vital question for retrospective and prospective clinical studies supported by in vivo and in vitro biomechanical studies.

Within the limitations of this study, it may be concluded that the type of coping used, plastic or machined, did not interfere in the level of microstrain at the time of axial load application. However, the place of axial load application had a direct influence, and axial loads applied on different application points produced a magnitude of bone microstrain within the physiological threshold.

Acknowledgments

The authors wish to thank FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo – Protocol #07/57696-6) for the financial support and Conexão Sistemas de Prótese for providing some materials. The authors also express their gratitude to Professor Ivan Balducci.

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