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Influence of angulation and vertical misfit in the evaluation of micro-deformations around implants

Influência da angulação e desajuste vertical na avaliação de microdeformações ao redor de implantes

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ABSTRACT

Objective: This in vitro study was to evaluate micro strains around of implant, under the influence of angulations and vertical misfit in three-element implant-supported fixed partial dentures during axial loading by using strain gauge analysis. **Material and Methods:** Three external hexagon implants with straight configuration and three external hexagon implants with angled (17°) configuration were inserted into two polyurethane blocks. To measure micro strain, four strain gauges were bonded onto the surface of each block. Plastic copings were adapted to a standard wax pattern and cast. An axial load of 30 kgf was applied on the center of each implant for 10 seconds, using a load application device. The vertical misfit was measured at six different points by using a stereo microscope with 100-X magnification. **Results:** The results showed that the values for different implant angulations were significant ($P = 0.0086$). The Pearson's correlation test between micro-strain and vertical misfit revealed no correlation between angled configuration ($P = 0.891$) and straight configuration ($P = 0.568$). **Conclusion:** The micro strain was higher for angled implants; no correlation was found between the vertical misfit and the strain values.

KEYWORDS

Biomechanics; Dental implants; Dental prosthesis.

RESUMO

Objetivo: Este estudo in vitro avaliou as microdeformações em torno de implantes, sob a influência da angulação e do desajuste vertical em próteses parciais fixas implanto-suportada de três elementos, durante uma carga axial por análise de extensometria. **Material e Métodos:** Três implantes de hexágono externo com a configuração linear e três implantes de hexágono externo angulado em 17 °, foram inseridos em dois blocos de poliuretano. Para medir a microdeformação, quatro extensômetros foram colados sobre a superfície de cada bloco. Coifas plásticas foram adaptadas a um padrão de resina e fundidas posteriormente. Uma carga axial de 30 kgf foi aplicada sobre o centro de cada implante durante 10 segundos, usando um dispositivo de aplicação de carga. O desajuste vertical foi medido em seis pontos diferentes, utilizando um microscópio estéreo com 100 X amplificação. **Resultados:** Os resultados mostraram que os valores para diferentes angulações de implantes foram significativos ($P = 0{,}0086$). O teste de correlação de Pearson entre deformação e desajuste vertical revelou não haver correlação tanto para o grupo angulado ($P = 0{,}891$) quanto para o grupo linear ($P = 0{,}568$). **Conclusão:** As microdeformações foram maiores para os implantes angulados; nenhuma correlação foi encontrada entre o desajuste vertical e os valores de microdeformação.

PALAVRAS-CHAVE

Biomecânica; Implantes dentários; prótese dentária.

INTRODUCTION

Strain gauge analysis is a technique for measuring deformations applied in mechanical engineering that employs a device to provide specific measures of strains under static or dynamic loading [1-4]. Strain gauges have been employed to record the strain's area, capturing change in the low current resistance; the data are subsequently processed and converted from analogic to digital [2,3]. This methodology has been applied in several studies in the field of dentistry [4-8].

Angled abutments are used for prosthetic corrections when it is not possible to correct the angulation of implants without grafting procedures due to a narrow alveolar ridge, leading to installation of implants in unfavourable prosthetic inclinations [9,10].

The biomechanical aspect plays a key role during rehabilitative treatment with dental implants. Functional loads are transmitted from the prosthesis to the supporting bone [11]. Bone resorption and loss may occur around the implant when the micro-strain exceeds the tolerable physiological limits of 4000 $\mu\varepsilon$. [11,12]

Studies carried out by using the principles of the strain gauge demonstrated favourable results for the clinical use of angled implants. Changes in the implant's angulation during installation can affect the distribution of stresses presented along the implant/bone interface. [13,14]

Vertical misfit between the metal structure and implant is another factor that was shown to influence the strain values around implants. [15] This misfit can create an increased instability and tensions in screws once the passivity of abutments is altered. [16]

This precision of the abutment/implant interface can influence the transfer of occlusal loads may be influenced by factors related with the accuracy of copings, once the machined structure is more precise than plastic copings. [17,18]

Further, the literature on this topic presents questions and contradictions for the optimal positioning of implants [17,18]. Studying the micro-strains around different prosthetic connections represents an effort to determine the physiological parameters as well as the levels that may be considered detrimental to the bone. The purpose of this in vitro study was to evaluate micro-strains around of implant under the influence of angulations and vertical misfit in three-element implant-supported fixed partial dentures during axial loading by using strain gauge analysis. The following hypotheses were formulated: The inclined position of the implants at 17° will not increase the values of micro-strain around the implants; the vertical misfit of the metal structures will influence the values of micro-strain.

MATERIAL AND METHODS

Specimen preparation

Two polyurethane blocks with dimensions of 70x40x30 mm were used for the insertion of three external hexagon implants (3.75x10 mm; AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brazil). In one block, the insertion of implants follow a linear configuration inclined at 17° to the side of the block. In the other block was used implants inserted in a linear configuration, parallel to each other and perpendicular to the surface of the block.

A metallic index [5] was used to standardize the perforations linearly and perpendicularly to the surface of the blocks. For drilling the block with angled implants, a second index with a 17° angulation was machined from stainless steel; the dimensions of the first index were followed so that it fit under the previous index, and the entire set was modified to a 17° angulation. The tube adapters were identified by colours and standardized according to the diameter compatible with the drilling cutters, thereby allowing the drilling to be performed with the same inclination. The following micro-unit abutments were placed on the settlement platform of each implant installed on the blocks: block 1, micro-unit abutments angled at 17° (AS TECHNOLOGY TITANIUM FIX - São José dos Campos, Brazil); block 2, micro-unit abutment (Figure 1). The abutments had a 2-mM-height brace, with installation at 20 N.cm torque. Plastic copings were manually screwed onto the abutments (AS TECHNOLOGY TITANIUM FIX - São José dos Campos, Brazil).

Figure 1 - Pillar micro-units installed on straight implants (A) and on angulated implants (B).

Fabrication of metallic superstructures

To obtain the superstructures, an acrylic resin pattern was generated by using a rectangular mold. All specimens had the same dimensions. A colourless acrylic resin (JET Articles Dental Classic Ltda., São Paulo, Brazil) was manipulated and poured into the rectangular mold, and the structure was removed after complete polymerization. Subsequently, the structures obtained in acrylic resin were placed in plastic copings, with a distance of 1 mm from the bottom edge of the plastic copings for levelling the structures. After this, the copings were attached with acrylic resin (Reliance Dental Mfg. Co., USA) onto the acrylic structures. The attachment between the structures and the plastic copings was obtained in a sequential manner (over the abutments of implants 1, 2, and 3) in which each coping was attached only after polymerization of the acrylic resin (Reliance Dental Mfg. Co., USA) of the previous coping. The wax patterns were sprued, invested, and cast as one piece by using an induction oven (Wirobond SG, Bego Bremer Goldschalgerei, Bremen, Germany), and the structures were obtained in nickel-chromium (Wirobond SG, Bego, Bremen, Germany). The structures were adapted individually onto the polyurethane block, which measured the stability of the assembly upon completion of screw tightening.

Strain gauge analysis

The surfaces of the blocks were carefully cleaned with isopropyl alcohol. Four linear electrical gauges (Kyowa Electronic Instruments Co., Ltd, Tokyo, Japan) were bonded onto each block by using a layer of cyanoacrylate-based adhesive (Loctite Super Bonder, São Paulo - Brazil). The gauges were positioned according to the scheme: SG1, to the right of implant 1; SG2, to the left of implant 2; SG3, to the right of implant 2; and SG4, to the left of implant 3.

The variations of electrical resistance were transformed into units of micro-strain through a signal conditioner electrical machine (Model 5100, Scanner - System 5000 - Instruments Division Measurements Group, Inc., Raleigh, NC - USA). All of the strain gauges were calibrated prior to each loading, and a vertical load of 30 kgf was applied for 10 s by using a load application device (DAC) [4,8]. The magnitude of micro-strain on each strain gauge was recorded in units of micro-strain ($\mu\varepsilon$). This procedure was repeated twice, resulting in a total of three readings per loading point: A, B and C. (Figure 2)

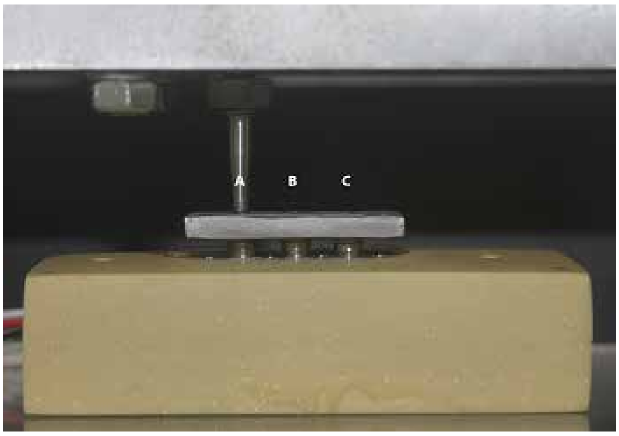

Figure 2 - Detail of static vertical loading on loading point A, illustrating the points B and C.

Vertical misfit analysis

Twenty specimens were analysed by using a stereo microscope (Discovery V20, Zeiss, Germany) at 100-x magnification. The vertical misfit was measured at six different points on each implant/abutment joint: three buccal points and three lingual points. The same examiner performed all measurements, with standardization of the dots between the distal, mesial, and average. The micrometre scale was used, as shown in (Figure 3).

Statistical Analysis

The experimental variables of this study were angled/straight implants and loading points (A, B, C), following a factorial scheme of 2x3. The response variable was the average micro-strain obtained in the analysis by strain gauge. The data were analysed statistically by using ANOVA repeated measures and post-hoc Tukey's test. Significance was accepted at $p < 0.05$. The relationship between vertical misfit and micro strain was investigated by using Pearson's correlation coefficient (p-value).

RESULTS

The mean values and standard deviations of micro strain obtained on the four strain gauges for the groups with angled implants and with straight implants are in Table 1. The results of the two-factor repeated measures ANOVA for the experimental conditions showed just significance for angulation of the implants ($P = 0.0086$). Tukey's test (0.05) of the mean micro-strains ($\mu\varepsilon$) showed no interaction between the configuration implants: straight implant mean = 843.0 ($\mu\varepsilon$) and angled implant mean = 2.281($\mu\varepsilon$). The Pearson's correlation test between micro-strain

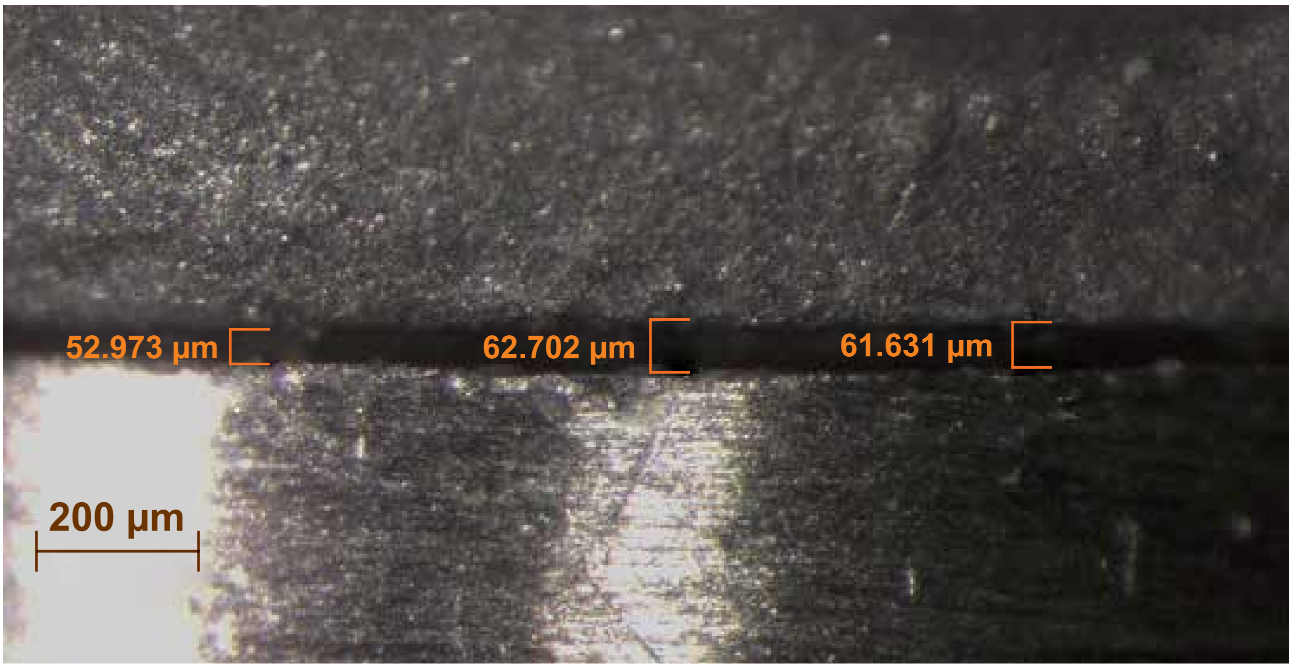

Figure 3 - Measurement of vertical misfit in the stereo microscope.

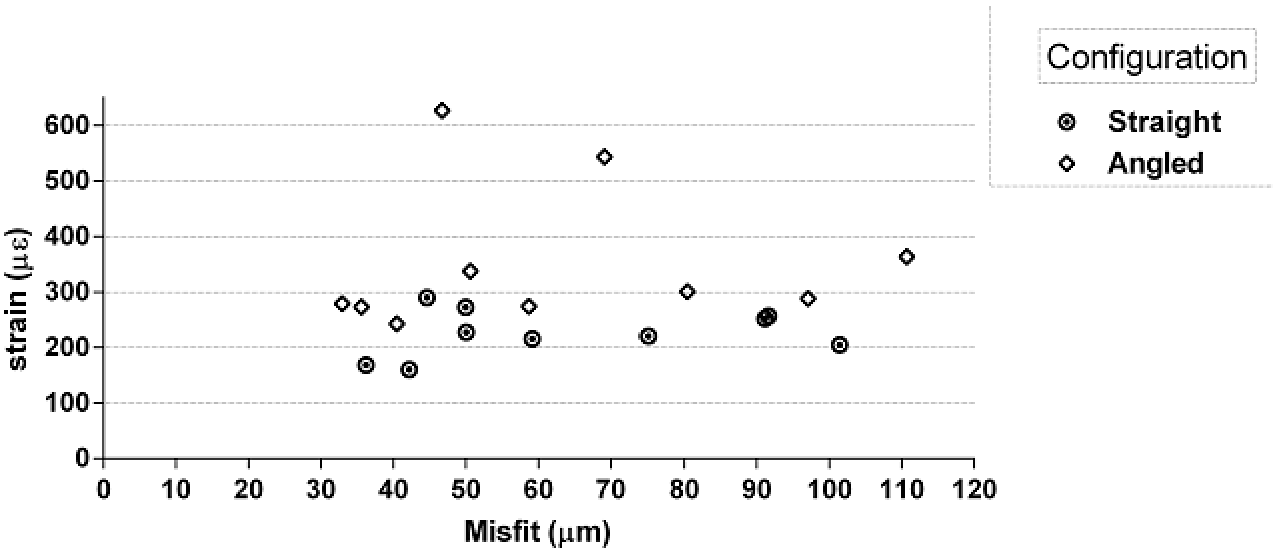

Figure 4 - Illustration of the lack of correlation between the mean strain and the mean vertical misfit.

and vertical misfit revealed no correlation between angled configuration (P = 0.891) and straight configuration (P = 0.568). The mean values are shown in (Figure 4).

DISCUSSION

Strain gauge analysis is a technique used for measuring strains associated with specific equipment, allowing in vivo [19,20] and in vitro [1,2,21,22] measurements of deformations during static or dynamic loading [4-6,13]. This study used artificial homogeneous models with uniform elastic properties represented by a polyurethane-based block, as described previously [4,6,13,23].

The bonding site of the strain gauges directly influences the type of deformation recorded; therefore, the authors selected the region around the edge of the implant platform because the stress tends to be concentrated in this region [11,24]. Although the strain gauges were bonded directly to the implant [7] or abutments [1,2] in other studies, we believe that the procedure is simpler and more reliable when the gauges are bonded on the flat surface of the polyurethane block.

Table 1 - Mean (± sd) values of micro-strain (με) obtained from a mean of four strain gauges at each loading point for the groups with angled implants and straight implants

Implant configuration		Loading point A	B	C
Straight	n= 10	1003.1 ± 279.5	534.2 ± 173.2	991.8 ± 352.7
Angled 17°	n= 10	2560.0 ± 395.4	1642.9 ± 127.9	2641.3 ± 214.8

A flat metal structure [2,5,25,26], was used to avoid the influence of the horizontal component with the existence of metal frame cusps [24], since the intention of the present study was to evaluate the effect only of axial loads.

The authors used a 300 N load [27], which is similar to that of previous studies [4,5,7,28,29]. The values obtained by applying the load at loading points A, B, C, D and E, to the group with straight implants showed no significant differences. These findings are contradictory to those of Vasconcellos et al. [22], in which a statistical difference was observed between the application points. The discrepancy between these results may be explained by small distortions in the metal, causing misfits between the abutments and coping casts, and the different type of alloy used. Our results corroborate those of other studies that did not detect micro strain differences at different axial loading points [4,8].

Similarly, in the angled implants group, no significant difference was found between the different points at which the axial loads were applied on the retaining screws of the structure, corroborating with findings of Ogawa et al. [1]. However, the study design of Ogawa et al. [1], differed from ours in several ways, because they used an arc-shaped metal structure and a different quantity of supporting implants and acrylic resin models to simulate the occlusal surface cusps and inclinations.

This research showed a significant increase of micro strain around angled implants (P= 0.0086). Thus, the first null hypothesis - the inclined position of the implants at 17° will not increase the values of micro-strain around the implants – was denied. Although the installation of an angled implant is feasible, the inclination of the implant creates more stress on periimplantar bone. For this study, it should be taken into consideration that the models had homogeneous and isotropic structure, which is unlike that found in bone tissue.

Corroborating with the present study, studies that used isolated implants, found more stress when inclined implants were analysed [6,7]. Another study found lower micro strain values in the groups with angled implants in cantilever situations [2], the discrepancy between the present study and the previous study [2] can probably be attributed to the effect of local bonding because the gauges were placed directly on the abutments and not on the surface of the resin block.

In this research, the groups with vertical implants and angled implants both had a mean of microstrain generated in different loading points below the physiological tissue limit of 3000 $\mu\varepsilon$ [11]. All means in both groups were within the normal range, between 100 and 2000, [11] which is characterized as a range of osteogenic balance.

This research analysed the vertical misfit values of 20 structures at six different points, and the correlation analysis revealed that the maximum average value of vertical misfit in the present study was 110 μm. In the present study, the misfit presented was not correlated to the values of micro strain, unlike studies that relate calcinable and pre-made pillars on vertical misfit, claiming that the adaptation may influence the distribution of deformation and stability [17,18]. In this way, the second hypothesis tested - the vertical misfit of the metal structures will influence the values of micro strain – was also rejected. The discrepancy between the present study and the previous studies [17,18] can probably be attributed to the lower maximum average value of vertical misfit presented. The axial loading may have also contributed to a different mechanical behaviour of implant/abutment interface. If the maximum average value of vertical misfit presented was higher and non-axial loading was tested, this study may have presented similar results to previous studies [17,18], The results found in this study suggest that complementary studies relating the vertical misfit and the mechanical behavior between the prosthetic components and implant are necessary.

CONCLUSION

In conclusion, with the limitations of this study, the positioning of the implant angled 17° resulted in higher micro strain values, but both groups were established within the physiological limits. Different loading points did not affect the stress distribution around the implants in neither group. The vertical misfit of the metal structures did not influence the micro strain values.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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