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LEONARDO FLORES LUTHI

INFLUENCE IN THE BIOMECHANICALS OF DIFFERENT METAL ALLOYS AND PROSTHETIC ABUTMENTS IN THE PROSTHESIS PARTIAL FIXED OF THREE ELEMENTS

INFLUÊNCIA DE DIFERENTES LIGAS METÁLICAS E PILARES PROTÉTICOS NA BIOMECÂNICA DE PRÓTESES PARCIAIS FIXAS DE TRÊS ELEMENTOS.

Piracicaba

2014

Universidade Estadual de Campinas
Faculdade de Odontologia de Piracicaba

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Thesis presented to the Piracicaba School of Dentistry of the University of Campinas in partial fulfillment of the requirements for the degree of Doctor in Dental Clinic, in the Dental Prosthodontics area.

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Orientador: Prof. Dr . Guilherme Elias Pessanha Henriques

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Prof. Dr. GUILHERME ELIAS PESSANHA HENRIQUES

Prof. Dr. CASSIUS REBELATO

Prof. Dr. ALOISIO ORO SPAZZIN

Prof. Dr. MARCELO FERRAZ MESQUITA

Prof. Dr. MAURO ANTONIO DE ARRUDA NÓBILO

RESUMO

Pilares tipo UCLA calcináveis são bem aceitos no meio odontológico por permitirem manipulação em laboratório a custo reduzido e a individualização das próteses em função de cada paciente. Porém quando utilizados para sobrefundição possuem prerrogativas de menores custos que os pilares pré-fabricados e melhor adaptação que os calcináveis. Assim o objetivo, deste estudo foi avaliar a influência na indução de tensão aos implantes por meio de extensometria utilizando próteses confeccionadas com pilares UCLA sobrefundidos em diferentes ligas metálicas. O presente estudo apresenta dois capítulos, sendo que o primeiro aborda as diferenças entre os pilares calcináveis e os sobrefundidos e suas respectivas ligas. Para tanto, foram confeccionados 40 infraestruturas metálicas sobre implantes simulando próteses parciais fixas de 3 elementos utilizando pilares UCLAs convencionais e pilares UCLAs metaloplásticos em Co-Cr e Ni-Cr, os quais foram fundidos ou sobrefundidos utilizando Co-Cr e Ni-Cr-Ti respectivamente (n=10). Com o auxílio da extensometria avaliou-se a tensão no momento da fixação da prótese sobre as replicas dos implantes. O teste estatístico empregado foi o ANOVA dois fatores, com o nível de significância de 5%. Os resultados obtidos apontam para um aumento na tensão gerada nos pilares calcináveis para ambas as ligas estudadas, sendo os pilares calcináveis em Co-Cr os que apresentaram os maiores valores de tensão. Nesse capítulo foi possível concluir que, os pilares sobrefundidos apresentaram menores valores de tensão. O segundo capítulo aborda diferentes metodologias usando *strain gauges* na avaliação da tensão. Foram confeccionados dois modelos para análise das tensões, um com gesso e duas réplicas de implantes, e outro em resina fotoelástica e dois implantes de conexão hexagonal externa. Foram utilizadas 40 infraestruturas metálicas utilizando pilares UCLAs calcináveis ou sobrefundidos em Co-Cr e Ni-Cr-Ti (n=10) totalizando oito grupos de estudo. A tensão foi avaliada em 3 momentos. Primeiramente no momento da fixação das peças sobre implantes ou réplicas, e posteriormente na aplicação de duas cargas com valores de 100 e 200N na região do pôntico (segundo pré-molar). O teste estatístico empregado foi o ANOVA de medidas repetidas com nível de significância de 5%. Os resultados mostraram que os pilares sobrefundidos em Co-Cr apresentaram os menores valores médios de tensão entre os grupos, e que existe diferença entre as técnicas empregadas para análise com *strain gauges*. Sendo assim, foi possível concluir que a liga de Co-Cr quando sobrefundida pode ser empregada na reabilitação com implantes e que a técnica que utiliza modelo com resina fotoelástica apresenta valores diferentes quando comparados aos modelo de gesso.

Palavras chaves: Implantes dentários. Prótese dentária. Biomecânica.

ABSTRACT:

UCLA abutments are well accepted in dentistry because they allow reduced cost and individualization of prostheses according to each patient. However, when used for overcastting they har as prerogatives lower costs than the prefabricated abutments and better adaptation than the castables. Thus, the aim of this study was to evaluate the induction of stress to the implants by means of strain gages analysis, using prostheses made of UCLA overcast abutments in different alloys. This study presents two chapters, in which, the first is about the differences between the abutments calcinable and overcast and their respective alloys. For this, forty metal implant infrastructures were used simulating Fixed Partial Dentures of 3 elements, using conventional UCLAs abutments and overcast UCLAs in Co - Cr and Ni - Cr , which were cast or overcast using Co - Cr and Ni - Cr -Ti (n = 10). With the aid of the strain gauge, the stress was evaluated at the time of fixation of the prosthesis on the replicas of the implants. The statistical test used was the two-factor ANOVA at a significance level of 5 %. The results indicate an increase in tension generated in the castable abutments for both alloys studied and also that, the abutments calcinable in Co - Cr present the highest levels of strain. So, in this chapter it was concluded that the lowest strain values are present in the overcast abutment . The second chapter discusses different methods using strain gauges and different values of tension. Two models were prepared for analysis of strain: one with plaster and two replicas of implants, and in other with photoelastic resin and two implants with hexagonal external connection. So, the forty infrastructures of calcinable or overcast UCLAs abutments in Co - Cr and Ni - Cr -Ti (n = 10) were used, totaling eight study groups . The strain was assessed three times. First, at the time of fixation of implant parts or replicas, and after, at the application time of two loads with values of 100 and 200N on the pontic (second premolar). The statistical test used was ANOVA at the significance level of 5 %. The results showed that overcast UCLA abutment in Co - Cr present the lowest values of tension among the groups, and also that there is not difference between the techniques for analysis with strain gauges. Thus, one was concluded that the Co - Cr alloy, when with overcast abutments in Co-Cr, more suitable rehabilitation with implants. Furthermore, the technique with photoelastic resin model showed diference of tension when compared to the plaster model.

Key Words: Dental Implants, Dental Prosthesis. Biomechanics.

SUMÁRIO

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1 INTRODUÇÃO

A introdução de implantes osseointegrados melhorou de maneira significativa a qualidade de vida da população, principalmente em pacientes totalmente edêntulos os quais, na sua grande maioria apresentam uma capacidade mastigatória reduzida restabelecendo assim a função mastigatória. Entretanto alguns problemas de ordem clínica podem ocorrer em função da biomecânica dos implantes ser diferente dos dentes naturais. Isso ocorre em virtude da interface implante/osso apresentar uma reduzida resiliência em comparação a interface osso/dente.

Sabe-se que um dente natural possui uma liberdade de movimento em torno de 100 μm, enquanto que os implantes quando osseointegrados apresentam uma movimentação em torno de 10 μm (Skalak 1983; Watanabe et al 2000). Esse fato faz com que a prótese quando instalada sobre implantes osseointegrados e submetida a função mastigatória transmita a força diretamente ao osso (Sahin & Çehreli 2001). Sendo assim, é importante que a instalação de implantes seja precisa, uma vez que toda a força mastigatória será dissipada no osso (SkalaK 1983; Glantz & Nilder 2000).

Durante as últimas décadas, pesquisadores têm enfatizado a importância da biomecânica e seus reflexos nos implantes dentários (Tramontino et al 2008; Abduo & Lyons 2012), dentre os fatores que afetam diretamente a biomecânica estão os procedimentos laboratoriais e clínicos utilizados na confecção das próteses, os quais podem causar distorções entre a plataforma do implante e a estrutura protética, sendo uma das causas das complicações em reabilitações sobre implantes, dessa maneira a seleção e o bom emprego dos componentes protéticos deverá minimizar estes fracassos (Abduo & Lyons 2012).

Sabe-se que o desajuste irá existir e quando em valores aceitáveis, os quais variam de 50 a 150 μm, não será o fator determinante para não integração dos implantes ao osso.(Jemt 1991; Tramontino et al 2008) Porém o desajuste é um fator isolado que quando observado em conjunto com a tensão gerada nos tecidos periimplantares e problemas de ordem periodontal podem levar à falha da osseointegração dos implantes (Jemt 1991).

O uso de um pilar intermediário entre as fixações e a estrutura protética - como recomendado pelo protocolo de reabilitação sobre implantes proposto por Branemark - é uma das formas de reduzir as tensões induzidas às fixações (Rangert *et al* 1991). Outro recurso que se pode utilizar são os equipamentos industriais de precisão, visando a obtenção de maior acuidade nos encaixes reduzindo desajustes, e minimizando as tensões geradas ao sistema de próteses sobre implantes.

Embora menosprezem os aspectos mecânicos favoráveis provenientes dos pilares intermediários, os pilares do tipo UCLA adquiridos em plástico calcinável e fundidos em diferentes ligas para a conexão direta ao implante são uma possibilidade para os tratamentos reabilitadores. Estes componentes possuem como vantagem o fato de poderem ser trabalhados nos laboratórios protéticos a custo reduzido, permitindo a confecção de peças parafusadas, cimentadas e individualizadas em função das necessidades de cada paciente. Todavia, os pilares plásticos depois de fundidos podem apresentar níveis elevados de desajuste marginal, gerando complicações biológicas e mecânicas como mucosites, tendência ao desaperto ou fratura de parafusos ou até a falha do implante decorrente do comprometimento da osseointegração (Lewis *et AL* 1998; Takahashi & Gunne 2003).

Como alternativas aos pilares intermediários e os do tipo UCLA de plástico calcinável surgiram os pilares sobrefundidos. Estes pilares apresentam base metálica pré-fabricada de conexão ao implante, associada a um cilindro plástico calcinável, como um monocomponente, desenvolvido para a realização de sobrefundições. Esses pilares apresentam prerrogativas de reduzir desajustes frente aos componentes calcináveis convencionais, em vista da base metálica pré-fabricada, além de permitir a individualização das restaurações a custo mais acessível quando comparados aos pilares intermediários totalmente pré-fabricados (Kano *et al* 2007).

Outra questão é o desenvolvimento de técnicas experimentais para avaliar a biomecânica dos implantes dentários. Sobre vários aspectos a avaliação clínica direta (imediata ou longitudinal), seria a melhor proposta para avaliar biomecânica na implantodontia. Porém, a dificuldade de análise das estruturas envolvidas torna a avaliação clínica direta do comportamento biomecânico entre a prótese, implante e osso quase impossível, visto que os aspectos éticos envolvidos, o tempo de duração desse estudo, e a grande quantidade de variáveis metodológicas envolvidas inviabilizariam o estudo (Cariello 2009).

Sendo assim, a avaliação da biomecânica com testes em laboratório, se apresenta como uma alternativa viável no entendimento das tensões geradas na interface osso/implante. Alguns fatores como: a carga mastigatória e sua a dissipação na interface implante/osso, frequência mastigatória, domínio das técnicas de moldagem e dos procedimentos laboratoriais como a temperatura da liga e o módulo de elasticidade do material de cobertura protética, e a qualidade óssea ao redor dos implantes podem influenciar na osseointegração dos implantes, e em alguns casos na perda dos mesmos. Na literatura encontram-se diferentes métodos para avaliação da tensão gerada na região periimplantar. Alguns pesquisadores utilizam extensômetros acoplados diretamente à replica dos implantes, outros fazem o uso de modelos a base de resina fotoelástica associada a colocação de extensômetros (Tramontino *et al* 2008; Cariello 2009; Pesqueira *et al* 2011).

Todavia, não se conhece ao certo, a existência de diferenças entre as variações de técnicas para análise de tensão, e se a tensão gerada pelos pilares calcináveis ou sobrefundidos pode induzir tensão aos implantes , sendo estes o objetivo do presente estudo.

Capítulo 1

The influence of casting procedures on machined and plastic UCLA abutments: a strain-gauge comparative analysis

1 - LEONARDO FLORES LUTHI, MSC - PhD student, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

2 -RAFAEL LEONARDO XEDIEK CONSANI, PhD – Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

3 - MARCELO FERRAZ MESQUITA, PhD – Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

4 - MAURO ANTONIO DE ARRUDA NÓBILO, , PhD – Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

5 - GUILHERME ELIAS PESSANHA HENRIQUES, PhD – Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

Address of the corresponding author:

Leonardo Flores Luthi

Guilherme Lugisland – 474-201

Joaçaba – SC. Brazil. Postal Code: 89600-000.

Phone (55) 49 3551-2200

E-mail: leonardo.luthi@unoesc.edu.br

Abstract

The original protocol for the insertion of an acrylic/ceramic implant prosthesis calls for the use of a gold framework and an intermediary abutment. However, because of the low cost, alternative alloys and UCLA abutments are recommended in many clinical situations. In this study was used strain-gauge analysis to evaluate strain differences in four kinds of UCLA abutments with Ni-Cr-Ti and Co-Cr. Twenty infrastructures were prepared with Co-Cr alloy, and 20 with Cr-Ni-Ti alloy (n = 10) were obtained by casting from a master steel model containing two implants simulating a three-element fixed prosthesis. For each alloy, 10 infrastructure copings of the castable UCLA type were affixed directly to the implants with screwn. Another 10 were made with a UCLA abutment overcast with Co-Cr alloy or Ni-Cr-Ti alloy. The strain was measured after each infrastructure was inserted into the master model, calibrated with strain-gauge sensors. After the strain-gauge analysis, results were tabulated, and the Sigmastat 3.1 program was used for two-way statistical ANOVA. When the dental alloys and the abutments were compared, a statistically significant difference was observed only between cast abutments and overcast abutments in the above alloys ($p = 0.015$). A statistically significant difference in strain was observed between implants “A” and “B” for the Ni-Cr-Ti alloy; however, when compared with the different dental alloys, implants “A” and “B” showed no statistically significant difference between alloys. The overcast abutments showed the lowest stress values at levels indicated for use with implants. The Co-Cr alloy showed lower values of tension, making it more suitable for prosthetic implants.

Key words: Dental implants. Dental prosthesis. Dental restoration failure.

Introduction

Implants have been proven to be durable and reliable replacements for missing teeth[1-2], dramatically improving patients' quality of life[3,4]. However, early and late implant failures still seem to be unavoidable[5]. Late implant failures appear to be related mainly to biomechanical complications; however, the mechanisms responsible for these failures are not fully understood.

Occasionally, manufacturing procedures such as casting and investment techniques can distort metal frameworks[5]. Even after being polished, frameworks may not fit the implant platform exactly[6].

Passive adaptation of the metal framework reduces the stress to which it, the implant, and the peri-implant bone are subjected[7,8]. No passive implant-supported fixed prostheses can fail, loosen screws, fracture other components, or cause the peri-implant tissue to react adversely[9].

Implant manufacturers often use UCLA-type prosthetic abutments because of their versatility. They lower the costs of framework individualization and various types of rehabilitation (single, multiple, screw-type, or cemented). They also allow manufacturers to cast with not only precious but also semiprecious alloys. Despite this versatility, casting can distort the abutment's platform, which could compromise its adaptation to the implant[6.7]. To minimize these distortions, manufacturers have developed abutments for overcasting[6].

In an overcast abutment, the manufacturer pre-forms, in metal, the bottom of the abutment, the part touching the implant platform. Only the cylinder is calcinable, while conventional UCLAs, being wholly plastic, are entirely calcinable. Originally, such overcasting was performed with precious metals, but currently non-precious alloys, such as Co-Cr and Ni-Cr, are used as well[4]. Rehabilitative therapy with dental implants often leads to instability and the loosening of prosthetic screws[6,9]. The literature suggests that such instability can arise from factors other than impassivity[11], such as insufficient torque[12,13], screw settings and relaxing[14,15], and differences in screw shapes and materials.

High occlusal loads challenge the implant, its components, and its prostheses, sometimes eventually leading to mechanical failure. A one-piece 3.3-mm-diameter implant, under 500 N at a 45° angle, experienced more than 500 MPa of stress, which is the proof stress of grade 4 pure titanium.[16]

The applied occlusal load also stresses and eventually deforms the bone.

Strain is defined as lengthening or shortening in a long bone and is often expressed in microstrain (μƐ). A 0.1% deformation equals 1000 μƐ. The strain increases with stress on the bone, as through the loading of an implant. However, the same force may act differently on cortical and spongious bone tissue, depending on either tissue's stiffness; thus the amount of strain also varies with bone properties. A 25,000 - μƐ impact causes healthy bone to fracture. Mechanical loading, evoking stress and strain on load-bearing bones, can have a positive (anabolic) or negative (catabolic) effect on bone tissue.[17]

Frost reports four levels of mechanical strain, causing different bone responses: (i) disuse atrophy, resulting in net bone loss (50-100 μƐ); (ii) steady state (100-1500 μƐ); (iii) mild overload, resulting in net bone gain (1500-3000 μƐ); and (iv) fatigue failure or overload, resulting in net bone loss (> 3000 μƐ)[18]. In addition to force magnitude, other parameters, such as frequency[19], duration[20], and rest periods between loads[18], play a role in bone response to loading.

This study aimed to use strain-gauge analyses to evaluate the stress differences in four kinds of UCLA abutments with Ni-Cr-Ti and Co-Cr.

Material and Methods

Preparation of the cast infrastructure

For this study, a rectangular (20 x 15 x 20mm) steel matrix was made. In this matrix, two implants with an external hexagonal titanium connection and a 4.1 platform Branemark were placed. Over these two implants, two plastic UCLA abutments were screwed, one with a waxed prosthesis simulating a three-element fixed partial prosthesis.

The matrix/prosthesis was impression with silicone. After the silicone cured, half of the impression was invested to facilitate waxing of the future infrastructure.

Preparation of the plaster cast

To transfer the implant positions in the master cast, two metallic transfers were positioned over them, united with dental floss and pattern resin. After being cured, they were cut with a carborundum disc and re-united.

After this procedure, two replicas of the implant were screwed into the transfers, positioned within the silicone mold obtained above, and covered them with gypsum type IV, waited for two hours, and then removed the replicas from the transfers, thereby obtaining a plaster cast. This procedure was repeated 39 times for a total of 40 plaster casts.

Preparation of infrastructures for study

Over the plaster cast, two UCLA abutments (without counter-hexagon locking for multiple parts), were screwed (Table 1). The cast and abutments were positioned in the silicone impression, and filled it with the pattern resin to manufacture the structure. After the two parts of the silicone impression were joined, the acrylic resin were expected to take 20 minutes to cure before that could open it. Using a carborundum disc the region between premolars, were sectioned to avoid tension due to polymerization shrinkage of the resin. The new union with acrylic resin were finished only 24 hours before the inclusion process.

Inclusion of Standards

For inclusion in the coating, the infrastructures were fixed to cylindrical bars of wax (WaxRound; Dentaurum J.P. Winkelstroeter Kg, Ispringen, Germany), which served as a model after being coated to form the power conduits. The conduits' sustaining base was made with red wax (Epoxiglas; Epoxiglas Ind., São

Table 1: The different study groups

Group (n=10)	Descriptions of the UCLA abutment and dental alloy
1	UCLA cylinders with neck girdle on Co-Cr alloy, (055, 022, Conexão Sistema de Implante, São Paulo, SP, Brazil), and overcast alloy in Co-Cr (C StarAlloy; Dentsply, Hanau, Germany).
2	Similar to Group 1, using prosthetic castable UCLA cylinders (056, 021, Conexão Sistema de Implante, São Paulo, SP, Brazil) and cast alloy in Co-Cr.
3	UCLA cylinders with neck girdle on Ni-Cr alloy (118-121, UCLA Tilite; Neodent Implantes Osseointegráveis Ltda., Curitiba, PR, Brazil) and overcast in Ni-Cr-Ti (Tilite, Tilite Omega Ceramic Alloys, Talladium Inc., Valencia, CA, USA).
4	Similar to Group 3, using prosthetic castable UCLA cylinders (118, 005, Neodent Implantes Osseointegráveis Ltda, Curitiba, PR, Brazil) and cast alloy in Ni-Cr-Ti.

Paulo, SP, Brazil), including a triangular conduit to unite the base with the crucible wax sprues.

Rings were used to make the silicone size compatible with the arrangement of patterns. Each casting ring included two patterns of the same group. Around the standards liquid surface tension reducer was applied (Waxit; Degussa AG, São Paulo, SP, Brazil) and dried it for five minutes at room temperature. The silicone ring was then positioned on the base, forming the crucible, and phosphate liner deemed best for casting alternative alloys was poured (HS Gilvest; BK Giulini, Ludwigshafen, Germany), under vibration, after being handled in vacuo according to the manufacturer's instructions. After completion of the ring, the assembly was left at room temperature for two hours for subsequent casting.

Casting Process

The facing blocks were placed in a heating furnace (Vulcan 3550; DeguDent, San Diego, CA, USA). For groups 1 and 2, a Co-Cr alloy was used (C StarAlloy; DeguDent–Dentsply, Germany), and for groups 3 and 4, a Ni-Cr-Ti alloy was used (Omega Tilite Ceramic Alloys, Inc., Talladium). A die-casting machine provided high-frequency induction (Compact Megaplus; Dentaurum). The Ni-Ti-Cr rings were heated to 400°C for 30 min, then to 900°C for 20 min and the cast at 1329°C. For the Co-Cr alloy, the starting temperature was 300°C for 20 min, followed by 950°C for 20 min, and the casting temperature was 1370°C. The rings were allowed to return to room temperature after casting.

After cooling, the coated blocks were fractured, the products were recovered, the feeding conduits were cut with a carborundum disc, and the structures were blasted with aluminum oxide with an average particle size of 100 microns (Renfert GmbH, Hilzingen, Germany), under pressure of 4.2 kg/cm^2 according to the manufacturer's recommendations. Stones and wheels were used to finish the Ni-Cr-Ti and Co-Cr alloys, under a low-pressure jet of aluminum oxide.

Analysis of Tension

To analyze stresses, two replicas of Brånemark osseointegrations were fabricated with a standard cervical platform and external hexagonal prosthetics connection. The settings of replicas were changed to facilitate the uptake of tension, and strain gauges were positioned to assess extensometry.

For strain-gauge analyses, another plaster model was made. The implant replicas were screwed into two metallic transfers, positioned in the silicone cast, and covered with gypsum IV (Gilrock; BK Giuilini).

Measurements were performed with two electrical resistance strain gauges (PA-06-060BG-350L, Sensor Excel Engineering; Embu, São Paulo, Brazil), positioned directly in each fixation replica. Thus, an arrangement was obtained for raising tension known as the Wheatstone quarter bridge (Figure 1). A computer-controlled device captured electrical signals (ASD0500; Lynx Electronic Technology Ltd., São Paulo, SP, Brazil) and processed them with specific software (AqDados 7; Lynx).

The microstrains were calculated by reading the replicas' elastic deformation. As the replicas did not deform after the sensor readings, won confirmed that the microstrain was zero. A 20N torque was applied to the infrastructure, wich was measured by a digital torque meter.

After the strain-gauge analyses, the results were tabulated and used the program Sigmastat for statistical analysis by two-way ANOVA and Tukey (α=5%).

Results

Table 2 compares the dental alloys and the abutments. A statistically significant difference was observed between cast abutments and the overcast abutments only in the alloys (p = 0.015).

Table 2. The average tension values and standard deviation of the different abutments and alloys used in this study

Alloy	Strain (μƐ)
Co-Cr cast	1113.5 (45) A
Co-Cr overcast	405 (34) B
Ni-Cr-Ti cast	1095.5 (340) A
Ni-Cr-Ti overcast	481 (35) B

In Table 3, a statistically significant difference in stress can be observed between implants “A” and “B” for the Ni-Cr-Ti alloy, when compared with the different cast alloys in implants “A” and “B”.

Table 3. Average tension values and standard deviation in implants A and B

Group	Implant A	Implant B
Co-Cr Cast	1093 (473) Aa	1020.2 (335) Aa
Co-Cr Overcast	403.8 (45) Ab	407.2 (58) Ab
Ni-Cr Cast	1307.8 (513) Aa	756.6 (215) Bb
Ni-Cr Overcast	382 (64) Ab	579.6 (90) Ab

Means followed by different letters (minor, column; capital, line) indicate statistical difference according to ANOVA (α=5%).

Discussion

The increased price of gold in the 1970s led to the development of alternative alloys. Non-precious metal alloys, containing no gold, silver, platinum, or palladium, have fusion temperatures higher than those of gold alloys. This increases their contraction on cooling. Their thermal conductivity and weight are also lower than those of gold, which can complicate casting procedures, and their hardness complicates finishing and polishing. Dentists must compensate these problems. Conversely, their strength allows for the production of lighter frameworks and the maintenance of thin and delicate margins.[21]

In this study, cast abutments showed more tension under stress than did overcast abutments (Table 2). The explanation for the difference of microstrain at the time of tightening the screw lies in the process of wax casting. In addition, plastic abutments are more vulnerable to casting errors in the cervical region, where the prosthesis needs extensive finishing and polishing, which may cause a failure in the prosthesis' adaptation.

Differences in alloy composition affect different physical properties such as deformation, rigidity, hardness, Young's modulus, and melting temperature. The melting temperatures for different metals produce different cooling rates, which relates to the contraction of the materials from which structures are cast. Dental alloys should contract little when solidifying, to ease melting, casting, and polishing. Table 2 shows that Ni-Cr-Ti responded more to stress than did Co-Cr. Perhaps their different melting temperatures (Co-Cr, 1370°C; Ni-Cr-Ti, 1329°C) influenced these results.

Cast structures showed satisfactory adaptation, confirmed visually and by means of an explorer[24]. Çehreli et al.[23] reported similar behavior in their evaluation. The present study was not concerned with gaps, but with the seating of the test specimens on the abutment. Jemt and Book[22] reported the extreme difficulty of checking visually for 30-μƐ-wide discrepancies with the naked eye. Conventional laboratory procedures, while able to produce a wide variety of screwed or cemented copings, cannot produce metallic structures with passive adaptation[24].

The present study used strain gauge (SG) analysis of two-unit screw implant-supported FPDs with external hexagons, changing the type of prosthetic abutment (plastic and overcast). The popularization of plastic abutment has reduced dental costs nationwide. The mean microstrain values recorded for EH systems were similar regardless of the type of abutment used. Karl et al.[9] achieved similar results from a study using the same number of fixations, although their prosthesis was built with five elements. Heckmann et al.[25] also found no difference between these two types of abutment. Previous SG studies have also reported similar results[25,26,27], with plastic or overcast abtument microdeforming during tightening of the retention screws at the same rate, with and without prefabricated abutment before[25,26] and after[27] the application of dental ceramics. The care and procedural complexity involved in the handling of multiple-element prostheses are very different from those involved in the handling of single-element prostheses. This may explain the different results for single-element prostheses reported by Carr et al.[3] and Byrne et al.[2], who evaluated gold machined abutment.

Implant-abutment joint designs should reduce peak bone interface stress and strain[7]. EH design generates a compressive force during the tightening of abutment screws. In EH, the abutment screw is the only element that keeps the two surfaces together. Hence, from a prosthetic point of view, the screw is important to strains near the bone, abutment, and implant. Each of our specimens was screwed to the abutment with the same torque sequence.

The structure of implant-supported prostheses, when fused to alternative alloys (Ni-Cr-Ti and Co-Cr), showed acceptable values of tension in accord with reports in the literature. Any existing variations in performance can be explained by differences in composition.

Thus, these factors may influence levels of adaptation of the casting and, therefore, the microstrain generated by the implant, regardless of the type of abutment used (UCLA or intermediate) and the type of prosthesis (single- or multiple-unit). In this study, a metal base machined in the UCLA abutment guaranteed optimal results with the Co-Cr alloy (Table 3), since overcasting may have strained the pillars and increased tensions. Strains in the casting can be minimized with careful finishing and polishing of the structures[6]. However, even this does not eliminate performance-impairing deformation[7]. This may influence the results presented in Table 3. Another factor in such deformation is poor adaptation of the edges due to their plastic composition. When torqued, the cast structures showed greater narrowing and generated more tension.

Some alternative alloys have been used to fabricate implant frameworks, but not many are made with Co-Cr, which has low cost in relation to that of gold, good biocompatibility, and resistance to corrosion due to its protective surface layer of Cr_2O_3. It also has good casting properties and a high specific weight. Its hardness makes it difficult to adjust, and it has a high modulus of elasticity [6,7,21,].

Most of the distortion caused by casting occurs due to the volume change of materials: plaster, waxes, investment, casting metals, impression material, and esthetic coverage. The type of alloy used in prosthetic frameworks can also interfere with adaptation. Differences in alloy composition, as noted above, generate different physical properties. Regardless of the type of abutment (UCLA or intermediary) or prosthesis (single-or multiple-unit), entirely calcinable abutment will generally fit worse than overcast ones. In single-unit rehabilitations, the benefit of overcasting is more evident because of the anti-rotational system inside the abutment. In this study, visual evaluation of the anti-rotational polygon demonstrated that, after casting, overcast abutments presented higher-quality edges.The misrepresentation of the polygon's angles and edges during conventional casting procedures may compromise a single-unit framework's settlement and stability. As such, a metallic pre-machined anti-rotational polygon would improve the framework's fit and reduce the chances of biomechanical failure. Nonetheless, one-piece cast frameworks that do not present angulation may not accrue such noticeable benefits.

Conclusions:

The overcast abutments showed the lowest values of strain indicated for use with implants.

The Co-Cr alloy showed lower values of tension, and thus is more suitable for use in the preparation of prosthetic implants.

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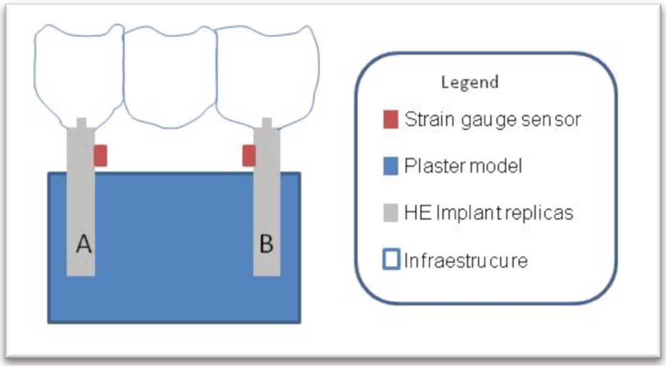

Figure 1. Showed a plaster model and the position of strain gauge sensors.

Capítulo 2

Two methods for evaluating the biomechanics of Pre-machined UCLA's abutments about implants: A strain-gauge analysis.

1 - Leonardo Flores Luthi, MSc - PhD student, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

2 - RAFAEL LEONARDO XEDIEK CONSANI, PhD – Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

3 - MARCELO FERRAZ MESQUITA, PhD – Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

4 MAURO ANTONIO DE ARRUDA NÓBILO, , PhD – Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

5 - GUILHERME ELIAS PESSANHA HENRIQUES, PhD – Professor, Department of Prosthodontics and Periodontology, Piracicaba Dental School, Campinas State University, Piracicaba, São Paulo, Brazil

Address of the corresponding author:

Leonardo Flores Luthi

Guilherme Lugisland – 474-201- Joaçaba – SC. Brazil. Postal Code: 89600-000.

Phone (55) 49 3551-2200 - E-mail: leonardo.luthi@unoesc.edu.br

Abstract

The aim of this study was to use strain-gauge analyses to evaluate two different techniques for evaluate tension in implant abutments. In this study, two kinds of strain-gauge analyses were used to evaluate stress differences in four kinds of UCLA abutments with Ni-Cr-Ti and Co-Cr. The strain was measured after each infrastructure was inserted into an epoxy resin cast calibrated with strain-gauge sensors, or a plaster cast and strain-gauge calibrated directly at the replicas. Increased stresses were observed when different occlusal loads were applied by two strain-gauge methods. After the strain-gauge analyses, results were tabulated, and the Sigmastat 3.1 program was used for three-way statistical ANOVA. When tensions were evaluated, it was observed that the tension values were more elevated in the infrastructures when the epoxy resin cast was used. The use of resin for analysis with strain gauges did not show difference in the results, and the overcast abutments of Co-Cr showed lower strain than other abutments.

Key words: Dental prosthesis. Strain-gauge analyses. Biomechanics.

Introduction

A crucial factor affecting the outcome of implant treatment is the way occlusal forces are transferred to the bone–implant interface via the superstructure and the implant. The force magnitudes in the vicinity of implants depend on the implant design and the structural and mechanical properties of the interface.[1]

The interface must tolerate occlusal forces without adverse tissue response. It is therefore essential to design an implant that distributes functional forces within physiological levels in peri-implant bone.[1,2,3]

However, in the last decade, there have been continuing concerns regarding late implant failure associated with the loss of osseointegration following functional loading.[4,5,6]

Implant failures can occur in a cluster pattern and appear to be related to bone quantity, implant length, individual's smoking habits, and the presence of periodontitis in the opposing dentition.[7,8,9] Re-treatment in these circumstances may be difficult, if not impossible, at times.[10] Occlusal overload and peri-implantitis, or a combination of the two, have been suggested as risk factors for late implant failure.[11,12,13,14] However, direct causal relationships have yet to be clearly shown.[15]

Occlusal overload has been defined as a load that exceeds the biological and mechanical load-bearing capacity of the implant and its prosthesis, wich may result in the biological failure of osseointegration and the mechanical failure of the prosthesis.[16]

Considering that strain magnitudes determine bone response,[17,18,19] the strain magnitudes around implants under functional loading are more important than the initial misfit-induced strains on superstructures or implants, for two fundamental reasons. First, the elastic deformation of the prosthesis and implant components might change the initial nature (compressive or tensile) of strains at prosthesis connection points after functional loading. Second, a load-dependent increase in strain occurs in cortical bone around implants; the magnitude of this increase is expected to be much higher than that of initial misfit-induced strains.[21,22]

However, if the resultant bone strain exceeds 3000 µƐ, the minimum effective strain threshold of pathological overload, the functional adaptive capacity of the bone-modeling mechanism cannot accommodate the strain, and a loss in bone mass can be expected.[22] When the fracture threshold set point of 25 000 µƐ is reached, the ultimate strength of bone is exceeded, and catastrophic bone fracture occurs.[23,24] Hence, an occlusal overload situation may be confirmed through the quantitative measurements of occlusal load magnitudes and resultant peri-implant bone strain and their comparisons with the minimum effective strain threshold of pathological overload (30.000 µƐ).[23]

For enhanced predictability of the fit of an implant prosthesis, in vitro studies should be performed to provide a biomechanical understanding of any fabrication technique or material before its clinical application. The fit of implant frameworks can be assessed in vitro by dimensional measurements or modelling techniques. The main advantage of modelling techniques, such as strain gauge, photoelastic, and finite element analyses (FEA), is the assessment of the effect of the misfit on the peri-implant structures, framework, or even the implant components. It is widely accepted that strain-gauge analysis is an efficient in vitro tool for detecting hidden inaccuracies of otherwise clinically acceptable frameworks. [25,26,27,28]

Strain is defined as the ratio between the length of an object under stress and its original dimension; it is a dimensionless entity. Strain gauge (SG) is considered an indirect measurement that analyzes a physical effect, mechanical deformation, based on electrical measurements taken with a device called a transducer. In short, it can be stated that deformations are normally imperceptible to the naked eye, so a SG is needed to measure them. Its working principle is based on the variations of the electrical resistance transformed into deformation levels.[29] In the literature, several methods have been reported for evaluating stress by means of a strain gauge, some with the strain directly on the implant replica and others with epoxy resin casts, but there are no studies showing whether there are differences between these two techniques. Therefore, the aim of this study was to use a strain gauge to evaluate two different techniques for evaluate tension in implant abutments.

Materials and Methods

For this study, two casts were made (epoxy resin and plaster) for analysis with strain-gauge sensors (Table 1).

Table 1. Mechanical properties of materials used in this study

Structures	Elastic modulus (GPa)
Dental Implant (Titanium)	110.0
Epoxy Resin	1.37
Plaster	56.0
Ni-Cr-Ti alloy	206.0
Co-Cr alloy	210.0
Cortical Bone	13.7
Sponjous Bone	1.37

For this study, the steps for preparation of the cast infrastructure, plaster casts, infrastructures, inclusion of standards, and casting processes for study were the same. In the present study, the infrastructures were divided among eight groups (n = 10) in accordance with the type of abutment, dental alloy, and strain-gauge analysis (Table 2).

Table 2. Descriptions of the UCLA abutment, dental alloy, and cast

Group	Description
1	Retained by screws using prosthetic UCLA cylinders with neck girdles on Co-Cr alloys, (055, 022, Conexão Sistema de Implante, São Paulo, SP, Brazil), and overcast alloy in Co-Cr (C StarAlloy; Dentsply, Germany), and strain-gauge analysis performed in a plaster model.
2	The same as for group 1, although with a resin model used for analysis.
3	Similar to Group 1, using prosthetic castable UCLA cylinders (056, 021, Conexão Sistema de Implante, São Paulo, SP, Brazil) and cast alloys in Co-Cr, with plaster for the analysis.
4	The same as in Group 3, except that a resin model was used for the analysis.
5	Prosthetic UCLA cylinders with neck girdles on Ni-Cr-Ti alloys (118-121, UCLA Tilite; Neodent Implantes Osseointegráveis Ltda., Curitiba, PR) and overcast in Ni-Cr-Ti (TALLADIUM Tilite® Omega Ceramic Alloys, Talladium Inc., Valencia, CA, USA), with plaster for the analysis.
6	The same as for group 5, although with a resin model used for the analysis.
7	Similar to Group 3, with prosthetic castable UCLA cylinders (118, 005, Neodent Implantes Osseointegráveis Ltda, Curitiba,

	PR) and cast alloy in Ni-Cr-Ti. With plaster for the analysis.
8	The same as in group 7, although a resin model was used for the analysis.

Analysis of Tension

For stress analyses in groups 1, 3, 5, and 7, two replicas of Brånemark osseointegration were fabricated with a standard cervical platform and external hexagonal prosthetics connections. The settings of replicas were changed to facilitate the uptake of tension, and strain gauges were positioned to assess extensometry(Figure 1).

For strain-gauge analyses, another plaster model was made. The implant replicas were screwed into two metallic transfers, positioned in the silicone cast, and covered with gypsum IV (Gilrock; BK Giuilini, Ludwigshafen, Germany).

Measurements were performed with two electrical resistance strain gauges (PA-06-060BG-350L, Sensor Excel Engineering; Embu, São Paulo, Brazil), positioned directly in each fixation replica. Thus, an arrangement known as the Wheatstone quarter bridge was obtained for increasing tension. A computer-controlled device captured electrical signals (ASD0500; Lynx Electronic Technology Ltd., São Paulo, SP, Brazil) and processed them with specific software (AqDados 7; Lynx)[24].

The microstrains were calculated by readings of the replicas' elastic deformation. As the replicas did not deform after the sensor readings, the microstrain was confirmed to be zero. A 20-N torque was applied to the infrastructure, which was measured by a digital torque meter. After 2 minutes, the screws were de-torqued, and if the replicas did not deform after the sensor readings, the microstrain was confirmed to be zero. After this process, screws were inserted into the infrastructure with 20-N torque, as measured by a digital torque meter, a 100-N load was applied to the second premolar, and the tension was observed. After this process, another 200-N load was applied in the same location, and stress was measured in all specimens.

For groups 2, 4, 6, and 8, epoxy resin casts were made (Figure 2). For this process, a master steel cast was impressed with silicone for duplication (Silicone Master, Talladium do Brasil, SP, Brazil). With the aid of a transferents , two HE implants (4.1 x 13 mm; Titamax, Neodent, Curitiba,PR, Brazil) were positioned in the silicone impression and covered with epoxy resin (Araltec, SP, Brazil). After 72 h, the silicone impression was removed, and the two strain gauges were positioned in the resin epoxy. After this process, the same steps were performed as in groups 1, 3, 5, and 7 for analyses of the stress and load.

After the strain gauge analysis, the results were tabulated, and the Sigmastat program was used for three-way ANOVA and Tukey (α=5%) statistical analysis.

Results

When the values of stress generated with the 200-N and No load were compared, statistically significant differences were observed among the groups ($p = 0.01$). When the values of stress generated with 200- and 100-N loads were compared, statistically significant differences were observed among all groups (p = 0.01). When the 100-N-load groups were compared with the ‘no loads only’ group, there were no statistically significant differences in the Ni-Cr overcast (p = 0.12) (Table 3).

Table 3. The average values of tension (μƐ) and standard deviationin the epoxy resin model with different loads.

	No load	100 N	200 N
Co-Cr cast	691 (120)B	1153.4 (123)C	1795 (520)A
Co-Cr overcast	678 (102)B	1068.3 (862)C	1214 (418)A
Ni-Cr-Ti cast	723.5 (98)B	1321.1 (171)C	1930 (498)A
Ni-Cr-Ti overcast	864 (146)D	1125.7 (124)D	1821 (177)A

Means followed by different letters in the line indicate statistical difference according to ANOVA; (α=5%).

When stress values generated with the 100-N load and no load, and the 200- and 100-N loads, were compared, statistically significant differences were not observed only in Ni-Cr-Ti cast (p = 0.23) . When stress values generated with 200-N loads and “no loads” were compared, statistically significant differences were observed among all groups (p = 0.02) (Table 4).

Table 4. The average values of tension (µƐ) and standard deviation in the gypsum model with different loads

	No load	100 N	200 N
Co-Cr cast	545.5 (105)D	858 (164)C	1055 (649)A
Co-Cr overcast	410 (54)D	610 (120)C	945.5 (380)A
Ni-Cr-Ti cast	1001 (174)BD	1182 (136)BE	1246 (246)AE
Ni-Cr-Ti overcast	462 (204)D	701 (421)C	1759 (712)A

Means followed by different letters in the line indicate statistical difference according to ANOVA; (α=5%).

When values in Tables 3 and 4 were compared, there was a statistically significant numerical increase of the stress generated on the implants that were evaluated with the resin and which were evaluated directly over the implants (p = 0.02).

Discussion

Edentulism in the Brazilian population remains significant, and full or partial rehabilitation with dental implants is well-accepted by professionals and patients alike. However, there are still problems that result in the failure of osseointegration. [4,5]

The present study used different occlusal loads to simulate the different masticatory stresses generated at the cervical region of the implant, with UCLA abutments used directly in the implants. The first hypothesis tested in this study was that the stress level would increase with the increase in masticatory load, and that this increase could potentially harm the implants. Analysis of the data presented in Table 1 demonstrated that the observed stress value in this study was similar to the modulus of elasticity of cancellous bone only when screws were tightened and was below the threshold modulus of elasticity of the cortical bone for groups with 100- and 200-N loads. [29,30]

The strain values were similar to the modulus of elasticity of cancellous bone when values of the "no load" and 100-N-load groups were observed for all abutments, except the Ni-Ti-Cr cast. When the stress generated with the 200-N load was observed, values were consistent with the elastic modulus of cortical bone. Thus, only the occlusal load did not lead to implant failure. [22,32,33,34] This is based on the mechanostat theory posited by Frost, that bone-remodelling activities remain in the bone bruise when strain is in the range of 200–1000 µƐ. The high strain level ranging from 1000–3000 µƐ stimulates remodelling activity and results in an increase in bone density, while the bony structure subjected to pathologic strain above 3000 µƐ induces generation of internal cracks that cannot be repaired by ordinary remodelling activity and will cause bone failure.[22,23,24] Thus, the use of this criterion provides a method for the identification of failure regions due to tensile or compressive overloading, particularly if there is excess load at the initial stage of implant osseointegration. [35]

The second hypothesis evaluated in this study, that there was a difference between the two methodologies involving a strain gauge, was confirmed. Some studies compared stresses caused by the use of straight and angled pillars.

Compressive strengths of different loads focused on straight and angled pillars with various angles. The results showed that strain gauges bonded to the middle region of the implant body are a valid method for evaluation of stress distributed along the implant-bone interface. Loading incidents in the vertical direction show a higher stress in the apical region of the implants when photoelasticity is used, but in loads with angled pillars, the magnitude of stress generated will be concentrated in the cervical region of the implants. As the load was always applied in pontic prostheses, the tension was concentrated in the internal cervical abutment, which is why the position of the sensors was crucial.[36,29,37] Another point that can be taken into account regarding load application on implants is that resin may have become detached from the implant, which may explain the differences between numerical techniques. Cehreli[27], have reported that value calculated for maximum shear stress of the resin is similar to the modulus of elasticity of cancellous bone and is more susceptible to the deformation model.[38]

The microstrain magnitudes may vary between prostheses and implants with the use of abutments. In the present study, we observed differences in stress between the different abutments only when the use of strain gauges directly on the implant (Table 3) or the photoelastic resin (Table 4) was evaluated. These results came from studying the work of Tramontino[36] and Vasconcelos[29], who reported that the type of abutment did not interfere in the magnitude of microstrain, but that the implant-abutment joint and axial loading location influenced this magnitude.

Conclusions

The use of resin for analysis with strain gauges did not show lower results when compared with the plaster model.

The overcast abutments of Co-Cr showed lower strain than other abutments.

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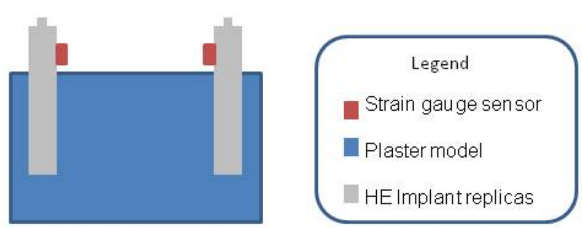

Figure 1. Shows a plaster model and the position of strain gauge sensors.

Figure 2. Shows a resin model and the position of strain gauge sensors.

Considerações Gerais

Fatores biomecânicos, são apontados na literatura, como as principais causas de falha ou insucesso com próteses sobre implantes. Alguns trabalhos relatam que existe uma tolerância na capacidade de absorção dos impactos gerados ao sistema prótese/implante/osso, e que excisavas cargas oclusais podem ser nocivas a esse conjunto (Isidor 1996, Frost *et al*, 2001). Principalmente, quando utiliza-se implantes com conexão do tipo hexágo externo, e sobre estes implantes são utilizados pilares UCLAs parafusados diretamente sobre os implantes (Kano *et al* 2007, Delben 2009).

A utilização de próteses com pilares do tipo UCLA, apesar de apresentarem desvantagens biomecânicas importantes como por exemplo a soltura do parafuso com uma frequência maior que em componentes intermediários, ainda é amplamente utilizada nos consultórios em função do apelo comercial que possuem(Bhering *et al* 2013).

O capitulo 1 aborda aspectos relevantes sobre esse assunto quando estuda as possíveis diferenças na geração de tensão com o uso de *strain gauges* utilizando diferentes pilares protéticos e ligas metálicas para fundição.

Os valores médios de tensão foram menores quando da utilização da liga de Co-Cr e pilar metaloplástico. Alguns autores apontam para o fato de que a tensão inicial esta atrelada a uma distorção tridimensional da infraestrutura, que acontece no momento em que é realizado o torque dessas infraestruturas (Abduo & Lyons, 2012). No presente estudo o posicionamento dos sensores favoreceu essa captação de tensão visto que estudos prévios mostram que a maior deformação ocorre em regiões cervicais internas dos implantes. Esse fato também foi observado quando da utilização de cargas de 100 e 200 N sobre essas infraestruturas (capítulo 2). Apesar de um aumento na tensão com aplicação das cargas de 100 e 200 N em todos os grupos, as infraestruturas que utilizaram a liga de Co-Cr e pilar metaloplástico apresentaram uma menor deformação e consequentemente uma menor geração de tensão. A literatura mostra que 50%

das falhas biomecânicas são causadas pela técnica de obtenção desse tipo de infraestrutura metálica (Karl *et al*, 2012). E que essas falhas poderiam induzir a um aumento nas tensões geradas, todavia no presente estudo de acordo com Frost *et al* em 2001, os níveis de tensão não atingiram os valores considerados patológicos.

Outro ponto analisado é a diferença de metodologia empregada na utilização dos sensores, alguns estudos apontam para a necessidade da utilização da resina para ánalise com strain gauges (Chereli *et al* 2004, Cariello 2009), visto que a resina apresenta um módulo de elasticidade semelhante ao do osso. Porém no presente trabalho ficou evidente a dificuldade de trabalhar com esse material, visto que a sua técnica de obtenção é extremamente difícil e requer uma certa habilidade e treinamento prévio na obtenção dos modelos. Outro aspecto que pode contribuir para alteração dos resultados é a deformação que a resina sofreu ao aplicar-se a carga, chegando ao ponto de inviabilizar o uso, necessitando-se a confecção de outro modelo de resina. A metodologia com o uso dos *strain gauges* tem a vantagem de apresentar dados numéricos, diferentemente dos resultados obtidos quando do uso da fotoelasticidade, que em sua grande maioria apresenta resultados qualitativos. Porém a grande desvantagem do uso da extensometria é a utilização de sensores que captam a tensão em pontos específicos. A escolha da posição dos sensores baseou-se em estudos prévios com modelos fotoelásticos e elementos finitos que demostraram que para esse padrão de infraestruturas a tendência é que os valores máximos de tensão estariam concentrado na região cervical interna dos implantes(Ueda *et al* 2004; Nagasawa *et al* 2008; Tonella *et al* 2011).

A literatura é controversa ao tratar de passividade, visto que mesmo com a tecnologia CAD/CAM não foi possível ainda obter uma prótese com 100% de adaptação, e esse desajuste pode levar a um aumento de tensão(Karl *et al* 2012). No presente estudo as infraestruturas foram avaliadas visualmente e com o auxilio de uma sonda exploradora realizou-se o teste tátil para verificar o nível de adaptação das peças (Kan *et al* 1999). Essa manobra foi realizada com o intuito de garantir os menores valores de desadaptação possível, visto que a passividade pode ser um fator contribuinte com o aumento da tensão gerada sobre os implantes.

Vale ressaltar que a tensão gerada quando avaliada isoladamente não leva a falha dos implantes, porém atua como um agente desencadeador. A metodologia empregada com infraestruturas planas facilita a confecção adaptação dessas peças sobre os implantes, diferente de uma infraestrutura mais complexa e com um número maior de implantes. No presente estudo não foram avaliados outros fatores que também podem levar a falha dos implantes, como a fadiga do parafuso, pré-carga dos mesmos, a contaminação bacteriana, a capacidade do paciente higienizar essas próteses, e o tipo do osso.

CONCLUSÃO:

Dentro das limitações do estudo conclui-se que:

Diferentes materiais para avaliação de tensão apresentam resultados diferentes.

O aumento constante da carga sugere um aumento da tensão gerada sobre implante.

Os pilares sobrefundidos em Co-Cr apresentam menores valores de tensão.

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