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Strain Gauge: study of strain distributions around three Morse taper prosthetic connections with offset positioning in machined and plastic copings under vertical load

Extensometria: estudo das microdeformações ao redor de três conexões protéticas cone Morse, com posicionamento compensado (offset) em coifas usinadas e plásticas sob carga vertical

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ABSTRACT

The aim of this study was to evaluate through strain gauge the strain distribution occurred around 3 Morse taper implants with positioning offset, by varying the types of copings: plastic and machined. Microunit prosthetic abutments were connected onto the implant platforms. Ten frameworks composed of 3 copings were casted in cobalt-chromium alloy as single block (Co-Cr). Half of the copings were machined (n=5) and half were made of plastics (n=5). Four strain gauges were placed into the polyurethane block tangential to the 3 implants. The frameworks were fixed at their respective sites with the aid of a retaining screw with torque of 20 N.cm, achieve with a mechanical torquemeter. The vertical load of 30 Kg was applied through a spherical point of 2 mm diameter for 10 s, onto each one of the 3 screws of the framework through a device for load application The records of the strain reading were submitted to ANOVA and Tukey tests (5%). There were statistically significant differences (p=0.0174) between the coping type used (machined and plastic). The micro strain mean values were: point C at the machined coping 282.5 μm (±120.8), point B at the machined coping 229.5 μm (±76.1), point A at the machined coping 209.8 μm (±55.0), point C at the plastic coping 155.0 μm (±30.5), point B at the plastic coping 146.2 μm (±25.8) and point A at the plastic coping 130.36 μm (±21.83). It was concluded that there was a significant difference between the coping types, once the plastic coping exerted smaller micro strain on Morse taper implants than the machined copings.

KEYWORDS

Biomechanics; Dental implant; Dental prosthesis.

RESUMO

O objetivo deste trabalho foi avaliar por meio da extensometria as microdeformações ocorridas ao redor de 3 implantes cone Morse com posicionamento compensado (offset) inseridos em um bloco de poliuretano. Sobre a plataforma dos implantes foram conectados pilares protéticos microunit. Dez supra estruturas constituídas por 3 coifas foram fundidas em monobloco com liga de Cobalto-Cromo (Co-Cr), sendo que metade das supra estruturas foram utilizadas coifas usinadas (n=5) e a outra metade de coifas plásticas (n=5). Quatro extensômetros foram colocados no bloco de poliuretano tangenciando os três implantes. As supra estruturas foram fixadas nos respectivos locais com o parafuso de retenção com torque de 20 N.cm, obtidos com um torquímetro mecânico. A carga estática vertical de 30 Kg foi aplicada com uma ponta esférica de 2 mm de diâmetro durante 10 s, sobre cada um dos 3 parafusos da supra estrutura utilizando o dispositivo de aplicação de cargas. Os registros foram submetidos ao teste ANOVA e Tukey (5%). O resultado estatístico mostrou que houve diferença significante (p=0,0174) para o efeito de aplicação de carga. Os valores médios de microdeformação: ponto C na coifa usinada 282.5 μm (±120.8), ponto B na coifa usinada 229.5 μm (±76.1), ponto A na coifa usinada 209.8 μm (±55.0), ponto C na coifa plástica 155.0 μm (±30.5), ponto B na coifa plástica 146.2 μm (±25.8) e ponto A na coifa plástica 130.36 μm (±21.83).

Concluiu-se que a coifa que exerceu menor microdeformação em implantes cone Morse foram as coifas plásticas.

PALAVRAS CHAVES

Biomecânica; Implante dentário; Prótese dentária.

INTRODUCTION

The cautious control of biomechanical loading on dental implants is imperative to enable the long-term success of rehabilitation [1]. However, the precise mechanism of the load transferring is not fully understood, but it is certain that there is a remodeling response around the bone under particular tension [2,3]. Since both the definition and principles of osseointegration, various abutment/implant connection designs are available for clinical use in order to improve loading distribution [4].

The application of a functional loading induces tension and strain to bone/implant complex [5-7]. And the amount of this occlusal load transmitted to the implants and the tension induced depends on where the load is applied [8,9].

The major types of anchorage unit load are: non-axial and axial loads. The axial force is the most favorable, because it distributes the tension more evenly throughout the implant, while the non-axial load exerts higher gradients of tension on the implant as well as on the peri-implantar bone [10].

The mechanical and biological complications between abutment/implant such as the screw loosening, fracture of the crown as well as the inflammation of the peri-implantar tissues have been reported by several authors [11]. Esposito et al. 1998, [12]. Cardoso et al [13] and are of great relevance because they enable to assure the longevity of the restorations to the patients. One of the possible complications could be reduced according to Rangert and cols. [14] and Sahin et al. [15] by the insertion of the implant at an offset position, decreasing the bending moment.

Among the implant systems commercially available, morse taper implant system has an implant/abutment connection so-called “self-locking” with an angle < 5° [7]. Its locking system through friction between the components enables a closer contact between the implant body and the prosthetic abutment [15] and this design allows large resistance to friction and to lateral forces, integrity during larger period and function and great contact at the implant/abutment interface, favoring a safer connection [1,8,10,15-20].

The taper connection was proposed to be more biomechanically stable than external or internal hexagon connection [21-23]. The reduction of the micromovements allows resistance and higher stability [21]. The potential mechanical advantages of the internal taper design over the hexagon connection were previously reported on in vitro [21] and in vivo [24] studies.

One way to evaluate the strain distribution around the implants “in vitro” studies is the use of strain gauge, which is a technique for the recording of micro strain through the alteration of the electrical resistance. The function of this circuit is to convert a resistance change to an electrical voltage which can therefore be measured with great accuracy at the place where the strain gauge is placed [25,26].

The aim of this study was to verify the strain distributions occurring around each one of 3 morse taper implants at offset positioning, by varying the CoCr casting obtained through machined and plastic copings, during the application of axial loads.

MATERIAL AND METHODS

A polyurethane block (Polyurethane F16 Axson, Cercy – France) was constructed from a silicon mold (Silicone rubber for molding: Clássico artigos odontológicos, Catanduva- São Paulo, Brazil). The block was finished with the aid of 200 to 600 grit sandpapers to obtain surface as regular as possible. The final dimensions comprised 95 mm length x 45 mm width and 20 mm height.

To achieve the offset positioning of the morse taper implants, an aluminum matrix was constructed and machined comprising 3 parts [35]. These parts are overlapping each other and have perforations that enable the screwing of specific screws to achieve their union. Two of these parts have 3 central perforations at 3 mm among each other to guide the perforation of the block to insert the implants. In the block perforation, a set of standardized twist drills (AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brasil) was used. The protocol to execute these perforations followed the conventional patterns, except for the asepsis. The mean speed of the perforation was 1800 rotations per minute. The implants were placed with the aid of a surgical ratchet (AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brasil) with a torque of 40 N.cm onto each morse taper implant.

Over each morse taper implant, Microunit prosthetic abutments were connected (AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brasil) with torque of 20 N.cm with the aid of a mechanical torquemeter (AS TECHNOLOGY TITANIUM FIX – São José dos Campos, Brasil).

The uniaxial strain gauges KFG-02-120-C1-11N30C2 (Kyowa Eletronic Instruments Co., Ltd – Tokyo – Japan) were bonded to the polyurethane block with the aid of a cyanoacrylate-based adhesive (Super Bonder Loctite, São Paulo - Brazil). The 4 strain gauges were tangential to each one of the prosthetic abutments and to determine accurately the bonding sites, a straight line was drawn so that 2 strain gauges were placed onto the implant extremities and other 2 strain gauges were positioned diametrically at the central abutment parallel to those of the extremities. The plates of the terminals were bonded to the upper extremities of the greater sides of the polyurethane block, where the electrical connections were performed. To construct the samples to be placed onto the prosthetic abutments of the implants, 10 rectangular coping wax-up were obtained: 5 for the machined and 5 for the plastic copings. These coping wax-ups were embedded into silicon rings with graphite-free, phosphate bound investment (Bellavest SH Bego, Bremen – Germany). Casting was performed with Co-Cr alloy (Wirobond SG, Bremen, Germany) and the metal injection was carried out through a conventional centrifuge device. After the cooling of the samples, they were individually adapted to the prosthetic abutments at the block, where the abutment/coping stability was assessed without torque. The copings showing instability were excluded from the study (Figure 1).

The application of the static axial loads was executed through a load application device (DAC) onto each implant by using a spherical tip of 2 mm diameter with load of 30 kg for 10 s over each retaining screw of the framework. The electrical resistance changes were transformed into micro strain units (με) electrical signal conditioner (Model 5100B Scanner – System 5000 – Instruments Division Measurements Group, Inc. Raleigh, North Carolina – USA,) which also recorded the information. Data was recorded through strain-smart software in a Pentium IV computer with 1.1Ghz, 256MB of RAM. All procedures were repeated twice and the strain distributions were determined by the charging recorded by 4 strain gauges.

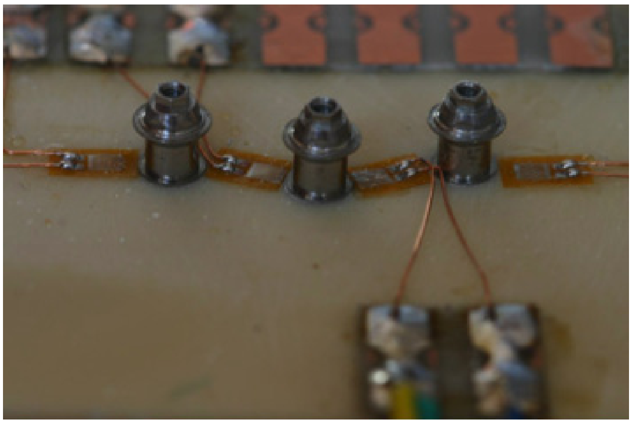

Figure 1- Abutments placed at the offset positioning with the respective strain gauges.

RESULTS

Data recorded through strain gauge were submitted to statistical analysis through ANOVA and Tukey tests to compare the micro strain magnitude measured with the coping type and the points of load application. Homocedacity was obtained through logarithmic scale.

The descriptive statistics for the coping type is displayed in table 1.

TABLE 1 – MICRO STRAIN (ME) DATA REGARDING TO THE COPING TYPE, OBTAINED THROUGH FOUR STRAIN GAUGES

Coping	n*	Mean (log)	Standard Deviation
Plastic	15	143.85 (2.15)	26.55
Machined	15	240.6 (2.35)	87.7

*application points versus number of samples

The micro strain means for the interaction factor between the coping type and the application point are seen in tables 2 and 3.

TABLE 2 – MICRO STRAIN (ME) DATA REGARDING TO THE INTERACTION BETWEEN THE PLASTIC COPING AND THE POINT OF LOAD APPLICATION, OBTAINED THROUGH FOUR STRAIN GAUGES

Application point	n*	Mean	Standard Deviation	Coefficient of Variation
A	5	130.36	21.83	16.75
B	5	146.2	25.8	17.68
C	5	155.0	30.5	19.71

*number of samples

TABLE 3 – MICRO STRAIN (ME) DATA REGARDING TO THE INTERACTION BETWEEN THE MACHINED COPING AND THE POINT OF LOAD APPLICATION, OBTAINED THROUGH FOUR STRAIN GAUGES

Application point	n*	Mean	Standard Deviation	Coefficient of Variation
A	5	209.8	55.0	26.24
B	5	229.5	76.1	33.14
C	5	282.5	120.8	42.76

* number of samples

Strain distributions data for the coping type and application point were submitted ANOVA of repeated measures of point of load application, as seen in table 4.

TABLE 4 – RESULTS OF REPEATED MEASURES ANOVA

Effect	Gl	SQ	MQ	F	P
Coping	1	70198	70198.2	8.93	0.0174*
Residue I	8	62854	7856.8		
Load application (LA)	2	12136	6068.2	2.48	0.1150
Interaction (cylinder/LA)	2	3578	1789.2	0.73	0.4963
Residue II	16	39097	2443.6		
Total	29	187865			

*p<0.05

Following, Tukey test for multiple comparison were applied and the results are shown in table 5.

TABLE 5 –TUKEY TEST FOR MICRO STRAIN MEANS IN THE 3 EXPERIMENTAL CONDITIONS (COPING TYPES)

Coping	Point	Mean (log)	Homogenous groups
Machined	C	282.52 (2.42)	A
Machined	B	229.51 (2.33)	AB
Machined	A	209.76 (2.31)	AB
Plastic	C	154.97 (2.18)	AB
Plastic	B	146.23 (2.15)	AB
Plastic	A	130.36 (2.11)	B

*Means followed by the same letters are not statistically different.

DISCUSSION

Several scientific studies have demonstrated the success of oral implantology as restorative and rehabilitative treatment. Thus, several studies have been conducted to understand and reduce the number of complications which may occur after the implant installation and masticatory load application. Several techniques have been used to assess the biomechanical loads over the implants, such as finite element analysis and strain gauge [8,25,27].

The bone amount is one of the factors influencing on the result of implant treatment. The bone surrounding the implants is not a homogenous substrate, so that its physical properties vary according to age, functional state, and systemic factors of the patients [15,28,29]. It is difficult to conduct in vivo studies, because the placement of the strain gauge inside the mouth and obtainment of reliable data would be impossible. Therefore, in vitro studies have employed homogenous and isotropic materials [26,27,30,31]. For this purpose, this study used a polyurethane-based block which has a modulus of elasticity similar to that of the human bone marrow (Polyurethane: 3.6 GPa/ bone marrow: 4.0 to 4.5 GPa) [3,32].

Many strain gauges studies used special devices to apply the load on the implants [1,8], however, other coupled them to universal testing machine [26]. The load application device (DAC) employed in this study showed results compatible with those of the universal testing machine (EMIC). The load amount used in this present study (30 kg) was based on the study of Merick-Stern in 1995 [33] who researched the occlusal force in patients wearing implant-support fixed partial dentures and found a mean value of 30.6 kg for the posterior teeth.

An ideal model for micro strain assessment is not available yet. Some studies placed the strain gauge on the prosthetic units [31]; other [10] opted to bond them onto the implants. Notwithstanding, the placement of the strain gauge onto the surface of the polyurethane block close to the cervical area of the implant is justified because this is the area where the greatest strain distribution occurs after the load application [26,27].

Aiming to remove any type of dimensional alteration, this study eliminated the steps of transfer impression of the implants and dental cast obtainment. Both the machined and plastic copings were directly adapted onto the implants and incorporated to the standardized wax-ups. Several studies [32,34-36] reported that the metallic frameworks constructed onto dental casts produced highest deformations than those constructed without the impression procedures.

According to the results obtained, the loading performed onto the points of application A, B and C (Table) 1 showed the highest micro strain occurring in the implants with machined copings at offset positioning. Point C for the machined copings (282.5 με ±120.8) undergone the highest micro strain, while point A for plastic copings (130.36 με ±21.83) undergone the lowest micro strain. According to table 4, ANOVA test showed that the statistical differences were related to the coping types (p = 0.0174).

These results suggested that the coping type, either machined or plastic, influences on micro strain when submitted to vertical load application at offset positioning, because in this present study, the machined copings exhibited the highest micro strain results. Nishioka et al. [34], compared different machined and plastic copings in external and internal hexagon implants and verified that there were no statistically significant differences regarding to the coping types for both prosthetic abutments. Other studies [35,36] exhibited statistical differences for other factors different from those of this present study. Nishioka et al. [36] assessed the strain distribution caused in internal and external hexagon implants verifying the highest micro strain values in the internal hexagon implants. In another study, Nishioka et al. [35] compared 3 types of prosthetic connectors: external hexagon, internal hexagon, and morse taper, both at linear and offset positioning and the data obtained showed that there were statistically significant differences regarding to the prosthetic connector. Thus, these aforementioned studies are not in agreement with the findings of this present research. Notwithstanding, Frost in 1994 [2] demonstrated that tensions between 100 $\mu\varepsilon$ and 2000 $\mu\varepsilon$ generated in the bone tissue did not produce pathological damage but a physiologic window resulting in bone remodeling required for bone tissue maintenance. In this present study, the micro strain simulated in the polyurethane block did not surpass 600 $\mu\varepsilon$. To generate a bone structure loss damaging to the oral rehabilitation with implant-supported fixed partial dentures, the deformation should surpass the physiologic threshold of 4000 $\mu\varepsilon$ [2,3].

Unlikely, Carr et al. [37] in a study with single crowns, demonstrated the accuracy of the frameworks obtained through machined copings which were higher than that of plastic cylinders. The results of smaller deformation obtained by the plastic copings of this present study can be attributed to the fact that we employed multiple prostheses, so that a possible pre-adaptation of the coping prior to casting due to the plastic deformation of the material itself could have favored the adaption at the moment of the plastic coping placement onto the prosthetic connector.

CONCLUSION

Based on the methodology employed and results obtained, it can be concluded that the used of either plastic or machined copings altered the final result of tension distribution after axial loading. The site of axial loading application did not influence on the micro strain magnitude. The axial loads applied onto different points of the implant produced a micro strain magnitude within the physiologic threshold.

REFERENCES

1. Çehreli M C, Iplikçioglu H, Bilir Ö G. The influence of the location of load transfer on strains around implants supporting four unit cement-retained fixed prostheses: in vitro evaluation of axial versus off-set loading. J Rehabil. 2002,29:394-400.
2. Frost, H. M. Wolff's law and bone's structural adaptations to mechanical usage: an overview for clinicians. Angle Orthod. 1994, 64:175-188.
3. Wiskott, H. W., Belser, U. C. Lack of integration of smooth titanium surfaces: a working hypothesis based on strains generated in the surrounging bone. Clin Oral Implants Res. 1999,10:429-44.
4. Freitas-Júnior AC, Almeida EO, Bonfante E A, Silva NR, Coelho PG. Reliability and failure modes of internal conical dental implant connections. Clin Oral Implants Res. 2012 Mar 19. doi: 10.1111/j.1600-0501.2012.02443.x.
5. Bidez MW, Misch CE: Force transfer in implant dentistry: basic concepts and principals. J Oral Implantol. 1992,23:264-74.
6. Branemark PI, Zarb GA, Albrektsson T. Tissue-Integrated Prostheses. Osseointegration in Clinical Dentistry. Chicago: Quintessence,1987. p.129.
7. Van Oosterwyck H, Duyck J, Vander Sloten J, Van der Perre G, De Cooman M, Lievens S, et al. The influence of bone mechanical properties and implant fixation upon bone loading around oral implants. Clin Oral Implant Res 1998,9:407-418.
8. Assif D, Marshak B, Horowitz A. Analysis of load transfer and stress distribution by an implant-supported fixed partial denture. J Prosthet Dent. 1996,75:285-91.
9. Skalak R. Biomechanical considerations in osseointegrated prostheses. J Prosthet Dent 1983,49:843-8.
10. Akça K, Cehreli MC, Iplikçioglu H. Evaluation of the mechanical characteristics of the implant-abutment complexo f a reduced-diameter Morse-taper implant. A nonlinear finite element stress analysis. Clin Oral Impl Res. 2003,14:444-4.
11. Rangert B, Krogh PH, Langer B, Van Roekel N. Bending overload and implant fracture: a retrospective clinical analysis. Int J Oral Maxillof Imp 1995,10:326–34.
12. Esposito M, Hirsch JM, Lekholm U. Thomsen P. Biological factors contributing to failures of osseointegrated oral implants (II). Etiopathogenesis. European Journal of Oral Sciences. 1998,106:721–64.
13. Cardoso LC, Luvizuto ER, Trevisan CL, Garcia IR Jr, Panzarini SR, Poi WR. Resolution of a titanium implant fracture after a recurrent trauma. Dental Traumatology. 2010,26:512–5.
14. Rangert BR, Sullivan RM, Jemt TM. Load factor control for implants in the posterior partially edentulous segment. Int J Oral Maxillofac Implants. 1997,12:360-70.
15. Sahin S C, Ehreli MC, Yalcin E. The influence of functional forces on the biomechanics of implant-supported prostheses – a review. J Dent. 2002,30:271-282.
16. Solnit G S, Schneider R L. An alternative to splinting multiple implants: use of the ITI system. J Prosthodon. 1998,7(2):114: 9.
17. Mangano C, Mangano F, Shibi J A, Ricci M, Sammons R L, Figliuzzi M. Morse taper connection implants supporting ''planned'' maxillary and mandibular bar-retained

overdentures: a 5-year prospective multicenter study. Clin. Oral Impl. Res. 2011, 22:1117–24.

18. Mangano C, Mangano F, Piattelli A, Iezzi G, Mangano A, La Colla L. Prospective clinical evaluation of 1920 Morse taper connection implants: results after 4 years of functional loading. Clin. Oral Impl Res. 2009,20:254-61.
19. Sutter F, Webber H P, Sorensen J, Belser U. The new restorative concept of the ITI dental implants system: designan engineering. Int J Period and Rest Dent. 1993, 13:409-31.
20. Glantz P O, Rangert B, Svensson A, Stanfford G D, Arnvidarson B, Randow K. et al. On clinical loading of osseointegrated implants. A methodological and clinical study. Clin Oral Implants Res. 1993,4(2):99-105.
21. Merz BR, Hunenbart, S. Belser, UC. Mechanics of the implant-abutment connection: an 8-degree taper compared to a butt joint connection. The Int J Oral Maxillof Implants. 2000,15:519–26.
22. Norton MR. An in vitro evaluation of the strength of a 1-piece and 2-piece conical abutment joint in implant design. Clinical Oral Implants Research. 2000,11:458–64.
23. Steinebrunner L, Wolfart S, Ludwig K, Kern M. Implant-abutment interface design affects fatigue and fracture strength of implants. Clinical Oral Implants Res. 2008,19:1276–84.
24. Levine RA, Clem DS 3rd, Wilson TG Jr, Higginbottom F, Solnit G. Multicenter retrospective analysis of the iti implant system used for single-tooth replacements: results of loading for 2 or more years. Int J Oral Maxillofacial Implants. 1999,14:516–20.
25. Clelland NL, Gilat A, McGumphy, EA, Brantley WA. A photoelastic and strain gauge analysis of angled abutments for implant system. Int J Oral Maxillofac Implants 1993,8:541-8
26. Kim WD, Jacobson Z, Nathanson D. In vitro stress analyses of dental implants supporting screw retained and cement retained prostheses. Implant Dent. 1999, 8(2):141:51.
27. Çehreli M, Duyck J, De Cooman M, Puers R, Naert I. Implant design and interface force transfer: a photoelastic and strain-gauge analysis. Clin Oral Implants Res 2004 Apr,15(2):249-57.
28. Hsu J T, Fuh LJ, Lin DJ, Shen YW, Huang HL. Bone strain and interfacial sliding analyses of platform switching and implant diameter on an immediately loaded implant: experimental and three-dimensional finite element analyses. J Periodontol. 2009; 80(7):1125-32.
29. Trisi P, Perfetti G, Baldoni E, Berardi D, Colagiovanni M, Scogna G. Impalnt micromotion is related to peak insertion torque and boné densite. Clinical Oral Implants Research. 2009;20(5):467-71.
30. Akça K, Cehreli MC, Iplikçioglu H. A comparison of three-dimensional finite element stress analysis with in vitro strain gauge measurements. Int J Prosthodon 2002:15:115-21.
31. Heckmann SM, Karl M, Wichmann MG, Winter W, Graef F, Taylor T D. Cement fixation and screw retention: parameters of passive fit. An in vitro study of three-unit implant-supported fixed partial dentures. Clin Oral Implants Res. 2004 Aug;15(4):466-73.
32. Watanabe F, Uno I, Hata Y, Neuendorff G, Kirsch A. Analysis of stress distribution in a screw-retained implant prostheses. Int J Oral Maxillofac Implants. 2000; 15 (2):209-18.
33. Merick-Stern R, Assal P, Merickse E, Ing WB. Oclussal force and oral tactile sensibility measured in partially edentulous patients with ITI implants. Int J Oral Maxillofac Implants. 1995;10(3):345-54.
34. Nishioka RS, de Mello Nishioka L N, Abreu C W, Vasconcellos L G, Balducci I. Machined and plastic copings in three-element prostheses with different types of implant abutment joints a strain gauge comparative analysis. J Appl Oral Sci. 2010; 18(3):225-30.
35. Nishioka R S, Vasconcellos LG, de Melo Nishioka L N. External hexagon and internal hexagon in straigt and offset implant placemente: strain gauge analysis. Implant Dent. 2009;18(6):512-20.
36. Nishioka RS, Vasconcellos LG, de Melo Nishioka GN. Comparative strain gauge analysis of external and internal hexagon, morse taper, and influence of straight and offset implant configuration. Implant Dent.2011;20(2):24-32.
37. Carr AD, Brunski JB, Hurley E. Effects of fabrication, finishing and polishing procedures on preload in prostheses using conventional “gold” and plastic cylinders. Int J Oral Maxillofac Implants. 1996;1(5):589-98.

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