Implant Abutment Deformation During Prosthetic Cylinder Screw Tightening: An In Vitro Study

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Purpose: Nonpassive fit frameworks are believed to lead to implant overload and consequently loss of osseointegration. This is one of the most commonly reported failures of implant prostheses. In an ideal situation of passive fit, when torque is applied to bring the abutment-cylinder interface together some amount of deformation can be expected, and it should be homogeneous along the periphery of the abutment. The aim of this study was to verify the amount of abutment deformation that can be expected when a free-standing cylinder is screwed into place. This could give insight into what should be accepted as passive fit. ***Materials and Methods:*** Strain gauges were bonded to the sides of five standard abutments that had machined palladium-silver cylinders or cobalt-chromium cast cylinders screwed into place. Measurements were taken to verify the deformation at each site. ***Results:*** Values of abutment deformation after abutment screw tightening ranged from –127.70 to –590.27 $\mu\varepsilon$. The deformation recorded for palladium-silver prosthetic cylinder tightening ranged from 56.905 to –381.50 $\mu\varepsilon$ (mean: 173.298 $\mu\varepsilon$) and from –5.62638 to –383.86 $\mu\varepsilon$ (mean: 200.474 $\mu\varepsilon$) for cobalt-chromium cylinders. There was no statistically significant difference among the two groups. ***Conclusion:*** Both abutment screw tightening and prosthetic cylinder screw tightening result in abutment deformation, which is compressive most of the time. *Int J Prosthodont 2009;22:391–395.*

The relevance of osseointegration in today's prosthodontic practice is well recognized. Both totally and partially edentulous patients greatly benefit from this technique. Failure rates are low and easily surmounted by the improvements in function, esthetics, and quality of life.

Nevertheless, failures do occur and are considered to be related to a range of biologic and mechanical factors. Among the most commonly reported failures are: resorption of the peri-implant bone crest, peri-implantitis, loss of osseointegration, screw loosening and fracture, and fracture of the prosthesis, prosthetic components, and even the implant itself.[1–5] Yet, according to Isidor,[6] although it has been stated that occlusal forces may be associated with loss of oral implants, a causative relationship has never been convincingly demonstrated.

Many times the cause of failure is attributed to a nonpassive framework, which leads to implant overload.[2,7–12] Framework passivity has become a concern in implant prosthodontics and all efforts have been made to pursue it. Restorative dentists have the task of obtaining a passive fit without any accepted clinical parameters for horizontal, vertical, or angular discrepancies. Thus, the goal is to create a fit as accurate as clinically possible to avoid strains in the components. Therefore, the way passivity of fit is understood leads to the belief that no stresses or strains must exist at all.

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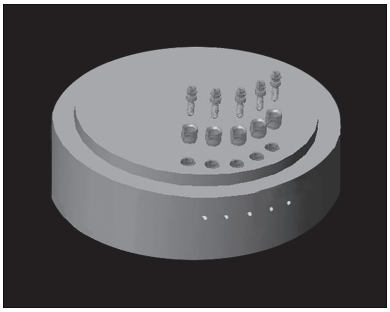

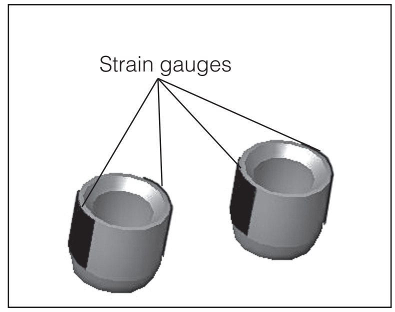

Fig 1 *(left)* Master cast with implant replicas secured by Allen screws, standard abutments, and abutment screws.

Fig 2 *(right)* Strain gauges bonded to the sides of the abuments.

That may not be true, since when torque is applied to bring the joints together a tensile force appears on the screw, which is then elongated. This leads to the development of a compressive axial force between the cylinder and abutment, which maintains the union between the components.[1,13,14] Compressive forces deform the components to a measurable level. If the compressive force is homogeneous along the periphery of the abutment-cylinder interface, or in other words, if the cylinder fits properly to the abutment, deformation of the abutment should also be homogeneous and measurable. Usually, machined components are preferred to cast ones because casting may produce a rough surface, making it even more difficult to achieve a proper fit. Machined cylinders need to be overcast to create multiple element frameworks, which in itself is another complicating factor. Therefore, this study was aimed at evaluating the deformation to which abutments are submitted when free-standing cylinders are screwed onto them to verify what level of deformation can be expected in this situation. This could lead to the determination of a measurable parameter to what constitutes a passive fit framework.

Materials and Methods

A round master cast measuring 67 mm in diameter by 25 mm in height was fabricated in steel, following the model proposed by Chao et al.[15] Five holes were drilled on its upper side where implant replicas (external hex, 3.75 mm in diameter) were placed. To avoid dislodgement, each implant replica was fixed by Allen screws transfixing the master cast horizontally. Four-millimeter standard abutments were then manually screwed into the replicas (Fig 1).

Two linear strain gauges (KFG–02-120-C1-11, Kyowa Electronic Instruments) were bonded to the sides of each abutment, diametrically opposed to each other and parallel to their long axis, using cyanoacrylate (Fig 2). The strain gauges were connected to a data acquisition board (SC–2042–SG, National Instruzments) that sent the signal to a reading board (PCI–MIO–16XE–10, National Instruments) installed in a microcomputer at a four signal-per-second rate. Inputs from the 10 strain gauges were analyzed with the aid of LabVIEW FDS version 5.1 for Windows (LabVIEW, National Instruments). The abutments were numbered from one to five in a clockwise direction in order to facilitate the readings.

A previously calibrated electronic torque controller device (Torque Controller, Nobel Biocare) was used to tighten the abutment screws to 20 Ncm. Readings of deformation in microstrains ($\mu\varepsilon$) occurring at each strain gauge began when the torque meter was started. An initial accommodation phase could then be detected, followed by an increase in the deformation until reaching a stable level. Precision of the readings was of the order of 1×10^{-6}.

Approximately 500 readings were taken at each strain gauge but only the last 100 were taken into account to calculate the mean to ensure that only maximum and stable levels of deformation were recorded. The procedure was repeated five times for each abutment/strain gauge to calculate the mean. For convenience, before initiating the readings of deformation caused by the cylinder screw tightening, the output of the measuring system was set to 0 to separate this deformation from the deformation caused by the abutment screw tightening.

Two sets of prosthetic cylinders for standard abutments (five machined palladium-silver [Pd-Ag] cylinders and five cast cobalt-chromium [Co-Cr] cylinders) were subsequently screwed onto the abutments using a force of 10 Ncm (titanium screws). The same sequence of data acquisition described for the abutments was followed for the prosthetic cylinders. The results were arranged in tables and analyzed using the Mann-Whitney test ($P = .05$) to verify possible statistical differences.

Results

Values of abutment deformation after abutment screw tightening ranged from –127.70 to –590.27 $\mu\varepsilon$ (Table 1). The negative values demonstrate that compression occurred. The following results represent the

Table 1 Means of Abutment Deformations (με) After Abutment Screw Tightening

	Abutment 1		Abutment 2		Abutment 3		Abutment 4		Abutment 5	
	SG 1	SG 2	SG 3	SG 4	SG 5	SG 6	SG 7	SG 8	SG 9	SG 10
1	–113.02	–153.79	–147.14	–142.98	–571.98	–528.92	–359.11	–235.10	–410.51	–368.59
2	–136.98	–171.27	–144.97	–133.16	–625.35	–578.30	–329.50	–232.67	–352.95	–321.18
3	–133.66	–151.80	–116.85	–171.93	–615.21	–570.48	–332.33	–253.14	–322.68	–307.87
4	–136.82	–182.92	–103.70	–129.99	–558.85	–530.25	–286.91	–242.15	–346.30	–343.64
5	–118.01	–188.24	–116.18	–114.52	–579.96	–544.71	–308.20	–223.02	–361.77	–334.99
Mean	–127.70	–169.60	–125.77	–138.52	–590.27	–550.53	–323.21	–237.23	–358.84	–335.25

SG = strain gauge.

Table 2 Means of Abutment Deformation (με) After Prosthetic Cylinder Screw Tightening (Pd-Ag)

	Abutment 1		Abutment 2		Abutment 3		Abutment 4		Abutment 5	
	SG 1	SG 2	SG 3	SG 4	SG 5	SG 6	SG 7	SG 8	SG 9	SG 10
1	–218.36	84.91	–374.08	–411.34	8.823	–58.429	–266.28	–81.40	–235.50	–125.83
2	–199.06	43.61	–361.44	–433.96	12.65	0.17	–209.71	–96.38	–365.26	–127.00
3	–193.90	51.44	–365.76	–395.54	46.28	–34.29	–204.88	–74.58	–347.30	–122.01
4	–210.04	58.60	–265.78	–318.52	7.66	–43.61	–152.63	–93.72	–360.61	–155.46
5	–173.60	45.95	–288.24	–348.13	57.60	–27.967	–170.10	–78.74	–143.48	–114.52
Mean	–198.99	56.90	–331.06	–381.50	26.60	–32.83	–200.72	–84.96	–290.43	–128.96

SG = strain gauge.

Table 3 Means of Abutment Deformation (με) After Prosthetic Cylinder Screw Tightening (Co-Cr)

	Abutment 1		Abutment 2		Abutment 3		Abutment 4		Abutment 5	
	SG 1	SG 2	SG 3	SG 4	SG 5	SG 6	SG 7	SG 8	SG 9	SG 10
1	–251.14	–437.12	–291.24	–312.53	–7.49	–82.07	–180.42	–87.06	–289.74	–47.96
2	–222.19	–356.78	–371.58	–367.26	–5.66	–100.20	–121.67	–84.90	–269.27	–88.39
3	–294.23	–486.01	–280.92	–290.24	–14.31	–68.92	–134.99	–96.21	–253.80	–71.91
4	–272.93	–308.87	–324.18	–406.02	11.49	–74.74	–181.09	–94.38	–269.94	–101.53
5	–217.03	–330.50	–310.37	–405.18	–12.15	–61.76	–188.57	–137.15	–263.12	–109.36
Mean	–251.50	–383.86	–315.66	–356.25	–5.63	–77.54	–161.35	–99.94	–269.17	–83.88

SG = strain gauge.

Table 4 Mann-Whitney Test*

Group	Mean	Median	Sum of posts	Mean post	No.
Co-Cr	200.474	176.506	29.0	5.8	5
Pd-Ag	173.298	142.842	26.0	5.2	5

*Exact probability = 0.841270; probability = 0.75402253.

deformation caused exclusively by prosthetic cylinder tightening with no interference of the previous readings of abutment screw tightening.

The mean deformation recorded for the Pd-Ag prosthetic cylinders was 173.29 με (range: 56.90 to –381.50 με) (Tables 2 and 4). A mix of deformation by tension (positive values) and compression (negative values) forces was detected for this group. For the Co-Cr cylinders, the mean deformation was 200.47 με (range: –5.62 to –383.86 με) and was caused only by compression forces (Tables 3 and 4).

Although deformation by tension forces could be detected in the Pd-Ag cylinders, no statistically significant differences were found between them and the Co-Cr cylinders (Table 4).

Discussion

Previously, no method has been described to establish a reliable parameter for passive fit. Photoelasticity, finite element analysis, and strain gauge measurements have been proposed as tools to determine stresses/strains in implant prostheses. The use of strain gauges in this study aimed at defining the mean level of abutment deformation that can be expected when a free-standing cylinder is screwed into place with no interference in passive fit, such as laboratory procedures.

Initially, it should be highlighted that the magnitude of the values found was minimal. The highest mean value of deformation was –625.35 $\mu\varepsilon$ for abutment screw tightening (abutment no. 3). Variations in machine procedures are the likely reason for this result. Conversion to the percentage of deformation yields the value of 0.062% deformation.

It should also be observed that low levels of abutment deformation do not necessarily represent a desirable condition. In fact, deformation levels close to 0 may indicate that the components are completely apart and consequently not transmitting any force to one another. In this instance, the prosthetic screw and the framework would be overloaded, and the framework adaptation would be forced by the torque applied to the screws.[16] The results of this study corroborate the findings of Isa and Hobkirk,[1] who demonstrated that screw tightening generated compression and tension stresses on the abutments, even when using a framework with a misfit as small as 10 μm.

Considering a system formed by a screwed joint, only compression forces should affect the abutments in an ideal condition of passive fit. However, tension forces were observed on the machined cylinders. Clelland et al[17] found tension forces ranging from 23 to 309 $\mu\varepsilon$ and compressive forces of 3 to 403 $\mu\varepsilon$. Duyck et al[16] also found a large variation in force transmission among abutments upon screw tightening. These authors state that such results occurred because the prosthesis did not establish a homogeneous and uniform contact with the surfaces of the abutments and may have presented adequate fit only at one side.

The wide variation of deformation to which the abutments were subjected may not be uniquely associated with vertical misfit. Millington and Leung[18] reported that the increase in vertical external misfit does not yield the proportional and linear increase of the forces exerted on the abutments. The authors suggested that horizontal and angular internal misfits, whose detection is difficult, contribute to the instability of the screws and generate tension forces on the implant components. The same was observed by Sahin and Cehreli,[10] who also highlighted that an acceptable marginal fit between components does not mean the achievement of a passive fit. Helldén and Déran[19] and Tan et al[20] stated that the distortions may be masked when the tightening torque is applied on the screws, leading the framework to seem well-fitted and yielding external preload tensions on the system. Such distortions, which are difficult to detect, may be responsible for the variability of the results observed in this study.

The method employed for evaluating passive fit of prosthetic cylinders to the abutments as a function of abutment deformation could be regarded as useful, since it revealed that despite the small magnitude of the outcomes, some amount of deformation is always present and is measurable, varying from 173.29 $\mu\varepsilon$ (Pd-Ag machined cylinders) to 200.47 $\mu\varepsilon$ (Co-Cr cast cylinders). There is still a difficulty to overcome to apply these parameters to the clinical situation: It is not viable to connect strain gauges to patients' mouths to take measurements, which would give more reliable results. Therefore, the proposed method must be regarded as a source of information for what can be expected in an ideal condition. Variations in the amount of abutment deformation and the presence of tension forces should be related to poor quality fit of frameworks.

The clinical relevance of this study relies on the importance of understanding the mechanisms of force transmission from the framework/prosthetic cylinders to the abutments, from these to the implants, and consequently, to the surrounding bone. In this study, the abutments were rigidly fixed to a metallic master cast simulating the bone. Since bone is the living tissue that ultimately responds to the stresses in the system, a model that takes into account the mechanical properties of bone needs to be developed to quantify bone stress after implant prosthesis connection.

Conclusions

Both abutment screw tightening as well as prosthetic cylinder screw tightening result in abutment deformation, which is compressive most of the time. Considering that no external interferences were present, such as laboratory procedures, the level of abutment deformation found is what is expected in passive fit frameworks.

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Literature Abstract

Cement selection for cement-retained crown technique with dental implants

Cement-retained restorations have a prominent disadvantage, which is that the restoration cannot be easily retrieved to evaluate mobile implants or other mechanical failures. One way to solve this problem is the use of an appropriate cement that usually has sub-maximal retentive properties but is also retentive enough to ensure that the restoration does not become easily dislodged. The aim of this paper is to assess and compare the retentive nature of common dental cements that have been adapted for use in the cement-retained crown technique and compare them with two cements that were specifically formulated for this purpose. Each group composed of 10 regular diameter implant analogs was embedded into stainless steel disks. Unmodified abutments were then torqued onto these analogs with the screw access covered with Cavit. Test crowns were then waxed, sprued, and cast with the sprue left parallel to the path of draw, for use with an Instron machine later. The test crowns were then fit onto the abutments and internal surface particles abraded. The cements used in this study included Temp Bond, Ultratemp (regular set), ImProv with petroleum jelly, ImProv without petroleum jelly, Premier implant cement with and without KY Jelly, TR-2 cement, Fleck's cement, Ketac Cem, Fuji Plus, and Ultratemp (firm set). The crowns were cemented under a 2-kg weight and left for 24 hours before subjecting to a pull test with the Instron unit. The results showed that Ultratemp (regular set) had a significantly higher value than the other cements and TR-2 and Premier with KY Jelly had significantly lower values than the other groups. There was no determination of what constitutes a threshold value that provides adequate retention and the authors did note some shortcomings of this in vitro test, which included lack of thermocycling, recycling of the abutment crown combinations (although they had been cleaned after each test), and castings were made from a base metal alloy, which may have had differing results if a precious metal alloy had been used. In conclusion, the authors note that within the limitations of the study they could not suggest which cement could be better at retaining cement-retained crowns or that a particular threshold should be accomplished to achieve this. This study was meant to present the different available cements as a guide for the clinician in selecting the appropriate cement

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