Effect of cyclic load on vertical misfit of prefabricated and cast implant single abutment

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ABSTRACT

Objectives: The purpose of this *in vitro* study was to evaluate misfit alterations at the implant/abutment interface of external and internal connection implant systems when subjected to cyclic loading. Material and Methods: Standard metal crowns were fabricated for 5 groups (n=10) of implant/abutment assemblies: Group 1, external hexagon implant and UCLA cast-on premachined abutment; Group 2, internal hexagon implant and premachined abutment; Group 3, internal octagon implant and prefabricated abutment; Group 4, external hexagon implant and UCLA cast-on premachined abutment; and Group 5, external hexagon implant and Ceraone abutment. For groups 1, 2, 3 and 5, the crowns were cemented on the abutments and in group 4 crowns were screwed directly on the implant. The specimens were subjected to 500,000 cycles at 19.1 Hz of frequency and non-axial load of 133 N in a MTS 810 machine. The vertical misfit (µm) at the implant/abutment interface was evaluated before (B) and after (A) application of the cyclic loading. Data were analyzed statistically by using two-away ANOVA and Tukey's post-hoc test ($p<0.05$). Results: Before loading values showed no difference among groups 2 (4.33±3.13), 3 (4.79±3.43) and 5 (3.86±4.60); between groups 1 (12.88±6.43) and 4 (9.67±3.08), and among groups 2, 3 and 4. However, groups 1 and 4 were significantly different from groups 2, 3 and 5. After loading values of groups 1 (17.28±8.77) and 4 (17.78±10.99) were significantly different from those of groups 2 (4.83±4.50), 3 (8.07±4.31) and 5 (3.81±4.84). There was a significant increase in misfit values of groups 1, 3 and 4 after cyclic loading, but not for groups 2 and 5. Conclusions: The cyclic loading and type of implant/abutment connection may develop a role on the vertical misfit at the implant/abutment interface.

Key words: Dental implants. Prostheses and implants. Misfit.

INTRODUCTION

The treatment option of single-implant supported restorations has been largely accepted by the outcomes of longitudinal studies reported in the literature[12-28]. In spite of high prosthetic success rates, mechanical complications are commonly found on such restorations, and the most frequent is the loosening of the screw that connects prosthesis to the implant. Simon[29] (2003) reported 7% of screw loosening for single-implant supported molar and premolar crowns after a ten-year follow-up[29]. A more recent extensive critical review reported a cumulative incidence of screw loosening of 12.7% after 5 years[18]. The problems related to this type of complication yield overload and injury to the implant/bone interface, besides the long time and high costs required for prosthetic reconstruction[4]. Interactions between clinical and laboratorial aspects such as implant components impairment, are reported as possible causes for screw loosening leading to loss of preload, which is the tension delivered on the screw when torque is applied upon tightening[14,27].

The structural geometric design of the implant connection has also been mentioned as a differential condition for maintenance of the stability at the implant/prosthesis interface[1-11]. Considering two large groups of implant connection, namely external and internal, a greater stability of the implant/abutment interface has been correlated to internal connections in which the abutment walls are in close contact with the internal surface of the implant, reducing the possibility of micro-movements during loading[2]. In experimental studies where static and dynamic loads are delivered to implant systems with external and internal connection, a significant improvement in the behavior was found for the internal connection[1,9,10].

The passive fit at implant/abutment or of prosthetic cylinder abutment interface may also influence screw stability. When components cannot be passively fit and the screw is tightened in an attempt to enhance seating, damages to the internal connection threads may occur, leading to screw loosening and likelihood of fracture and implant loss[4,7-22]. The fit of prosthetic components can be assessed by measurement of the vertical misfit at the implant/prosthetic components interface[3,20]. The ideal vertical fit would be no gap[20]. However, Tsuge, et al.[30](2004) observed very low microgap values for premachined internal and external connection implants, ranging from 2.3 µm to 5.6 µm, corroborating that even premachined abutments can present microgap at the implant/abutment interface.

On the other hand, casting and polishing procedures on premachined cast-on components are known to influence passive fit[8]. Kano, et al.[20] (2007) and Lewis, et al.[23] (1988) demonstrated that the use of cast burnout abutments can result in greater vertical misfit and decrease percentage of applied torque, which may influence the final screw joint stability. Using a different methodology, Byrne, et al.[7] (1998) assessed the vertical fit of premachined and premachined cast-on abutments to implants and concluded that casting-on with gold-palladium alloy had a significant effect on the vertical adaptation of the premachined cast-on gold UCLA abutments.

In regular prosthetic protocols premachined components are used to reduce the risk of mechanical complications[22]. In order to provide more versatility in overcoming angulated and esthetic problems, plastic burn-out patterns UCLA abutments were introduced[17]. UCLA abutments allow esthetic restoration to be finished very close to the implant head, solving many esthetic dilemmas. The use of this prosthetic option has increased even though the fit of the abutment to implant interface is not satisfactory as the fit provided by premachined abutments[7]. Due to this increased search for components many alternatives have been developed to reduce misfit, such as the premachined UCLA abutments.

Cyclic loading of the implant-prosthesis assembly induces micromotion of the joint components, which could wear down the microscopically rough areas of the contacted surfaces, contributing to screw loosening by decreasing the preload[25]. Among the factors that contribute to screw instability are misfit of the prosthesis[21], insufficient tightening force[13,14,26], screw settling[25] biomechanical overload[26], and differences in screw material or design[19].

A cyclic loading test is intended to simulate components in function what permits analyze of a possible interaction between misfit and loading. The present study aimed at evaluating the vertical misfit at the implant/abutment interface of premachined cast-on and premachined abutments of external and internal connections before and after cyclic loading.

MATERIAL AND METHODS

Distribution of groups

Five groups (n=10) of different implant systems selected for this study are shown in the Figure 1. The types of implant systems are illustrated in Figures 2 and 3. Implants were vertically embedded in hexagonal acrylic resin blocks and connected to

Group	Implant	Prosthetic Connection	Dimensions	Abutment	Abutment preparation	Crown
1	Master screw/ Conexão, Brazil	External hexagon	13X3.75 mm	UCLA gold abutment	Cast on with PdAg alloy	NiCr alloy* cemented
2	Colosso/ Emfils, Brazil	Internal hexagon	13X4.0 mm	Premachined Ti abutment	Milled	NiCr alloy* cemented
3	TMI/ Pressing Dental, Italy	Internal octagon	13X3.7 mm	Premachined Ti abutment	Milled	NiCr alloy* cemented
4	Master Screw/ Conexão, Brazil	External hexagon	13X3.75 mm	UCLA gold abutment	Crown cast-on with PdAg alloy**, and directly screwed on implant	
5	Master Screw/ Conexão, Brazil	External hexagon	13X3.75 mm	Ceraone Ti abutment	No preparation	NiCr alloy* cemented

*Lite cast B, Will-Ceram, USA / **Porson 4 - Degussa Division, Dentsply, Germany.

Figure 1- Five groups of implant systems used in this study

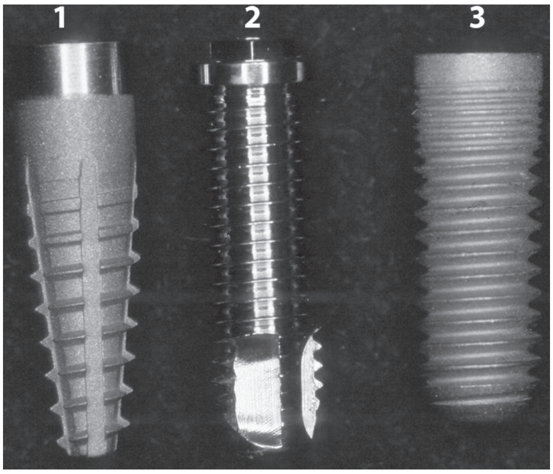

Figure 2- Implant systems used in the study: Intern Octagon (1); External Hexagon (2) and Intern Hexagon (3)

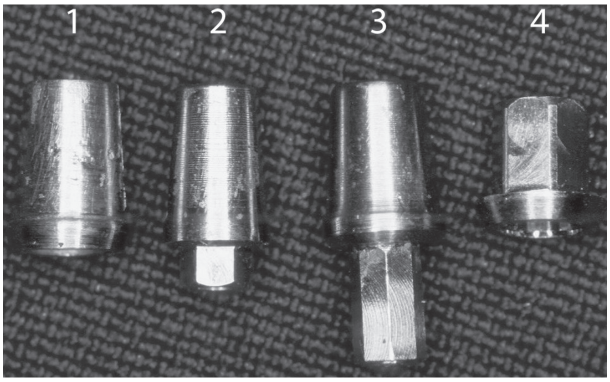

Figure 3- Prosthetic abutments used in the study. (1) UCLA Gold Abutment – groups 1 and 4; (2) Internal Hexagon Premachined Ti – group 2; (3) Internal Octagonal Premachined abutment – group 3; (4) Ceraone Ti – group 5

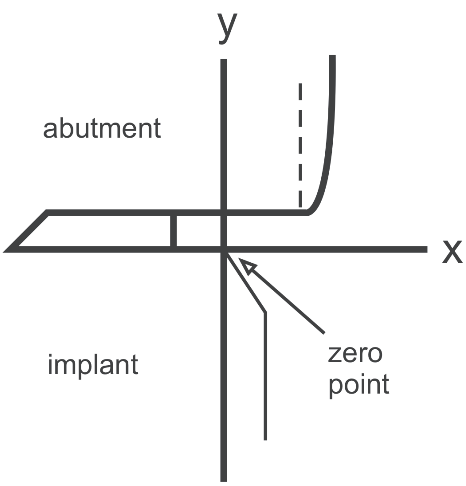

Figure 4- Reference points for measurement of the implant/abutment interface. Zero point was defined as the intersection of the x and y axes. Vertical misfit followed definitions by Kano, et al.[24] (2007)

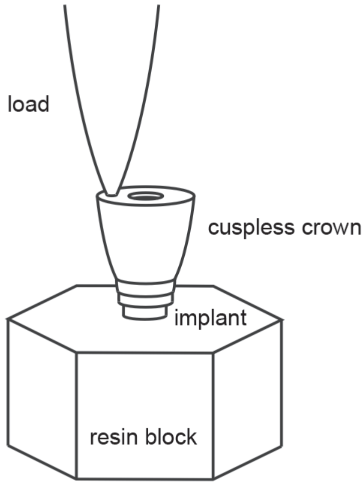

Figure 5- Scheme of application of non-axial loading of cyclic loading test on the specimens where F is the force applied and S is the specimen

the respective abutment. Abutments from groups 1, 2 and 3 were prepared to receive a cemented conventional crown. For group 1, UCLA premachined cast-on abutments were waxed with 6-mm height, 4 walls inclination and 1 mm cervical metal collar, and cast on with PdAg alloy (Porson 4 - Degussa Division, Dentsply, Germany). Premachined titanium abutments from group 2 and 3 were milled to same dimensions as group 1. Abutments from group 4 were waxed with a total height of 8 mm and an occlusal surface diameter of 8 mm, with screw access in the occlusal surface, and cast on with PdAg alloy. Abutments from group 5 were used as received.

For groups 1, 2, 3 and 5, cuspless premolar crowns were waxed with the same dimension as group 4 abutments (total height of 8 mm and an occlusal surface diameter of 8 mm with screw access in the occlusal surface) and cast with NiCr alloy (Lite Cast B, Will-Ceram, USA). For casting, abutments from each group were cast together by the same operator, following manufacturer's alloy instructions. After investment, castings were sandblasted with glass beads at 2.8 Bar until complete cleaning. A 4x-magnifying lens was used to check the integrity abutments contact interface. Samples with internal cast imprecision such as external bubbles were fitted to an implant replica using round diamond burs and liquid fit checker (Accufilm IV, Parker, USA). After finishing and polishing procedures crowns were cemented to the abutments with zinc phosphate cement (Hy-Bond Zinc Phosphate Cement, Shofu, Japan) following the manufacturer´s instructions. For all groups titanium screws were used to screw the abutment to the implants with 30 Ncm torque, as recommended by manufacturer, using an analog

Table 1- Means ± standard deviations of vertical misfit at the implant/abutment interface before and after the cyclic loading test (µm)

Group	Before	After	Samples(n)
1	12.88±6.43	17.28±8.77	10
2	4.33±3.13	4.83±4.50	10
3	4.79±3.43	8.07±4.31	10
4	9.67±3.08	17.78±10.99	10
5	3.86±4.60	3.81±4.84	10
All groups	7.14±5.54	10.20±9.11	50

Table 2- Tukey test for comparisons of groups before fatigue test

Group	Mean (µm)			
5	3.86	|		
2	4.33	|	|	
3	4.79	|	|	
4	9.67		|	|
1	12.88			|

Groups joined by a vertical bar did not present any statistically significant difference to each other (p<0.05)

Table 3- Comparisons of groups after the fatigue test

Group	Mean (µm)		
5	3.81	|	
2	4.83	|	
3	8.07	|	
1	17.28		|
4	17.78		|

Groups joined by a vertical bar did not present any statistically significant difference from each other

torquemeter (Tohnichi BTG60CN, Tokyo, Japan) with a precision of ±2%.

Measurement of vertical misfit at implant/abutment interface

Analyses were performed before (B) and after (A) cyclic loading by one examiner, using a microscope (Mitutoyo TM, model 5050, Mitutoyo Corporation, Tokyo, Japan), code 176-811A, under 150x magnification (15x ocular and 10x objective) and micro-metric heads (code 164-162), with precision of 1µm. The hexagon of the acrylic resin base allowed the samples to be evaluated in six sides. The occurrence of a vertical gap at the implant/abutment interface, visible on the microscope through passage of light, was deemed as vertical misfit. Using the eyepiece cross-hair reticule as a reference, the sample was positioned so that the X line passed through the horizontal platform of the implant and the vertical Y line crossed the X line at the most external point of the horizontal platform of the implant. The intersection between X and Y lines was defined as point (X=0) from which vertical misfit was measured for all specimens[20] (Figure 4). For each side, three measurements were recorded and a mean value was obtained for each side. The final vertical misfit of each sample was obtained as a mean of all 6 sides, and it was recorded in micrometers.

Application of cyclic loading

The cyclic loading test was performed on a Material Testing System, MTS-810 (MTS Corporation, USA) cyclic loading machine, with an axial load of 133 N, at a 3 mm laterally distant from the center of the implant, at a frequency of 19.1 Hz for 500,000 cycles (Figure 5). One sample of each group was loaded at the same time in the loading machine.

Vertical misfit data were analyzed and statistically treated using SPSS version 11.0 for Windows (SPSS Inc., Chicago, IL, USA) with ANOVA and Tukey *post hoc* tests (p<0.05)

RESULTS

Vertical misfit values before and after cyclic loading for each group were displayed in Table 1. Significant differences were found among groups (p<0.05).

Before cyclic loading, groups 1 (12.88±6.43 µm) and 4 (9.67±3.08 µm) presented significantly higher misfit values when compared to group 5 (3.86±4.60 µm) (p<0.05) (Table 2). No statistically significant difference was found when comparing internal (groups 2 and 3) and external connections (group 5) for premachined abutments before and after loading (p=0.38) (Table 3)

After cyclic loading, the highest values were found in groups 1 (17.28±8.77 µm) and 4

Table 4- Tukey test for comparisons of vertical misfit before and after loading test (p<0.05)

Group	Loading	Mean±sd (μm)
1	Before	12.88±6.43[a]
	After	17.28±8.77[b]
2	Before	4.33±3.13[a]
	After	4.83±4.50[a]
3	Before	4.79±3.43[a]
	After	8.07±4.31[b]
4	Before	9.67±3.08[a]
	After	17.78±10.99[b]
5	Before	3.86±4.60[a]
	After	3.81±4.84[a]

Groups with different letters are statistically different from each other; sd= standard deviation.

(17.78±10.99 μm), whereas the lowest mean misfit was observed in group 5 (3.81±4.84 μm), 2 (4.83±4.50 μm) and 3 (8.07±4.31 μm) (Table 3).

Comparing each group before and after loading a significant increase in vertical misfit was observed in groups 1, 3 and 4 (Table 4).

DISCUSSION

This study compared the effect of cyclic loading in the vertical misfit at the implant/abutment interface of external and internal implant systems. In addition, it assessed the influence of using premachined and premachined cast-on abutments.

The ideal vertical fit would be no gap[20]. However, even the premachined abutments (groups 2, 3 and 5) showed discrepancy, but no difference was found in marginal misfit when these groups were compared to each other despite the fact that they were different to each other in relation to the type of implant connection, i.e. external hex, internal hex and octagonal internal connection. Explanation for the presence of an implant-abutment misfit in the premachined groups may yield imprecise machining of implant parts[4,22]. The mean vertical misfit values found in the present study that ranged from 3.81 μm to 8.07 μm are very similar to those found by Tsuge, et al.[30] (2004) both for internal and external hexagon connections, that ranged from 2.3 μm to 5.6 μm. This result corroborates that premachined abutments used in the present study have similar precision machining of components of other companies.

When comparing external hex connections systems, premachined cast-on abutments (group 1 and 4) showed greater vertical misfit values than premachined abutments (group 5) for both before and after loading analysis. This may be due to the fact the premachined cast-on UCLA abutment used in groups 1 and 4 underwent to a laboratory process of casting, despite their premachined condition. On the other hand, premachined abutments used in groups 5, did not undergo any additional laboratory process. The misfit analysis has also demonstrated an increase in vertical misfit for groups 1 and 4 when before and after loading results were compared. Since the modification caused by the laboratory procedures influenced the vertical misfit in groups 1 and 4, it seems reasonable to suggest that assemblies balance in these groups was unstable. This instability might have increased the movement between the abutment and the implant, screw loosening or implant deformation and consequently increased the vertical misfit observed after loading when compared to before loading values.

The internal octagonal connection of group 3 also demonstrated an increase in vertical misfit after loading (Table 4). It was expected that this group where premachined abutments were used would not be influenced by loading. A possible explanation for this result can be attributed to the usual thin walls demanded for internal connections, which could be the weakest point allowing enlargement of implant upper border during the loading test and an increase of the vertical misfit. Unfortunately, literature lacks of information for internal octagon implant system connections.

Kano, Binon and Curtis[20] (2007) reported the vertical misfit at hexagonal interface of machined, premachined cast-on and plastic burnout abutments cast with NiCr or CoCr alloys to implants. They found values of 5.6±6.4; 11.1±8.2; 8.0±9.3 and 7.0±3.8 respectively. In a similar previous work, Kano, et al.[21] (2004) have measured the vertical misfit at interface of premachined standard abutments and plastic burnout abutments cast with NiCr or CoCr alloys and found values ranging from 4.13±4.29 for the former group to 23,18±6.96 to CoCr group and 25,06±7.75 for NiCr group. Their results are in accordance with this work, when suggest that the laboratory procedures can influence implant/ abutment interface.

Using a different methodology, Byrne, et al.[7] (1998) assessed the vertical fit of premachined and premachined cast-on external hex abutments at 2 sites: the abutment/implant interface and screw-to-screw seat. The authors concluded that casting-on with gold-palladium alloy had a significant effect on the vertical misfit of the premachined UCLA abutments joined to implants. However, even the premachined UCLA abutments of their study had few internal areas of contact with screw heads, what may suggest that even with well-adapted external areas, the internal cast-on abutment surface may be negatively modified.

The above studies did not used any aging process, instead measured just the vertical misfit between different components. In the present study, cyclic loading test simulated components in function. It was observed that misfit values were increased after loading for groups that presented high misfit values before loading. This may suggest that the use of premachined cast-on abutments should be used with caution, since initial poor misfit can get even worst when samples are subjected to loading.

CONCLUSION

From the obtained results, the following could be concluded:

1 - Premachined abutments presented better vertical misfit than premachined cast-on abutments for external hex implant connection, for both before and after loading analysis.

2 - Cyclic loading did not influence the vertical misfit values of premachined abutments with internal and external hex connections.

3 - Cyclic loading increased vertical misfit of premachined cast-on external hex abutments and premachined octagonal internal connection abutments.

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