Original Article

Effects of Cyclic Loading on Screw Loosening, Vertical Misfit, and Microleakage at the Fixture-angulated abutment interface

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ABSTRACT

Background and Aim: This study assessed the effects of cyclic loading on screw loosening, vertical misfit, and microleakage at the fixture-angulated abutment interface.
Materials and Methods: This in vitro study evaluated 12 implants in two groups (n=6). The implants were mounted in self-cure acrylic resin. The abutment screw was torqued to 30 N/cm by a digital torque-meter and re-torqued after 5 min. Six points at the fixture-abutment interface were inspected under a stereomicroscope (x75 magnification), and the distance between the two reference points was measured. Six implant-abutment assemblies then underwent cyclic loading (75 N, 1 Hz, 500,000 cycles) while the remaining six (control group) were stored at room temperature. The distance was measured again at the same 6 points after cyclic loading. Vertical misfit was calculated by subtracting the before and after values. The torque loss was measured by a digital torque-meter. The assemblies were then immersed in fuchsine and incubated at 37°C for 24 h. Next, the abutment was unscrewed and the fixtures were cut in half. The penetration depth of fuchsine was measured at 3 points of each fixture half under a stereomicroscope at x75 magnification, and the mean of the six measurements (entire fixture) was reported as the microleakage score of each sample. Data were analyzed using t-test.
Results: Cyclic loading significantly increased the misfit (P=0.001) and microleakage (P=0.01), and decreased the detorque value (P=0.04). No case of screw loosening was noted in any group.
Conclusion: Cyclic loading significantly increases the vertical misfit, microleakage, and torque loss.
Keywords: Dental Implants; Dental Implant-Abutment Design; Dental Leakage

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Introduction

Microgap between the abutment and implant fixture remains a major problem, causing biological and mechanical implant complications, and peri-implantitis.(1,2) The failure rate of dental implants is reportedly less than 10%.(3,4) Hsu YT et al.(5) were the first to suggest the possibility of leakage of microorganisms through the microgap between the abutment and implant fixture.

Several factors affect the implant-abutment interface microgap and subsequent microleakage including the type of implant, implant-abutment connection geometry, and the amount of tightening torque.(6-12)

Microgap at the fixture-abutment interface can have biological consequences such as peri-implant mucositis, peri-implantitis, crestal bone loss, mouth malodor, and mechanical problems such as the loosening and fracture of the abutment screw, abutment fracture, and occasionally implant body fracture.[13]

Screw loosening is a rare occurrence that occurs irrespective of the abutment-implant connection type, and leads to prosthodontic problems. Screw loosening has been reported in single or multi-unit restorations and can cause mechanical complications such as fracture of components. Such fractures are more frequent in single-unit implants placed in the posterior area since they are continuously subjected to masticatory forces.[14] Several factors have been suggested to decrease the possibility of screw loosening such as proper preload of screws, narrow occlusal surface, centric occlusal contacts, flattening of cusps, and decreasing the abutment height.[14-19] Many studies have assessed screw loosening, formation of microgap, mechanical and biological failures, effects of dynamic loading on bacterial colonization, and the impact of cyclic loading on screw loosening of dental implants.[20-23] However, information regarding the impact of cyclic loading on screw loosening, vertical and horizontal gap, and microleakage through the fixture and angulated abutment interface is limited. Thus, this study aimed to assess the impact of cyclic loading on screw loosening, vertical misfit, and microleakage at the fixture and angulated abutment interface.

Materials and Methods

This experimental in-vitro study evaluated 18 implants in three groups (n=6). The minimum sample size was calculated to be 6 in each group considering α=0.05, B=0.2, study power of 80%, minimum significant difference of 3 units, and standard deviation of 1.8 using Minitab software. Implantium dental implants (Dentium, South Korea) with 10 mm height and 4 mm diameter with Morse Taper implant-abutment connection and internal hexagon anti-rotation were used in this study. Angulated abutments (15 degrees) with 6 mm height and 1 mm collar height were also used. The implants were mounted in round molds with 34 mm diameter and 19 mm height, containing clear self-cure acrylic resin (Meliodent; HeraeusKulzer GmbH, Germany) (Figure 1).

Figure 1. mounted implant

A surveyor (J.M. Ney Co., Bloomfield, CT, USA) was used in order to mount the fixtures in the acrylic mold in a completely vertical position (90° relative to the horizontal surface).[24]After complete setting of the acrylic resin, angulated abutments with 6 mm height and 1 mm collar height were tightened on the fixtures to 30 N/cm torque by a digital torque-meter (Lutron Electronic Enterprise CO., Taiwan) according to the manufacturer's instructions [1,23,24]. The abutment screw was retorqued to 30 N/cm after 5 min to compensate for the settling effect.[3]

The implant-abutment assemblies were then coded from 1 to 18. Two reference points were marked on each assembly. The upper reference point was the most inferior point of the abutment while the lower reference point was the highest point of the fixture. Next, 6 points at every 60° angle of the fixture-abutment interface were inspected under a stereomicroscope (NSZ-810; Novel, Chine) at x75 magnification, and the distance between the two reference points was measured at the aforementioned 6 points. Next, the samples were randomly divided into three groups (n=6). The test groups (groups 2 and 3) underwent cyclic loading (Chewing Simulator CS-4, SD Mechatronik, Germany) with 75 N load (Figure 2)

Figure 2. Cyclicloading of case group

Applied along the longitudinal axis of each assembly perpendicular to the abutment surface with 1 Hz frequency (Figure 3).

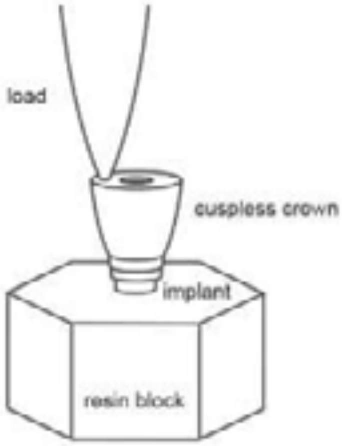

Figure 3. non-axial Vertical cyclic loading

A total of 500,000 cycles were applied, corresponding to 20 months of clinical service.[25]The control samples (group 1, n=6) remained at room temperature and did not undergo cyclic loading. Next, images were obtained from the samples at the aforementioned six points under a stereomicroscope at x75 magnification (Figures 4 and 5), and the difference between the values measured before and after cyclic loading indicated the vertical misfit of the respective assembly, and was recorded in micrometers (µm).[26]

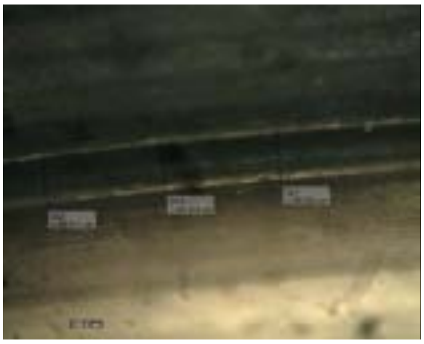

Figure 4. fixture-abutment interface under the stereomicroscope

The detorque value of each sample in groups 1 and 2 was also measured by an observer blinded to the group allocation of assemblies using a digital torque-meter.

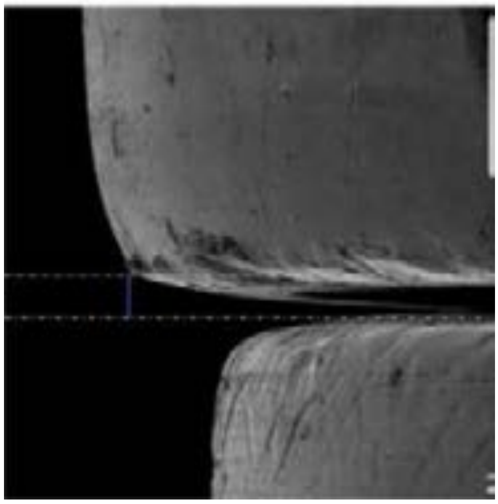

Figure5.vertical misfit

To assess the inward microleakage, 0.05% fuchsine (Merck, Germany) was used.[4,6]

The screw hole of the abutments in both the test groups and rge control group was sealed with one layer of red dental wax and one coat of nail varnish to prevent penetration of fuchsine from this surface into the abutments. All assemblies were immersed in fuchsine and incubated at 37°C for 24 h. To assess the microleakage, the abutment screw was removed with a wrench, and the abutments were separated. To assess the penetration depth of fuchsine through the implant-abutment interface, the fixtures were sectioned in half by a Mecatome (T-201A; Presi, France) such that 24 half-fixtures were obtained (Figure 6).

Figure 6. Sectioned fixture

The penetration depth of fuchsine into each semicircular fixture half was measured (Figure 7).

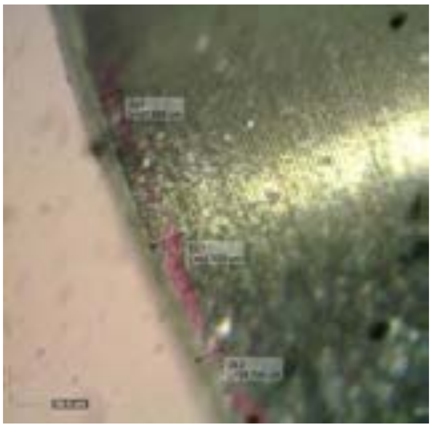

Figure 7. Fuchsine penetration at ×75 magnification of stereomicroscope

The mean of the values measured at 6 points was calculated and recorded as the microleakage score in micrometers (µm).[4,6]
The collected data were analyzed using SPSS version 20 (SPSS Inc., IL, USA). The Kolmogorov-Smirnov test confirmed normal distribution of data. Comparisons were made by t-test (alpha=0.05).

Results

Table 1 presents the vertical misfit in the test and control groups. According to t-test, the cyclic loading group showed significantly higher vertical misfit than the control group (P=0.001).

Table 1. Vertical misfit (µm) in the test and control groups (n=6)

Group	Mean± std. deviation	Minimum	Maximum	P value (t-test)
Control group	1.05±0.46 µ	0.65 µ	1.92 µ	0.001
Case groupIII	4.44±0.67 µ	3.47 µ	5.47 µ	

Table 2 shows the detorque values in the test and control groups. According to t-test, the cyclic loading group showed significantly lower detorque value compared with the control group (P=0.04).

Table 2. Detorque values (N/cm) in the test and control groups (n=6)

Group	Mean± std. deviation	Minimum	Maximum	P value (t-test)
Control group	24.33±0.81 N.cm	24 N.cm	25 N.cm	0.04
Case group II	22±2.09 N.cm	18 N.cm	24 N.cm	

Table 3 presents the microleakage scores in the test and control groups. According to t-test, the cyclic loading group indicated significantly higher microleakage score compared with the control group (P=0.01).

Table 3. Microleakage scores in the test and control groups (n=6)

Group	Mean± std. deviation	Minimum	Maximum	P value (t-test)
Control group	10.59±4.03 µ	5.43 µ	14.93 µ	0.01
Case groupIII	40.39±20.65 µ	16.9 µ	68.21 µ	

Discussion

This study assessed the effect of cyclic loading on screw loosening, vertical misfit, and microleakage at the fixture and angulated abutment interface. The results showed that cyclic loading significantly increased the misfit (P=0.001) and microleakage (P=0.01), and decreased the detorque value (P=0.04). No case of screw loosening was noted in any group.

Evaluation of the interface gap can be done with radiography, scanning electron microscopy, or other optical means.[26] Other accepted testing techniques include microbial or bacterial leakage models and molecular microleakage tests.[8]

Sahin and Ayyildiz[1] evaluated the correlation of microleakage and screw loosening in different implant-abutment connections. They also measured the reverse torque before and after the leakage test, and reported a significant correlation between the microleakage and screw loosening. They discussed that the pressure applied on the implant system would result in vertical misfit, screw loosening, and microleakage. However, they did not perform cyclic loading. Thus, our study better simulated the clinical setting than theirs. Koutouzis et al,[27] in a review study assessed the correlation of implant-abutment gap with microbial colonization. They showed that the gap at the implant abutment interface causes bacterial leakage irrespective of its size. They added that bacterial leakage occurs irrespective of the implant-abutment connection type. Their results were in agreement with our findings regarding the occurrence of microleakage through the implant-abutment interface. Rismanchian et al.[13] measured the size of microgap and assessed microbial leakage at 4 points of ITI implant-abutment interface. They demonstrated that the abutment type affected the mean size of microgap and the mean number of leaked colony forming units per milliliter through the implant-abutment interface in the first 5 h. However, the abutment type had no significant effect on microleakage at 24 h, 48 h or 14 days. Their results confirmed our findings regarding the occurrence of microleakage through the implant-abutment interface. However, they assessed microleakage qualitatively while in the present study, the amount of microleakage was quantified and scored. Jorge et al.[28] evaluated the effect of dynamic loading on oral bacterial colonization of the fixture-abutment interface with Morse Taper internal connection. They showed that implants with Morse Taper internal connection prevented bacterial penetration into the lower part of the threads at the fixture-abutment interface. They also demonstrated that dynamic loads increased the bacterial penetration potential. Their results supported our findings regarding greater microleakage as the result of cyclic loading. They used the bacterial leakage model for assessment of microleakage, which is more accurate than the dye penetration technique employed in the present study, and better simulates the clinical setting. de Jesus et al.[26] evaluated the implant-abutment interface vertical misfit in different implant and abutment systems under cyclic loading. They indicated that cyclic loading and type of implant-abutment connection both affected the vertical misfit. Their results were in accordance with the findings of the present study regarding the occurrence and increase in vertical misfit under cyclic loading. Also, comparison of their results with ours indicates that external hexagon and internal hexagon implants show greater vertical misfit than Morse Taper implants used in the present study after cyclic loading. Tsuge and Hagiwara [29] assessed the effect of implant-abutment connection system on torque maintenance, screw retention, and vertical misfit in implant-supported restorations prior and after cyclic loading. They reported a significant increase in torque loss following cyclic loading and showed that implants with Morse Taper connection experienced minimum torque loss. Also, cyclic loading decreased the vertical misfit, which was in contrast to our findings. This controversy in the results may be due to the use of three different implant-abutment systems in their study (two external hexagon and one Morse Taper). Also, the number of load cycles in their study was twice the rate in our study (1 million cycles) with 2 Hz frequency and 130 N load. Furthermore, the assemblies were mounted in acrylic resin with 30° angle, and a crown was placed over the abutments. Moreover, the assemblies were placed in distilled water at 37°C during cyclic loading. The current results regarding the significant correlation of vertical misfit and microleakage were in accordance with the findings of previous studies.[1,13,26-28]

Khraisat et al.[24] assessed the effect of abutment height on screw loosening after cyclic loading and showed that increasing the abutment collar height increased the torque loss, which confirmed the current findings regarding torque loss following cyclic loading. The amount of torque loss in the group with a collar height similar to that in our study was the same as the torque loss value reported in our study. However, groups with greater collar height experienced greater torque loss than the value reported in our study. Al-Jadaa et al.[25] evaluated the effect of lateral cyclic loading on abutment screw loosening in an external hexagon implant system. They reported greater preservation of reverse torque under eccentric loads compared with centric loads. Their results were in agreement with our findings since both studies showed torque loss following cyclic loading with no screw loosening. Thus, cyclic loading causes torque loss irrespective of the connection type, abutment type, direction of load application, and magnitude of applied load. Since the load applied in cyclic loading in the present study was 50% higher than that applied by Al-Jadaa et al,[25] it appears that increasing the applied load or increased duration of load application would result in greater torque loss. Junqueira et al.[30] assessed the impact of eccentric cyclic loading on abutment screw loosening in external hexagon and internal hexagon abutments with titanium and gold alloy screws. They reported torque loss in all groups following cyclic loading, which was similar to our finding. The torque loss in the gold screw group was 45% of the initial torque value while this rate was 26% in the present study, which may be due to different connection types (internal and external hexagon in their study versus Morse Taper in the present study), and different screw alloys since screw loosening less commonly occurs in titanium screws (due to high strength and superior physical properties of titanium and its subsequently greater tolerance to cyclic loading compared with gold alloy). Siadat et al.[23] compared screw loosening in interchangeable abutments connected to internally connected implants after cyclic loading. They indicated screw fracture following cyclic loading in some samples while no case of screw loosening occurred in the present study. Difference between their results and ours may be attributed to the use of abutment and implant from two different systems, higher magnitude of cyclic load (twice the value in our study), application of cyclic loads at 30° angle, and higher number of cycles which was twice the rate in our study. Junqueira et al.[30] evaluated the screw loosening of UCLA-type abutments following cyclic loading. They showed that cyclic loading, irrespective of the cast or pre-machined type of abutments, caused torque loss, which supported our results. The torque loss value in both groups in their study was greater than the value in our study, which may be due to the implant-abutment connection type (external hexagon in their study versus Morse Taper in our study), difference in the magnitude of applied load (higher in their study), and immersion of samples in distilled water at 37°C during cyclic loading in their study. The current results regarding the significant correlation of screw loosening with cyclic loading were in agreement with the results of previous studies.[13,24,25,30]

Assessment of vertical misfit, microleakage, and screw loosening in only one implant system was a limitation of this study. Thus, future studies are required to compare different implant systems in this respect. Also, the effects of different magnitudes of loads in cyclic loading and lateral cyclic loading on vertical misfit, microleakage and screw loosening should be evaluated in future studies. The effects of abutments with different heights should be investigated as well.

Conclusion

Screw loosening and torque loss significantly increase after cyclic loading. The vertical misfit and microleakage at the angulated abutment-fixture interface significantly increase after cyclic loading but within a clinically acceptable range for Morse taper connections.

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