FATIGUE EFFECT ON DENTAL IMPLANT-ABUTMENT INTERFACES

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Abstract: *Different kinds of contact geometries for implant abutment joints are currently being used. Component misfit in this joint has been implicated as one of several important factors of bacterial leakage. Moreover, gap between this interface affects implant physical stability under loading conditions. Physically unstable implants and bacterial leakage between these interfaces lead to loosening abutment, bone resorption, soft tissue inflammation or the failure of the dental implant under loading conditions. Manufacturing variations, insertion misfits, interface designs, implant loading can result in gap between these interfaces. In this experimental study, the objective was to clarify the effect of dynamic implant loading on the formation of micro gaps between different implant-abutment joints under simulated loading conditions. For this purpose, 24 morse taper implants and related abutments (solid and digital) were inspected under dynamic loading conditions.*

Key words: *Dental Implants, Micro gap, Implant Abutment Interface, Measurement*

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1. Introduction

Osseointegration is a dominant factor for the survival and success rate of dental implants (Albrektsson et al.,1981, Brånemark et al., 1969). The fact remains that clinical reviews have implied that the failure of dental implants can occur even if osseointegration has been achieved (Gealh et. al., 2011, Luterbacher et al., 2000, Walia. et al., 2012). Micro gaps are found to be an important factor for successful implantation. Many implant systems contain two components: the implant and the abutment. These pieces are interlocked with a retention screw system (Adell et. al., 1981, Weyant, 2003) Micro gaps ease occur in these kinds of systems. The micro gap between implant and abutment leads to biological and mechanical complications (Piatelli et al., 2001, Quirynen, &Van Steenberghe, 1993) Mechanical complications include micromotion of implant-abutment connection, unstable stress distribution, manufacturing tolerances, prosthetic fixation problems (Lee et al., 2016, Steinebrunner et al., 2005) Among these sources, micromotion can lead to abutment screw loosening, abutment screw fracture. Furthermore, implant body fracture can infrequently occur due to unfavourable stress distributions on the connection component under the occlusal loading (Cho et al., 2004, Huang et al., 2005). Micromotion between implants and abutments depends on the design of the implant connection (Saidin et al.,2012)

Biological complications include the bacterial colonization of abutment interface in two-part implant systems which is the major challenge in implant dentistry. The microgap between abutment implant connections creates a suitable environment for microbial growth and toxin production, resulting in peri-implantitis. Bacterial leakage in the implant-abutment interface is the major problem causing inflammation of the tissues around the implant, bone resorption, apical migration of the biologic width or failure of the implant. Thus, design and construction of abutment implants have a crucial role in the bacterial seal and peri-implant bone stability (Abrahamsson et al., 1996, Jansen et al., 1997, Steinebrunner et al., 2005). These biological problems due to the size of micro gaps and interference fit were analyzed by in vitro studies [Gil et al., 2014, Steinebrunner et al., 2005). Several implant-abutment connection models have been developed (Gealh et al., 2011) Morse taper design has been developed to overcome possible complications in the conical internal connection and has been used for several decades (Scacchi et al., 2000). Nonetheless, there is no available data for measurement that effects of gingival height and implant diameter on micro gap have been investigated in the Morse taper connection system.

Various techniques have been used to measure the micro gap and analyze the interface of the implant-abutment, including X-ray, optic microscope, 3D microtomography, measurements of the cross-sections etc. (Boeckler et al., 2008, da Silva-Neto et al., 2012, Meleo et al., 2012). Moreover, under several conditions, the micro gap was evaluated, including static loading, dynamic loading, applied different angles, and forces (Khraisat et. al., 2002, Norton, 2000, Sailer et al., 2009).

Micro gap size in these in vitro studies have shown considerable variety that can be ~50 µm(Breeding et al., 1993, Merz et al., 2000), ~100 µm (Park et al,.2008), <10 µm (Besimo et al.,1994). Therefore, to replicate and evaluate the behaviour of implant systems, the standard ISO 14801:2007 was improved to standardize these tests using cycling fatigue.

The purpose of this study was to measure micro gaps between implant and abutment interfaces for different abutment geometries, implant diameters, and gingival height via optical microscopy. The measurements were applied before and after the fatigue test.

2. Materials and Methods

In this experimental study, 3.7 mm diameter (P3.0) H 0.5 and H2 gingival height solid and digital abutment were selected and measured microgaps on both loading and non-loading side. For comparing effects of diameters 4.1 mm diameter (P3.5) H 0.5 and H 2 gingival height, solid and digital abutment was selected. All of the implant lengths were the same as 10mm (Table 1).

	Connection Type	H 0.5	H 2	H 0.5	H 2
P 3.0	Solid Abutment	0.007	0.010	0.008	0.007
(Ø 3.7)	Digital Abutment	0.005	0.010	0.004	0.007
P 3.5	Solid Abutment	0.009	0.011	0.008	0.010
(Ø 4.1)	Digital Abutment	0.008	0.013	0.006	0.006

Tab. 1. Sample groups with diameters, connection types and gingival heights

In this study, 36 samples of the same implant systems were used in the fatigue test to investigate the micro gap. Grade 4 pure titanium was selected as the material of implant systems which were fabricated by Dental Implant KA (Istanbul, Turkey). Each sample was composed of one implant and its abutment with two different abutment types; digital abutment type, which is connected to the implant by an internal screw; and solid abutment type, which has a threaded abutment directly inserted into the implant. Both of the abutments are in agreement with the platform-switching concept, whereas the diameter varies from 3.3 mm to 4.1 mm. Implant lengths (10mm) were the same with different implant diameters (3.7 mm, 4.1 mm), different gingival heights (H0.5 mm, H2 mm), different type abutments (solid, digital).

Before mechanical tests, torque wrenches were checked with a calibrated torque tester (Crane Electronics, Hinckley, UK). A calibrated ratchet was used for each insertion, as seen in Figure 1a. The abutment insertion torque value was applied according to the manufacturer's instructions. The torque-control device ensured the transmission of 25 N/cm force when inserting the abutments. Screws were retightened after 10 minutes to prevent abutment screw loosening.

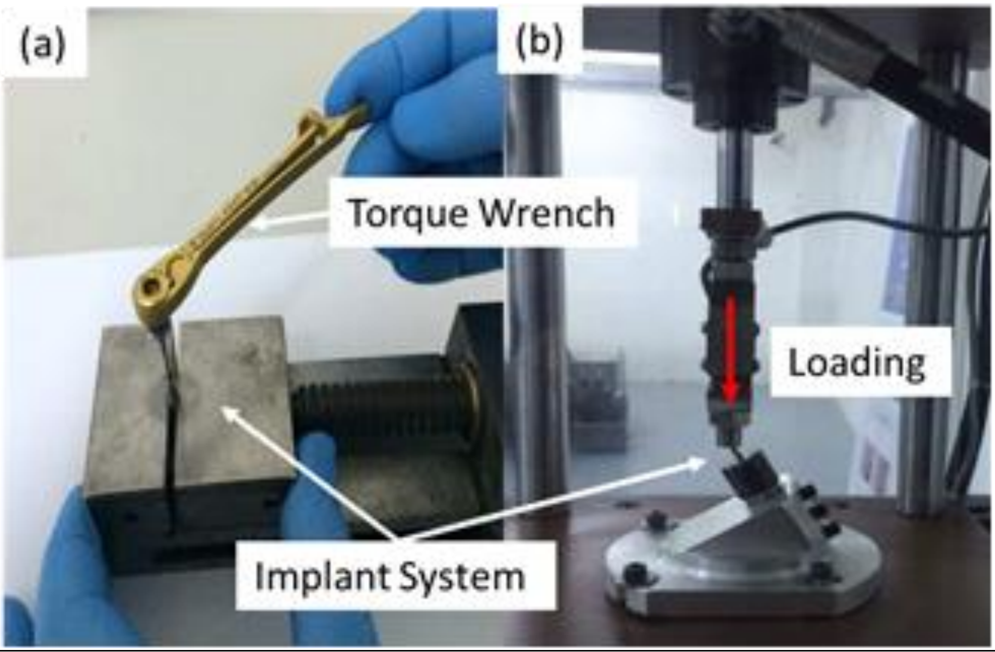

Fig. 1. a) Insertion of Abutment via Torqued Ratched b)Dynamic Fatigue Test of Implants

The fatigue test was performed according to ISO 14801:2007. In ISO standard, required loading cycles for a fatigue test were set forth as 2x106 cycles with up to 2 Hz loading frequency, and 5x 106 cycles between 2 Hz and 15 Hz loading frequencies. 100000 loading cycles were performed in this study to prevent screw and/or abutment fracture. A 30° angle to the z-axis of the tensile–compression machine was recommended by the standards of the FDA as the most unfavourable position. The dynamic loading was applied to each of the implant-abutment systems and in 30 kg/100000 cycles. The force was applied with a 30° angle to simulate the masticatory system (Figure1b).

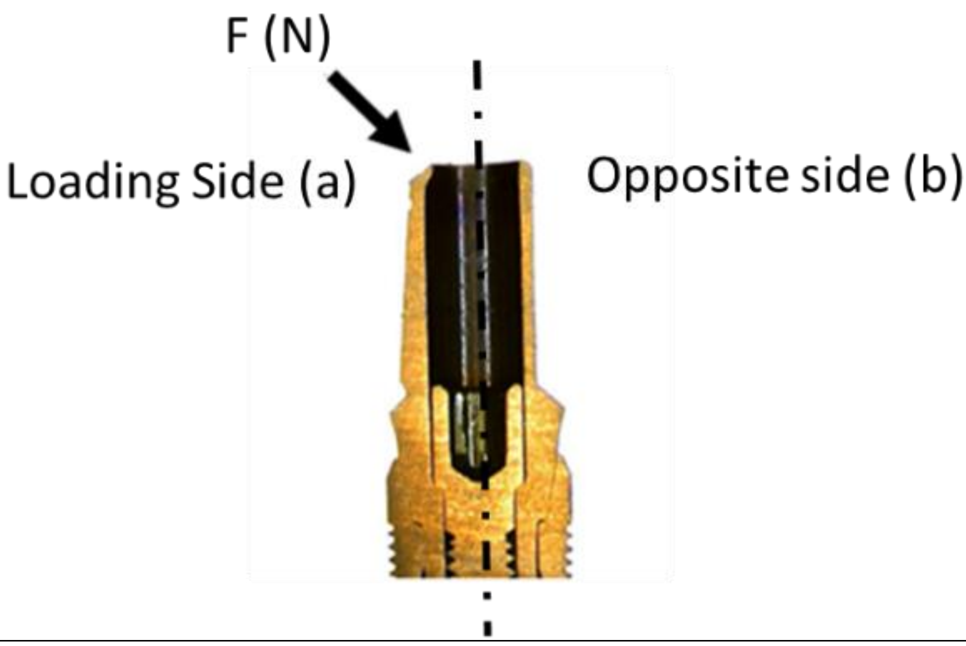

Fig. 2. Image showing the cross section of implant and loading direction

Before and after the dynamic fatigue test, the non-destructive testing method was applied by using radiographs (Balteau GFD 165 Type HDP/2) were produced with exposure times (0.1 seconds, 0.2 seconds) at 3 mA and 110 kV. The two exposure times were used to obtain radiographs with both higher and lower contrast, which were meant to investigate a possible impact on the examination (Figure 2).

Loaded and nonloaded specimens were embedded in epoxy resin and longitudinally cut. This process was performed by the use of wire erosion technique (ONA PRIMA E 250, ONA America Inc., USA). The specimens were analyzed with an optical microscope 100x magnification and measured with its program (Vision Measuring Machine Mitutoyo 359). Three repeated measurements were taken from optical microscopy to obtain a mean micro gap value between abutment and implant.

3. Results

The mean values of implant-abutment micro gaps of each implant system before the dynamic loading test are given in Table 2. For the 3.7 mm diameter (P 3.0); higher micro gap values were observed in H 2 gingival heights. Lower micro gap values were observed in the H0.5 gingival heights with the solid abutment. In other groups (P 3.5) 4.1mm diameter, there is no difference between the gingival heights, but abutment types are quite significant. The digital abutment has no micro gap between the implant-abutment interface. The measurement was numerically nearly zero, which means, cold welding can occur in an interference fit.

In Table 3 the mean values of micro gaps were presented after dynamic loading tests. A preliminary data evaluation shows that sample 2 has less implant-abutment contact surface compared to the other two types of connections.

		H0.5	H2
P3.0	Solid abutment	0.002	0.010
	Digital abutment	0.009	0.010
P3.5	Solid abutment	0.008	0.080
	Digital abutment	0.000	0.000

Tab. 2. Micro gaps between Implant and Abutments for All Assemblies before Fatigue test

Moreover, it was compared in platform 3.0 between before and after loading. Output data showed that under dynamic loading H0.5 solid abutment both side is 250% higher micro gap than the unloading conditions. When gingival height increased, the micro gap decreased in solid abutment and digital abutment P3.0. It can be explained with the abutment loosening during the cycling test. On the contrary, digital abutment with H0.5 had a 44% lower micro gap at both sides than unloading conditions.

	Connection Type	a (Loading Side)		b (Opposite Side)	
		H 0.5	H 2	H 0.5	H 2
P3.0	Solid Abutment	0.007	0.010	0.008	0.007
	Digital Abutment	0.005	0.010	0.004	0.007
P3.5	Solid Abutment	0.009	0.011	0.008	0.010
	Digital Abutment	0.008	0.013	0.006	0.006

Tab. 3. Micro gaps between Implant and Abutments for All Assemblies after Fatigue test a) loading side b) opposite side (Fig. 1)

Solid abutment P3.5, H0.5 had 12.5% higher micro gap value at the side of loading the opposite side is the same value. The digital abutment has a greater micro gap value at H2 after loading. Besides the attachment type, gingival heights were also observed.

According to the numeric results with the increase of the gingival heights, the micro gap increase in digital abutment types after loading. The possible reason for this increase is grounded with abutment loosening.

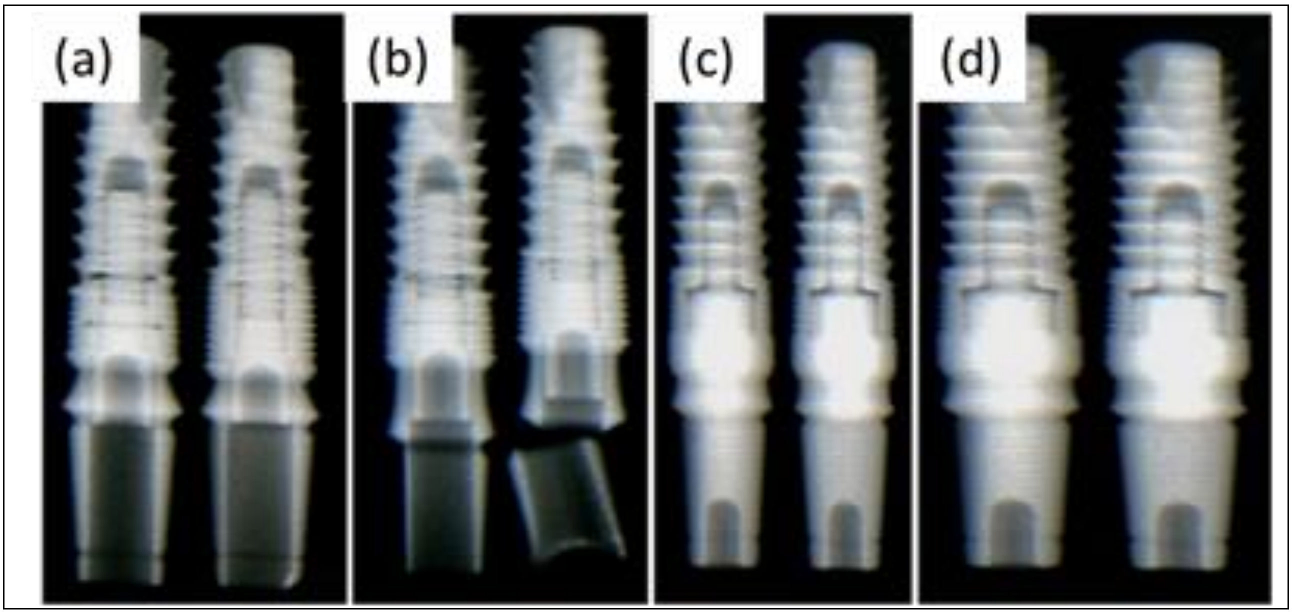

Fig. 3. Implant system radiograph images

With the effect of cycled loading and unloading, 3.0 mm diameter side from the loading side showed higher gaps. According to these observations, the most discrepancy is H2 gingival length 3.5 platform, digital abutment.

The fatigue test applied at the same cycles and attachments fastened with the same torque value. Generally, after dynamic loading test fractures, failures were not observed in the implant body or abutment system. Only in one case, H2 height with 3.0mm digital abutment was fractured abutment under dynamic loading Figure 3 (b).

4. Discussion

This study evaluated the micro gap between the implant and abutment under dynamic loading conditions and non-loading conditions. It was possible to observe a small micro gap value by analyzing the implant abutment micro gap analysis measurements with 100x magnification. The abutment-implant longitudinal section was analyzed to figure out the level of the micro gap.

The investigation of micro gaps is crucial because it seems reasonable that microbial penetration and colonization is either prevented or eased by the interference fit. Several measurement techniques have been used to measure the implant-abutment interface, including human observation of samples, 3D microtomographic techniques, Scanning Electron Microscope, Optic Microscope, X-ray, and others (Boeckler et al.,2005, da Silva-Neto et al., 2012, Meleo et al., 2012). In this experimental study, the optic microscope was chosen for simplicity and qualification.

In this study, a dental implant with a Morse-taper connection was investigated for the micro gap between implant and abutment interface under the dynamic fatigue test protocol and non-loading condition. The Morse taper connection systems have been proposed as an alternative to external hexagon connection types and provide mechanically better stability and less microbial leakage (Merz et al., 2000). Under the dynamic loading micro-movement of implant abutment systems facilitated microbial leakage through the implant-abutment interface (Steinebrunner et al., 2005). Microbial colonization of the interfacial gaps may initiate inflammation around the peri-implant zone and eventually result in marginal bone resorption (Quirynen &Van Steenberghe,. 1993)

Micro gaps between the implant-abutment interface lead to bacterial leakage microorganisms can penetrate through a gap as small as 10 µm. (Park et al.2008). Previous studies (da Silva-Neto et al., 2012, Jansen et al., 1997, Tsuge et al., 2008, Zanardi et al., 2012) have demonstrated that this gap was about 1.0 to 49.0 µm. Jansen et al. showed that distances of the implant-abutment micro gap were measured approximately 0 to 10 µm by SEM for thirteen implant-abutment combination systems. (Jansen et al., 1997). Boeckler et al. reported that clinically acceptable marginal gaps between 30 and 200 µm (Boeckler et al., 2005).In this study, it was found that the discrepancy of the dental implant- abutment interface is less than 10 µm.

5. Conclusions

In this experimental study, the size of the micro gap at the implant abutment interface was less than 10 µm in implant abutment systems tested. In some cases, the connection is perfectly adapted like cold welding between the implant and screw-retained abutment observed where the distance is zero. In some cases, H2 height with 3.0 mm digital abutment was fractured under dynamic loading. Analysis of the data set revealed 2 important observations.

The first observation is that 3.5 mm diameter, H2 gingival height, digital abutment specimens were able to maintain more micro gap after 100,000 cycles under dynamic loading. Besides these obtained results a further microbiological analysis study is needed to be done to determine the effect of fatigue on microbial leakage.

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