Investigation of Dynamic Fatigue Effect on Marginal Fit and Microgaps of Different Dental Implant-Abutment Interfaces

Cigdem Unlu Mercan[1,a)], Asli Gunay Bulutsuz[2], Ahmet Bulent Katiboglu[1]

[1]*Istanbul University, Faculty of Dentistry, Department of Oral and Maxillofacial Surgery, 34093, Fatih, Istanbul, Turkey*
[2]*Yildiz Technical University, Faculty of Mechanical Engineering, Department of Mechanical Engineering, Istanbul, Turkey*

[a)]dent.cigdem@gmail.com

Abstract. Today many different contact geometries for implant screw joints are being used. Component misfit in this joint has been implicated as one of several important factor of bacterial leakage. Moreover space between this interface effect implant physical stability under loading condition. Physically unstable implants inside the bone and bacterial leakage between these interfaces produce loosening abutment under loading, soft tissue inflammation or the failure of dental implant. Manufacturing variations, insertion misfits, interface designs, implant loading can result with space between these interfaces.In this experimental study the objective was to clarify the effect of dynamic implant loading on formation of micro gaps between different implant screw joints under simulated loading condition. Different type of abutment and implant geometries (Dental Implant KA products) are fixed with same torque values and loaded under same loading conditions with a dental loading simulator. The dental implant screw and abutment interface fit was controlled by means of radiographic method before and after the fatigue tests first, second, and thirdlevel headings (first level heading).

Keywords: Dental Implants; Micro gap; Implant Abutment Interface; Measurement

INTRODUCTION

Endoosseos dental implant systems have been in used for several decades to rehabilitation in completely and partially edentolus patients. Most of these implant systems contain two pieces: the implant and the abutment. These pieces are interlocked with a screw system [1-2]. Micro gaps are easy to occur in these kinds of screw systems. For implant osseointegration performance this micro gaps are found to be an important factor. According to the literature these gaps may result with biological and mechanical problems relates to the colonization of bacteria and misfixations of implants. Further thought biological problems; to date, size of micro gaps and interference fit are analyzed by researches in vitro studies [3-4].

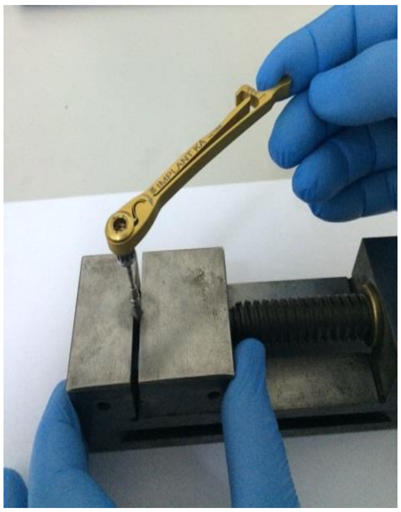
Mechanical problem sources can be classified as; micro motion of implant-abutment connection, unstable stress distribution, manufacturing tolerances, prosthetic fixation problems [6]. Among these sources micromotion can lead to screw loosening, fracture or infrequently body fracture occur due to unfavourable stress distributions on connection component under the occlusal load during physiological function [7-8]. Micromotion between implants and abutments are dependent on the design of the implant connection [5].

The aim of this study to measure microgaps between implant and abutment interface for different abutment geometries, implant diameters. The measurement applied before and after fatigue test.

MATERIAL AND METHODS

In this study thirty six samples of same implant systems were used in fatigue test to investigate micro gap. 24 most common implant systems were choosed for experiments. 72 implants were randomly divided in to three groups. Each sample was composed of one implant and its abutment with different abutment types. Implant systems were selected as Grade 4 pure titanium material. The implant systems were fabricated by Mode Medical, Dental Implant KA (Istanbul, Turkey). Implant lengths were same with different implant diameter (3.7 mm, 4.1 mm), different gingival height (H0.5 mm, H2 mm), different type abutments (solid, digital) .

Abutment insertion torque was applied according to the manufacturer instructions. A calibrated ratchet (Dental Implant KA) was used each insertion as seen Figure 1a. The torque-control device ensured transmission of 25 N/cm force when inserting the abutments. Micro gap formation examined as a means of evaluating dynamic fatigue at implant-abutment interface. Dynamic fatigue simulator was designed as close as possible to the human masticatory system. The dynamic loading was applied each of implant-abutment system and in 30 kg/100000 cycle. The force applied with a 30° angle to simulate masticatory system. (Figure1b)



(a)

(b)

FIGURE 1.a) Insertion of Abutment by means of Ratched b)Fatigue Test of Implants

For observation of microgaps dental radiographs (Balteau GFD 165 Type HDP/2) were produced with exposure times (0.1 second, 0.2 second) at 3 mA and 110 kV. The two exposure times were used to produce radiographs with both higher and lower contrast, which were meant to investigate a possible impact on the examination (Figure 2). Three repeated measurements were taken from radiographs to obtain micro gap value between abutment and implant (Table 1-2).

TABLE 1. Micro gaps between Implant and Abutments for All Assemblies before Fatigue

		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

TABLE 2. Micro gaps between Implant and Abutments for All Assemblies after Fatigue a)Side of compressions b)Other

		a		b	
		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

RESULTS AND DISCUSSION

Table 1 shows mean values of fixture abutment micro gaps of each implant system. In Table 2 the mean values of micro gaps were presented after fatigue tests. A preliminary data evaluation shows that sample 2 has less fixture-abutment contact surface compared to the other two types of connections.

In this study, dental implant with a Morse-taper connection was evaluated for micro gap between implant and abutment interface under the dynamic fatigue test protocol. The Morse taper connection systems have been in use for several years and more popular by means of tapered design that provide mechanically more stable and more effective in preventing microbial leakage[10]. Under the dynamic loading micro movement of implant abutment systems facilitated microbial leakage through implant-abutment interface[6]. Microbial colonization of the interfacial gaps may eventually result in bone resorption[4]. In our study the tests were performed following the guidelines previously published by the FDA at the Class II Special Controls Guidance Documents: Roots-form Endosseous Dental Implants and Endosseous Dental Implants–Abutments and the ISO 14801:2007.

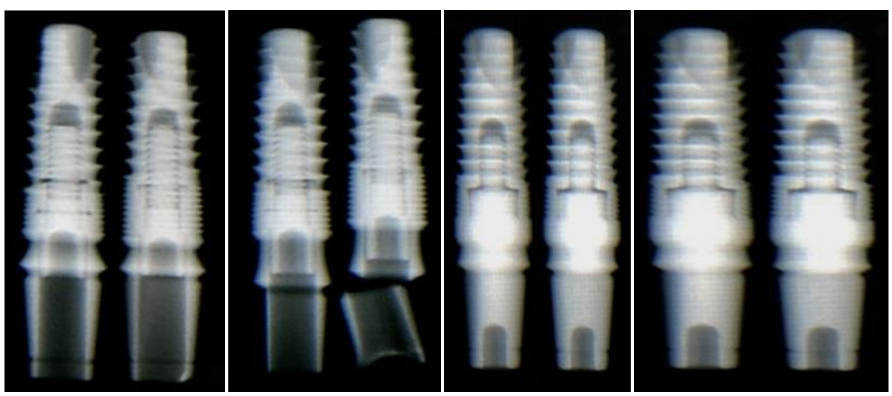


FIGURE 2. Representative radiographs of Microgaps

A 30° angle to the z-axis of the tensile–compression machine was recommended by the standards of the FDA as the most unfavorable position. Micro gaps between the implant–abutment interface lead to bacterial leakages microorganisms can penetrate through a gap as small as 10 µm. [11]. Jansen et al. showed that distances of the implant-abutment micro gap was measured the approximately 0 to 10 µm by SEM for thirteen different implant-abutment combination systems. [9] Boeckler et al. reported that clinically acceptable marginal gaps between 30 and 200 µm [12]. In this study we found discrepancy of dental implant- abutment interface <10 µm.

Katiboglu et al. evaluated diameter and length preferences in 1000 dental implants and reported that commonly used 4.1 diameter and 10mm length. Therefore in this experimental study we choosed 4.1mm diameter and 10 mm length[13]. Results in this study, before fatique test we compared to 3.0 mm diameter; the higher discrepancy value is H2 gingival height all of the platforms and the less discrepancy value is H0.5 gingival height with solid abutment. We evaluated that the after fatique 3.0 diameter side of fatigue test is comparatively a bit more than other side. Consequently, taking everything into account, the most discrepancy is H2 gingival length 3.5 platform, digital abutment.

CONCLUSION

The size of the micro gap at the implant-abutment interface was less than 10 μm in implant abutment systems tested. The gaps obtained are presented in Table 1.In some cases, the connection is perfect adaptation like cold-welding between implant and screw-retained abutment observed where the distance is zero. In some case, H2 height with 3.0mm 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 discrepancy after 100,000 cycles under dynamic loading. The second observation is that Radiographic examination is nondestructive analysis method but should be support the other destructive analysis like optic microscopy, scanning electron microscopy, scanning laser microscopy.

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REFERENCES

1. Weyant R. Short-term clinical success of root-form titanium implant systems. J Evid Based Dent Pract 2003;3:127-30.
2. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10(6):387–416.
3. Gil F. J, Herrero-Climent M, La´zaro P, Rios J. V. Implant–abutment connections: influence of the design on the microgap and their fatigue and fracture behavior of dental implants J Mater Sci: Mater Med 2014;25:1825–1830
4. Quirynen M, Van Steenberghe D. Bacterial colonization of the internal part of two stage implants. An in vivo study. Clin Oral Implants Res. 1993;4:158–161.
5. Syafiqah Saidin, Mohammed Rafiq Abdul Kadir, EshamsulSulaiman , Noor Hayaty Abu Kasim.Effects of different implant–abutment connections on micromotion and stress distribution: Prediction of microgap formation Journal of Dentistry 2012;40:467-474
6. Steinebrunner L, Wolfart S, Bossmann K, Kern M. In vitro evaluation of bacterial leakage along the implant–abutment interface of different implant systems. International Journal of Oral & Maxillofacial Implants 2005;20:875–81.
7. Cho SC, Small PN, Elian N, Tarnow D. Screw loosening for standard and wide diameter implants in partially edentulous cases: 3- to 7-year longitudinal data. Implant Dent. 2004;13:245–250.
8. Huang HM, Tsai CM, Chang CC, Lin CT, Lee SY. Evaluation of loading conditions on fatigue-failed implants by fracture surface analysis. Int J Oral Maxillofac Implant. 2005;20(6):854–9.
9. Jansen VK, Conrads G, Richter EJ. Microbial leakage and marginal fit of the implant–abutment interface. Int J Oral Maxillofac Implants. 1997;12:527–540.
10. Merz, B.R, Hunenbart, S, Belser, U.C, Mechanics of the implant-abutmentconnection: an 8-degree taper compared to a butt joint connection. InternationalJournal of Oral and Maxillofacial Implants, 2000:15(4):519-526
11. Park IS, Won SY, Bae TS, Song KY, Park CW, Eom TG, et al. Fatigue characteristics of five types of implant–abutment joint designs. Metals and Materials International 2008:14;133–8.
12. Boeckler, A.F.; Stadler, A. &Setz, J.M. The significance of marginal gap andoverextension measurement in the evaluation of the fit of complete crowns. Journalof Contemporary Dental Practice. 2005:15(4); 26-37
13. Ozdal O, Katiboglu G, Ozgul M, Unlu C, Tanyel C, Katiboglu AB. Dental implantlarda çap ve boy tercihlerinin değerlendirilmesi,; son bir yıl içerisinde kullanılan 1000 implantın seçiminde olası kriterler, Türk Diş Hekimliği Dergisi, 2014:89