Research Article

Comparative Evaluation of Vertical Microgaps and Torque Loss in Two Ball-Attachment-Systems of Mandibular Implant-Retained-Overdentures

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Abstract

Purpose: The purpose of this study was to evaluate the size of possible vertical microgaps and torque loss of two different-attachment-systems in mandibular Implant-Retained-Overdentures.

Materials and Methods: Two lab models with two parallel Straumann fixtures (at a 22 mm distance) were prepared. Straumann and Rhein 83 SRL balls and sockets (n=5) were used. All the samples were inserted in the artificial saliva. The samples were subject to fatigue test in Zwick/ROELL Zwickline machine (Z010 Germany) before and after 1100, 2200, 3300, and 5500 cycles under a 50 newton Load cell (51mm/min). At the end of each cycle the size of vertical microgaps at the implant-abutment-interface were recorded at four sites with a stereomicroscope (Olympus Japan, SZX_19, x200) by two experts. Torque loss was recorded before and after cyclic dislodgement of the ball attachments using a torque meter ((LT, Lutron TQ, 8800).

Results: Rhein ball abutments showed more vertical microgap than Straumann ball abutments (p<0.001). After cyclic loading, the percentage of torque loss in Straumann ball abutments was significantly lower than that of Rhein ball abutments (p=0.001).

Conclusion: Despite the limitations of this *in-vitro* study, the vertical microgap and torque loss were significantly higher in Rhein system than those of Straumann system. Of course, both systems showed an acceptable size of vertical microgaps after all fatigue-test-cycles.

Keywords

Introduction

Edentulous patients are usually dissatisfied with the mandibular-complete-dentures. Implant-Retained-Overdentures (IRO) increase patient's satisfaction, quality of life, and health [1-3]. Mandibular IRO with two implants is often considered as a standard treatment for the edentulous patients [4]. IRO attachments play a pivotal role in increasing the retention [5].

The abutment is placed on the implant by a rotatory-torque-force called "torque" which is laid on the screw, and is in fact the retentive force [6]. After applying the torque, there

might be a vertical or horizontal incompatibility in the Implant-Abutment-Interface (IAI). The incompatibility might be intensified by the processes of manufacturing implant components, clinical procedures, and laboratory stages [7]. The IAI is influenced by biological and mechanical factors. The biological factors such as micro-leakage, gingivitis, and bone loss might result from poor adaptation of abutments. The increase of fixture-fracture-risk, screws loosening, and preload reduction can be considered as the mechanical factors [8]. In addition, abutment misfit may result in plaque formation, difficulty in cement cleansing, and stress accumulation in the cervical area of implant [9].

Although implants are not prone to decay, the microorganisms that cause periodontal diseases around the teeth can also influence the tissues surrounding implants [10].

As the ball attachments of the Rhein 83 SRL (RS) are commonly used as compatible abutments on the fixtures of the Straumann System (SS) (Straumann Co, Switzerland), the aim of this *in-vitro* study was to compare the size of Vertical Microgap (VMG) and the percentage of Torque Loss (TL) or detorque in two compatible systems after fatigue test, So that the static TL was measured in this study. According to the null hypothesis, there would be no statistical difference between RS and SS in VMG and TL.

Materials and Methods

In order to construct the lab model, a cube (20 mm high, 32 mm long, and 13 mm wide) was made of heavy-body-silicon-impression-material (Coltene WhaladeSpeedex Putty) on a slab on which two implant fixtures (ITI System, Straumann Co., Switzerland, Φ 4.1mm) were placed parallel to each other using a surveyor (BEGO), as the parallel meter device. The fixtures had 22 mm distance from each other. The model was filled by self-curedclear-acrylic-resin (Germany, Heraeus, Kulzer, Meilodent). The same process was precisely repeated to prepare the second lab model (Figure 1).

Figure 1: Acrylic model with two parallel fixtures.

The ball and socket abutments of SS (Retentive anchor; Elito /Titanium male: Height=3.2 mm,Φ 3.6 mm, and Titanium female: Height=3.4 mm) and those of RS (normal sphero block abutments; Stainless steel male: Height 4.6 mm, Φ 3 mm, and Titanium-nitrate-coated female: Φ 2.5 mm)were placed on the fixtures in acrylic molds using a torque meter (LT, Lutron TQ, 8800),according to the manufacturer's instructions. The

abutments were re-tightened to the same torque after 10 minutes, so that the desirable preload could be attained. [10-12] Five minutes later, the initial torque loss was measured and recorded in each sample using the torque meter.

Then, once more the abutments were tightened to the prescribed torque. Then, four points were located on the IAI (Figure 2) [8]. A marker used to highlight the first point from which the TLbegan (in a clockwise manner).

Figure 2: Acrylic molds with retentive anchors.

Two experts assessed and recorded the VMGs in each model twice using a stereomicroscope SZX_19 (Olympus Japan) with 200 magnification.

Two Elliptical matrixes of the SS that contain spare-lamella-retention-inserts were placed on the retentive-anchor-abutments. In the cylinder containing the matrixes of the RS, there were two normal-stainless-steel-housings with normal-retentive-pink-cap, placed on the normal-sphero-block-abutments.

Spare-lamella-retention-inserts of SS were inserted, and then the especial wrench was applied to rotate the lamella (360 degree, clockwise). Normal-retentive-pink-cap was used in RS to approximately equalize the retention in both systems.

In order to simulate the intra-oral conditions, the lab models including the ball attachments of SS and RS practiced the placement and removal of the upper members including the females of each system.

The basic-acrylic-block was boxed with a thin layer of wax. After boxing, the block was filled with the self-cured clear-acrylic-resin (Figures 3 and 4).

Figure 3: The lab models including abutment and housing.
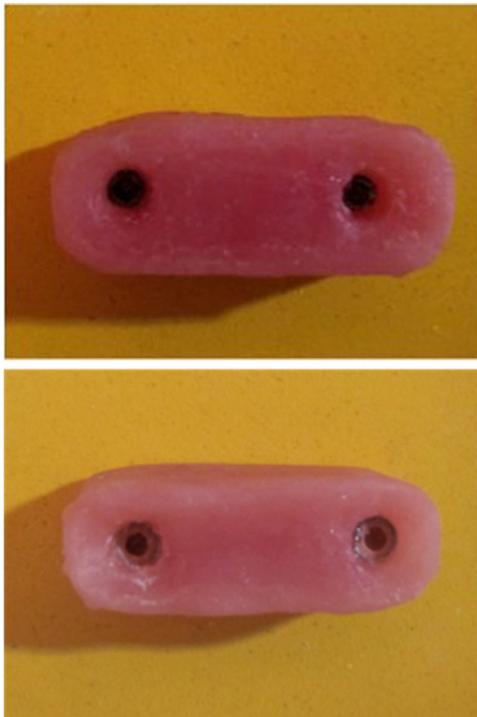

Figure 5: Completed model.

Figure 4: The upper member of lab models including the housing of two systems.
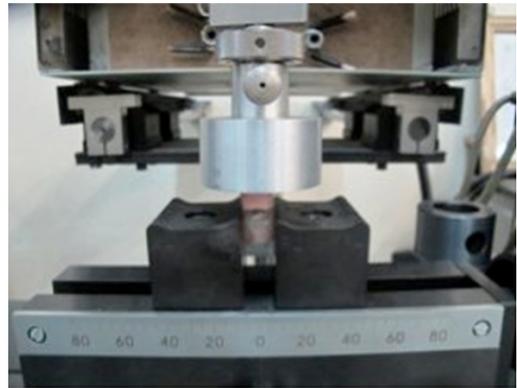

Figure 6: Load cell that is connected to upper member.

VMG was recorded by stereo microscope at the end of each cycle. The required time for each cycle was 5 seconds and the total time for each sample was 8 hours. Finally, the TL of each sample was recorded by the torque meter. Then, the new attachments were placed on the fixtures, and all mentioned steps were repeated for 5 pairs of RS attachments and 5 pairs of SS attachments. Spare-lamella-retention-inserts and normal-retentive-pink-caps were also replaced by the new ones for each pair of samples. No trace of loosening or mobility was observed in the balls or the housings during and at the end of the process.

Continuous variables (VMG and TL) were summarized as mean and standard deviations. In order to test the effects of independent variables (attachments systems and cyclic loading) on the mentioned dependent variables two-way ANOVA was used. However; due to significant interaction between them, statistical strategy was changed. So that in each cyclic loading the effect of different systems on the dependent variables was evaluated by independent student's T test. In order to evaluate the effect of cyclic loading on dependent variables, repeated measurement ANOVA was used (followed by bonferroni test for pair wise comparison). Level of significance was set at 0.05.

Results

The results of this study showed that in the RS there was statistically significant increase in the size of VMG at the end

After preparing the samples, a 50-newton-load-cell was fixed to the upper member of the lab model containing the housings by using an adhesive cement (Lord 411, US chemosil adhesive) (Figures 5 and 6).

Floating in a liter of the artificial saliva (200 mmol/l NAHCO3, 30 mmol/l P, 1.5 mmol/l CA, PH=7) which was prepared by the assistant of dental biomaterial synthetic laboratory (Faculty of Dentistry, Tehran University of Medical Sciences) at the room temperature, the samples were subject to fatigue tests in Zwick/ ROELL Zwickline machine (Z010 Germany) in 1100, 2200, 3300, 4400, and 5500 cycles. The machine was set at the pace of 51 mm/min, the force of 1000 Newton, and the mobility of 2.5 mm [13]. The numbers correspond to the pace of dentures' placement and removal on/from attachments during a five-year-period. The size of

of each cycle, compared to the baseline and the previous cycle. In other words, the size of the initial VMG increased from 31.73±0.43 micrometerat the baseline, to 34.26±0.63 micrometer at the end of the 5500 cycle (Table 1).

Cyclic Load	VMG (micrometer)	Mean difference (Standard error)	P-value
Baseline 1100	31.73±0.43 32.46±0.73	0.73 (0.16)	0.15
1100 2200	32.46±0.73 32.89±0.73	0.43 (0.05)	0.01
2200 3300	32.89±0.73 33.36±0.75	0.47 (0.04)	0.003
3300 4400	33.36±0.75 33.75±0.72	0.39 (0.03)	0.002
4400 5500	33.75±0.72 34.26±0.63	0.51 (0.04)	0.005

Table 1: Comparison of the size of the VMG (Vertical Microgap) of Rhein System attachments (RS) corresponding to the examined cycles.

The size of VMG in SS was examined separately. Similar to RS, the SS vertical microgap increased in size, but it was not statistically significant at the end of 1100 cycle. However, at the end of the four other cycles, the increase was statistically significant compared with the previous cycle (Table 2).

Cyclic Load	VMG (micrometer)	Mean difference (Standard error)	P-value
Baseline 1100	31.13±0.50 31.46±0.73	0.33 (0.20)	1
1100 2200	31.46±0.73 31.58±0.72	0.13 (0.005)	<0.001
2200 3300	31.58±0.72 31.71±0.72	0.12 (0.01)	0.01
3300 4400	31.71±0.72 31.84±0.74	0.13 (0.02)	0.049
4400 5500	31.84±0.74 31.84±0.74	0 (0)	1

Table 2: Comparison of the size of the VMG (vertical microgap) of Straumann System attachments (SS) corresponding to the examined cycles.

The mean differences, standard errors, and P-values of TL percentages before and after each cyclic loading for RS and SS are summarized in Tables 3 and 4, respectively.

Cyclic Load	TL (NCm)	Mean difference (Standard error)	P-value
Baseline 1100	20.94±1.01 20.29±0.85	0.65 (0.08)	0.02
1100 2200	20.29±0.85 19.62±0.87	0.67 (0.05)	0.004
2200 3300	19.62±0.87 18.89±0.90	0.73 (0.04)	0.001
3300 4400	18.89±0.90 18.16±0.74	0.73 (0.11)	0.04
4400 5500	18.16±0.74 17.52±0.67	0.64 (0.05)	0.003

Table 3: Comparison of the Torque Loss (TL) percentage of Rhein System attachments (RS) corresponding to the examined cycles.

Mean differences and P-values of VMG and TL percentage before and after each cyclic loading resulted from comparing RS with SS are summarized in Tables 5, and 6, respectively.

Cyclic Load	TL(NCm)	Mean difference (Standard error)	P-value
Baseline 1100	22.31±0.93 21.89±0.76	0.42 (0.10)	0.17
1100 2200	21.89±0.76 21.57±0.86	0.32 (0.06)	0.09
2200 3300	21.57±0.86 20.29±0.77	0.67 (0.07)	0.01
3300 4400	20.29±0.77 20.24±0.75	0.66 (0.03)	<0.001
4400 5500	20.24±0.75 19.72±0.75	0.52 (0.02)	<0.001

Table 4: Comparison of the Torque Loss (TL) percentage of Straumann System attachments (SS) corresponding to the examined cycles.

Cyclic Load (System)	VMG (micrometer)	Mean difference (Standard error)	P-value
Baseline (RS) Baseline (SS)	31.73±0.43 31.13±0.50	0.59 (0.29)	0.008
1100 (RS) 1100 (SS)	32.46±0.73 31.46±0.73	1.00 (0.46)	0.06
2200 (RS) 2200 (SS)	32.89±00.73 31.58±0.72	1.30 (0.46)	0.02
3300 (RS) 3300 (SS)	33.36±0.75 31.71±0.72	1.65 (0.47)	0.008
4400 (RS) 4400 (SS)	33.75±0.72 31.84±0.74	1.91 (0.46)	0.003
5500 (RS) 5500 (SS)	34.26±0.63 31.84±0.74	2.42 (0.44)	<0.001

*RS: Rhein system

#SS: Straumann system

Table 5: Mean differences and P-values of vertical microgap (VMG) before and after each cyclic loading resulted from comparing RS with SS.

Cyclic Load (System)	TL (NCm)	Mean difference (Standard error)	P-value
Baseline (RS)* Baseline (SS)#	20.94±1.01 22.31±0.93	1.37 (0.61)	0.06
1100 (RS) 1100 (SS)	20.29±0.85 21.89±0.76	1.62 (0.51)	0.01
2200 (RS) 2200 (SS)	19.62±0.87 21.57±0.86	1.28 (0.54)	0.045
3300 (RS) 3300 (SS)	18.89±0.90 20.29±0.77	2.01 (0.53)	0.005
4400 (RS) 4400 (SS)	18.16±0.74 20.24±0.75	2.74 (0.48)	<0.001
5500 (RS) 5500 (SS)	17.52±0.67 19.72±0.75	2.20 (0.45)	0.001

*RS: Rhein system

#SS: Straumann system

Table 6: Mean differences and P-values of TL (torque loss) percentage before and after each cyclic loading resulted from comparing RS with SS.

Discussion

SS attachments are widely substituted with RS, because RS attachments are really cost-effective. Despite the popular use of the different systems of the similar attachments in over dentures, the question always remains if the compatible systems might face gradual TL and screw loosening.

According to the results of the current *in-vitro* study, the VMGs observed in RS and SS were 31.73±0.43 μm and 31.13±0.489μm, respectively. The difference was not statistically significant. After 1100 cycles, there was a significant increase in VMG of RS, but SS still did not show any statistically significant difference. In both systems no trace of screw loosening was observed in the balls and sockets during and at the end of the process. Both systems can be considered acceptable clinically, because what is important is the loosening torque.

One of the limitations of this *in-vitro* study was the inability to recognize the VMGs smaller than 10 μm in size.

In the current study, pink caps were used for RS which have 800 to 950 gr retention and can be used utmost 12 months. While the initial retention force of spare-lamella-insert of SS is approximately 200 gr and its maximum retention is 1400 gr according to the manufacturer. By using a special screwdriver (Art. No. 046.154) the retention can be adjusted between 200-1400 gr. SS Lamellas were rotated 90 degrees clockwise to increase the retention up to 700 gr according to the manufacturer's instruction. This was another limitation of this study, as it was impossible to make the retention of both systems exactly equal to each other. This was the only possible method to approximately equalize the retention of both systems.

Kano et al. [8] compared the horizontal and vertical micro gaps of 4 types of abutments on the implants (conexao master; Brazil system) using an optical microscope (magnification of X 150) [8]. Their findings suggested that there was only a chance of 23% ideal conditions. The mean values of the horizontal microgaps were higher than that of the vertical microgaps. As the microgaps did not undergo the retention forces or cycles, significant differences in either the systems or the cycles indicated the TL of abutment screw. The microgap may result in bacterial leakage and bacterial colonization. Of course in most cases, the peak of the inflammatory cells occurs at 0.5 mm away from the coronal micro gap. Kano's work emphasized that there were no statistically significant differences in the examined groups in VMG. Of course, the combination of the horizontal and vertical micro gaps, and the subsequent movement of the abutment could result in less stability of the components. So there would be a larger area for aggregation of the bacteria and plaques, compared with the other types [8]. The present study showed that the size of VMG was 34.3 micrometer in RS and 32.0 micrometer in SS, following the 5500 cycle. This suggested that SS shows higher compatibility and mechanical endurance than RS during time. What might be controversial about the data revealed by Kano is high value of the standard deviation (in most groups) that is due to the absence of any micro gap in some samples of a group and larger micro gaps in other samples of the same group. These are attributed to both the different stages of casting and the manufacturing tolerance in the machined group. In contrast to Kano, all the samples of the present study showed VMG increase after subjecting to cyclic-fatigue-test. VMG increase in RS (37.21%) was more than in SS (32.44%). Since the gaps

are small (34.3, resp. 32.0 micrometer), the VMG of both systems are acceptable.

VMGs are small in size and the same among all systems. Thus examination, comparison, and overall judgment on all systems do not result in significant clinical changes. As put forth by Kano and other researchers, it is inevitable to have less than10 micrometer vertical gaps in pre-manufactured components [8,14-16].

Guindy et al. [15] reported the mean VMGs of 4 micrometers for titanium abutments [15]. The largest micro gap size was reported by Jansen et al who introduced the 10 micrometer VMG for the machined titanium abutments [14]. But, what approved by all investigations is the lack of statistically significant differences (in terms of the vertical micro gap) among all systems, and any possible differences (if any) are in the shade of the discrepancies in the measurement methods and the nature of the own systems.

Ma et al. evaluated how far the pre-manufactured components fit together, and demonstrated that the average vertical discrepancy between the abutment and the prosthetic cylinder (noble bio care) ranged from 23.1 to 33.1 micrometer, in the absence of any imposed forces [17].

This *in-vitro* study was only limited to the removal and placement forces. Then, it was not concerned with the forces frequently posed by the natural functions to the attachment sites. Under oral conditions, the restorations are influenced by various tensile, shears, and rotatory forces both in individual and combinational manners. Therefore, the quality of the forces is totally different compared with the pure tensile forces gradually made *in vitro*.

Despite these limitations, it is recommended to rely on *in-vitro* methods before different materials and components are clinically applied. If the laboratory examinations are accompanied with clinical studies, the results will be more promising, even though the clinical works are inevitably restricted by some other limitations such as simulation of the required circumstances in different patients.

Conclusion

In this study, the size of VMG and the percentage of the TL were significantly higher in Rhein system than Straumann, while both systems possessed an acceptable size of VMGs in all stages of examination. In both systems no trace of screw loosening was observed. So that RS and SS can be considered acceptable clinically.

Acknowledgement

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