Abrasion of abutment screw coated with TiN

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STATEMENT OF PROBLEM. Screw loosening has been a common complication and still reported frequently. **PURPOSE.** The purpose of this study was to evaluate abrasion of the implant fixture and TiN coated abutment screw after repeated delivery and removal with universal measuring microscope. **MATERIAL AND METHODS.** Implant systems used for this study were Osstem and 3i. Seven pairs of implant fixtures, abutments and abutment screws for each system were selected and all the fixtures were perpendicularly mounted in liquid unsaturated polyesther with dental surveyor. After 20 times of repeated closing and opening test, the evaluation for the change of inner surface of implant and TiN-coated abutment screw, and weight loss were measured. Mann-Whitney test with SPSS statistical software for Window was applied to analyze the measurement of weight loss. **RESULTS.** TiN-coated abutment screws of Osstem and 3i showed lesser loss of weight than non-coated those of Osstem and 3i ($P < .05$, Mann-Whitney test). **CONCLUSION.** Conclusively, TiN coating of abutment screw showed better resistance to abrasion than titanium abutment screw. It was concluded that TiN coating of abutment screw would reduce the loss of preload with good abrasion resistance and low coefficient of friction, and help to maintain screw joint stability. **KEY WORDS.** screw loosening, TiN-coating, abutment screw **[J Adv Prosthodont 2009;1:102-6]**

INTRODUCTION

One of the most common problems in implant supported restorations is loosening of abutment screw and prosthetic screw.[1-4] The factors related to the abutment screw and prosthetic screw loosening are as follows: improper tightening, improper fitness of the components, inaccurate fitness of the components, elasticity of the components, settling, remnants at screw hole, screw design, elasticity of the bone, elasticity of the screw joint, fictional coefficient, applied torque, rate of tightening, lubrication and etc.[5,6]

Preload denotes the force produced when screw is being tightened.[5,7] But while tightening the screw, significant part of clamping force, 90%, is lost due to the friction between the contact points of screw and only 10% of the force is transmitted to the preload.[7] For this reason, to reduce the loosening rate by increasing the preload, dry lubricants are used. Martin *et al*.[8] reported that Gold-Tite and Torqtite abutment screws allowed more preload than regular abutment screws. Drago *et al*.[9] found that Gold-Tite provided more stable connection between implant fixture and abutment.

Loss of preload is related to the screw joint deformation and abrasion where the clamping force is applied.[10] Deformation and wear at the screw joint is called 'settling' and this results in the decrease of preload by decreasing the surface friction.[11] The other factor associated with the screw loosening is the abrasion of components which is jointed with screw in the repeated delivery and removal of abutment. Weiss *et al*.[12] performed the test to evaluate the joint separating force after repeated delivery and removal of abutment and revealed that the more the number of the repetition, the less joint separating force of the abutment screw. And they found that the cause of screw loosening is the decrease of the frictional coefficient resulted from the wear of components which are jointed with screw head and thread.

TiN coating is the most widely used procedure to improve the properties of the metal, which increase the surface hardness, wear resistance and decrease the frictional coefficient of the metal.[12] Mezger *et al*.[13] reported that TiN coating was not appropriate in dental office in the aspect of the biological, physical and erosive characteristics. And they also reported that TiN coating was not proper to improve the properties of the metal. However, with the recent development of TiN coating technique, some dentists began to apply the TiN coating to the implant system. Scarano *et al*.[14,15] reported that TiN coating had good biocompatibility and it didn't have negative influence to the bone around the implant fixture, and it did not change the surface roughness as well. Researches about the applica-

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tion of TiN coating to the abutment screw are not enough. However, the characteristics of TiN coating, such as decreasing the frictional coefficient, increasing the resistance to wear, are expected to help reduce the loosening rate of the abutment screw.

Therefore, the purpose of this study was to assess the abrasion after the repeated delivery and removal of TiN coated abutment screw and to analyze the effect of TiN coating in abrasion.

MATERIAL AND METHODS

1. Material

Fourteen implant fixtures, abutments and abutment screws for two implant system were selected randomly (Table I). Standard fixture of Osstem (machined surface, 4.0D × 10 mm; Osstem Inc, Pusan, Korea) and Osseotite of 3i (Hexlock 4.0D × 13 mm; 3i/implant Innovations Inc, Florida, USA) were selected as implant fixture for this study. The connection of implant fixture and abutment was an external connection type having external hexagon on implant fixture in both systems. Cement type abutments were used in both systems.

Therefore, Avana Cemented Abutment (hex, regular, 5 mmD × 2 mmC × 5.5 mmH; Osstem Inc, Korea) and GingiHue™ Post abutment (4.1 mmD × 5 mmP × 2 mmH; 3i/implant Innovations Inc, Florida, USA) were used in this study. Titanium abutment screw was selected in both systems. To determine the effect of the TiN coating, some abutment screws were coated with TiN and the other abutment screws were kept intact as control.

2. Methods

Among the 14 abutment screws of Osstem and 3i respectively, 7 abutment screws were coated with TiN respectively. And the other abutment screws were kept intact as control. Abutment screws were divided into 4 groups according to the manufacturing company and TiN coating as follows. Group A was composed of uncoated abutment screw of Osstem (n = 7), group B was TiN coated abutment screw of Osstem (n = 7), group C was uncoated abutment screw of 3i (n = 7) and group D was TiN coated abutment screw of 3i (n = 7).

In our study, Radio Frequency (RF) sputtering method was used to apply the TiN coating. Ti abutment screws were cleaned with ultrasonic cleaner with the solution such as detergent, methanol and saline in the order named, before performing the coating. Presputtering was carried out for 20 minutes under 200W RF voltage condition. TiN coating was obtained by RF sputtering of Ti target from Ar and N_2 gas. TiN coating condition is described in Table II.

Each implant fixture was embedded in the polyesther(Epovia, Cray Valley Inc, Jeonju, Korea) perpendicular to the ground by using dental surveyor. This resin consists of resin itself and hardening agent. Embedding was completed when two agents were mixed and the hardening was finished. To give the repeated delivery and removal, embedded implant fixture was fixed in the specimen-holding apparatus. Each abutment was delivered to the fixture by using its abutment screw. Samples were placed at the specimen-holding apparatus and abutment was connected by tightening of the abutment screw. After finger screw driver was used to tighten the screw until the resistance was detected, digital torque controller (Brånemark system DEA 020 Torque controller) was finally used to apply the torque. To give the clamping force of the screw as much as 30 Ncm as recommended by the manufacturer, this digital torque controller was used to apply the same magnitude of the force with low speed. Delivery and removal of the abutment screw was repeated 20 times. All procedures were performed by one dentist who had experienced various implant restorations. We used precision electrobalance (Sartorius LA220S, Sartorius Corp., Goettingen, Germany) for measurement of weight loss. The scale of this unit was 1×10^{-6} mg. Measurement of weight loss was performed to evaluate the abrasion of the abutment screw in repeated delivery and removal. Samples were cleaned with ultrasonic cleaner and initial weight was measured before repeating delivery and removal test. Weight measurement was performed three times for each sample and the mean value of each sample was determined as a typical val-

Table II. Deposition condition of TiN Coatings

RF sputtering	Power	200 W
	Time	40 Min
	N_2 Gas	40 sccm
	Basic Pressure	1×10^{-6} torr
	Working Pressure	2×10^{-2} torr
	Temperature	300℃
	Coating thickness	2 - 3 ㎛

Table I. Kinds of implant system, abutments, screws and torque value used in this study

Implant system	Manufacturer	
	3i Innovation	Osstem
Implant Fixture	Standard self-tapping (4.0 D × 13 mmL)	Standard Hexlock (4.0 D × 10 mmL)
Abutment	GingiHue™ Post abutment (4.1 mmD × 5 mmP × 2 mmH)	Cemented abutment (4 mmD × 8 mmH)
Abutment Screw	Titanium alloy screw	Titanium alloy screw
Torque*(Ncm)	30	30

*Torque was applied according to manufacturer's manual.

ue. After twenty times of repeated delivery and removal, abutment screws were cleaned with ultrasonic cleaner and weight was measured in the same way. The weight loss was measured in all abutment screws of every group and the result was analyzed. SPSS (version 10.1) software was used, and Mann-Whitney test was used to assess weight change of abutment screw in Osstem and 3i after experiment. Significance level was 0.05.

RESULTS

Statistical analysis for the weight loss of abutment screw of each group was performed (Fig. 1). While mean weight loss value of group A, consisted of non-coated titanium abutment screw was 0.0181 ± 0.0145 mg, mean weight loss value of group B, composed of TiN coated abutment screw, was 0.0056 ± 0.0026 mg. There was a statistical significance between each weight loss of group A and group B, and TiN coated abutment screw had less value of weight loss ($P < .05$, Mann-Whitney test). Each mean weight loss value of group C and group D were 0.0069 mg ± 0.0023 mg and 0.0043 mg ± 0.0016 mg. A statistical significance was also showed in the comparison of mean weight loss of Group C and Group D, and TiN coated abutment screw had the less one ($P < .05$, Mann-Whitney test).

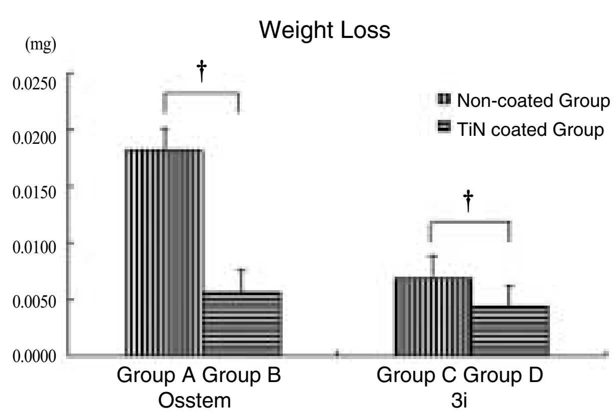

Fig. 1. Comparison of Mean Weight Loss of Osstem and 3i samples before and after test(† $P < .05$, Mann-Whitney test. n = 7).

DISCUSSION

Therefore, in this study, the effect of TiN coating on the abrasion of the implant fixture and abutment screw was evaluated after the repeated delivery and removal. Weight loss of abutment screw was measured to evaluate the amount of abrasion. The average weight loss of group A and B from Osstem was 0.0181 mg and 0.0056 mg respectively, which was statistically significant. The average weight loss of group C and D from 3i was 0.0069 mg and 0.0043 mg respectively, which was as well statistically significant. All uncoated titanium abutment screws of Osstem and 3i showed the statistical significant weight loss. This indicates that TiN coating could improve the surface hardness and reduce the abrasion of abutment screw. The result was in agreement with Sawase' s[16] result. His experiment using oral hygiene instruments, even if not a screw, revealed that TiN coating improves the resistance to abrasion. This property of TiN coating is supposed (expected) to increase the stability of screw joint with two advantages for screw joint. One is that it could reduce the loss of preload and the other is to prevent the decrease of opening force due to abrasion.

Clamping force produced by tightening the screw is called preload. Preload has complicated mechanism and it is not well known about the exact properties of contact surface while and after the tightening and their interaction. In the aspect of engineering, the loss of preload after the tightening is generally due to the plastic deformation on the contact surface of the component.[10] Plastic deformation of the screw and abrasion of the rough surface may occur while the screw is being tightened and after the tightening. And these affect the loss of the preload. Plastic deformation and abrasion are called settling or embedment relaxation. Bickford[10] found that preload was reduced as much as 5 to 40% by the embedment relaxation. Abokowitz *et al*.[17] explained that the loss or reduction of preload caused by galling and seizing observed in the contacting surface of two titaniums. They asserted that when repeated tightening and loosening applied, the friction force increased between titanium abutment screw and fixture which had the similar surface hardness and this resulted due to the tendency of galling and seizing. Increased friction force by

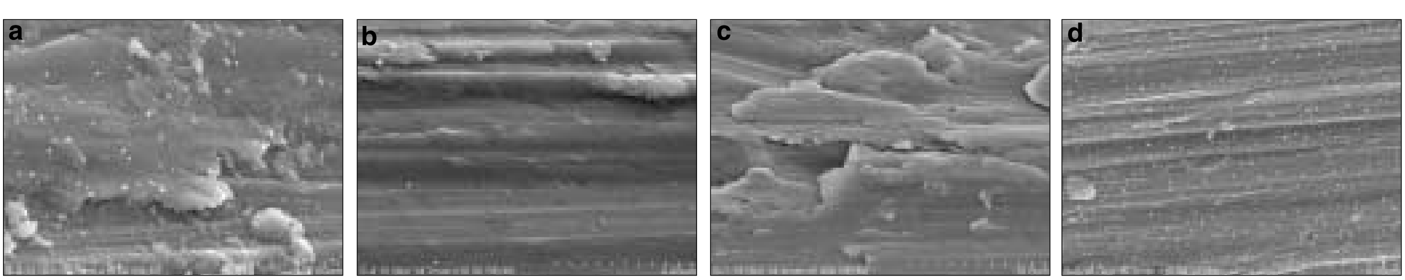

Fig. 2. Photomicrograph of internal mating surface of Osstem and 3i implant in SEM (Magnification × 10,000).
a. Group A, b. Group B, c. Group C, d. Group D.

galling and seizing as well as embedment relaxation would reduce the preload, when and after screw was tightened. For this reason, in group A and C, the friction force between abutment screw and fixture increased. And the more times tightening and loosening were applied, the lower preload was obtained. But this tendency was not observed on group B and D. It was because of the low coefficient of friction and high surface hardness. It was supposed that this nature of TiN coating would diminish the loss of preload during repeated tightening and loosening, and it would contribute to resistance of screw loosening in group B and D more than in group A and C. It was considered that TiN coated abutment screw would resist loosening with minimal loss of preload in the condition of repeated tightening and opening.

After the same experiments, thin layers, which were assumed to be made of titanium particle, were galled and seized by friction, were observed on internal surface of implants in group A and Group C (Fig. 2). It corresponds to the report of Abkowitz *et al.*[17] that galling and seizing of titanium between titanium abutment screw and titanium fixture by repeated tightening and loosening was observed. In group B and D, TiN coated abutment screw groups, galling and seizing of titanium particles were not observed on internal surface of implant, but only the slight scratch was found (Fig. 2). This is due to the low frictional coefficient and high surface hardness of TiN coating.

The accumulation of titanium particle produced by abrasion was found in the inner surface of implant of group A and group B(uncoated control group). However, There is no such particle in those of experimental group (group C and group D).

Group A and C, uncoated control group, showed more severe abrasion and deformation not only on the external surface, but also on internal surface of fixture than group B and C from the investigation of SEM. Considering the change of screw surface and internal surface of implant on SEM photograph, the hypothesis that weight loss of fixture of group A and C due to friction would be higher than that of group B and D, and it was proved with the measured results of weight loss.

The other effect of TiN coating is to prevent the reduction of opening force due to abrasion, when the abutment screw was unscrewing. According to experimental result, TiN coatings of abutment might reduce the abrasion effectively. It was considered that this result was obtained due to the properties of TiN coating, such as low frictional coefficient, high surface hardness and resistance to abrasion.

Weiss *et al.*[14] conducted experiments using 7 implant systems and opening torque was measured after 30 times and 200 times of repeated tightening and loosening of upper part, and reported that as the repetition increases, opening torque decreases. Also, they proposed that the decrease of the frictional coefficient caused by abrasion between abutment screw and its component due to repeated tightening and loosening of upper part, was the cause of decreased open torque. Considering this result, it is supposed that abrasion due to repetitive tightening and loosening of upper part has influence for opening torque as much as repeated loading. On the other hand, there is a report that TiN coatings of the abutment screw do not contribute to opening torque. Elias *et al.*[18] wrote that TiN coating did not affect the opening torque of the screw. However, that experiment compared and analyzed opening torque of only 6 repetitions of tightening and loosening. It is presumed that the difference of view point between Weiss and Elias might be caused by number of repetition. So it is considered that the Elias' s number of repetition cannot represent abrasion resistance of abutment screw and its components.

Therefore, it is expected that the low coefficient of friction and durability to abrasion of TiN coating will reduce the loss of preload and open torque.

CONCLUSION

In conclusion, TiN coating on abutment screw showed the durability to abrasion between abutment screw and its components after repetitive use of abutment screw. It is considered that this effect of TiN coating will improve the stability of the screw joint.

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