A STUDY ON SURFACE ALTERATION OF IMPLANT SCREWS AFTER FUNCTION

Myung-Ju Han, D.D.S., M.S.D., Chae-Heon Chung, D.D.S., M.S.D., Ph.D., Han-Cheol Choi, Ph.D.*

Dept. of Prosthodontics, College of Dentistry, Chosun University

Dept. of Dental Laboratory Technology and Metallogical Engineering, Kwangyang University*

Statement of problem. Surface alteration of the implant screws after function may be associated with mechanical failure. Theses metal fatigue appears to be the most common cause of structural failure.

Purpose. The purpose of this study was to evaluate surface alteration of the implant screws after function through the examination of used and unused implant screws in SEM(scanning electron microscope).

Materials and methods. In this study, abutment screws(Steri-oss, 3i), gold retaining screw(3i) and titanium retaining screw(3i) were retrieved from patients. New, unused abutment and retaining screws were prepared for control group. Each of the old, used screws was retrieved with a screwdriver. And retrieved implant complex of Steri-oss system was prepared for this study. Then, SEM investigation and EDS analysis of abutment and retaining screws were performed. And SEM investigation of cross-sectioned sample of retrieved implant complex was performed.

Results. In the case of new, unused implant screws, as maunfactured circumferential grooves are regularly examined and screw thread are sharply remained. Before ultrasonic cleansing of old, used implant screw, a lot of accumulation and corrosion products were existed. After ultrasonic cleansing of old, used implant screws, circumferential grooves as examined before function were randomly deepened and scratches increased. Also, dull screw thread was examined. More surface alterations after function were examined in titanium screw than gold screw. And more surface alteration was examined when retrieved with driver than retrieved without driver.

Conclusions. These surface alteration after function may result in the screw instability. Regularly cleansing and exchange of screws was recommended. We recommend the use of gold screw rather than titanium screw, and careful manipulation of the driver.

Key Words

Surface alteration after function, Implant screw, Gold and titanium screw

Successful implant therapy requires a dynamic equilibrium between biological and mechanical factors. The biological factors are generally considered multifactorial, whereas mechanical factors has been associated with screw joint instability between the abutment and the implant.[1] Factors may result in screw joint instability include inadequate preload, inadequate prosthesis or screw design, poor component fit, settling of surface microroughness, excessive loading, and elasticity of bone.[2]

The complications for related to screw are screw fracture and screw loosening.[3-5] Two mechanism of screw loosening have been investigated: excessive bending on the screw joint and settling effects. If a bending force on the implant restoration causes a load larger than the yield strength of the screw, a plastic permanent deformation of the screw results. The higher the yield strength of the screw, the less the plastic deformation in the screw for a given load.[3]

The other mechanism of screw loosening is based on the fact that no surface is completely smooth.[5-7] Even a carefully machined implant surface is slightly rough when viewed microscopically. Because of this microroughness, no two surfaces are in complete contact with one another. When the screw interface is subjected to external loads, micromovements occur between the surfaces. Wear of the contact areas might be a result of these motions, thereby bringing the two surfaces close to each other. The magnitude of settling depends on the initial surface roughness and surface hardness as well as the magnitude of the loading forces. Rough surfaces and large external loads increase the settling. When the total settling effect is greater than the elastic elongation of the screw, it works loose because there are no longer any contact forces to hold the screw.[3]

In the study by Jaarda et al.,[8] the contacting surfaces of implants play a major part in the torque preload relationship and ultimately in the fatigue life of the screws. Numerous investigators have examined the implant-abutment screw joint. Many studies have dealt with the assembly mechanisms and reported that an inaccurate interface places excessive stresses on the abutment screw joint, creating instability.[1]

When torque is applied to new screws and bolts with rough textured thread surfaces, energy is applied partially toward smoothing mating surfaces and less toward elongation of the screw. After engaging the threads, the surface asperities are flattened so more input torque is applied toward elongation of the screw and production of preload.[9] Recent studies suggest that surface characteristics may influence the success outcome of implants.[10] When used, gold rather than titanium abutment screws remained secure.[11]

Surface alteration of the implant screws after function may be associated with mechanical failure. These metal fatigue appears to be the most common cause of structural failure; it occurs under repeated loading at stress levels.[12]

Therefore, the purpose of this study was to evaluate surface alteration of the implant screws after function through the examination of used and unused implant screws in SEM(scanning electron microscope).

MATERIALS AND METHODS

Materials (Table I)

1) Abutment screws

The Steri-oss abutment screw(Bausch & Lomb company) was retrieved from the patient. The loading time before retrieval was 4.4 years. The 3i abutment screw(Implant Innovations Incorporated™) was also retrieved from the patient. The loading time before retrieval was 1.6 years. Each of the old, used abutment screws was retrieved with a

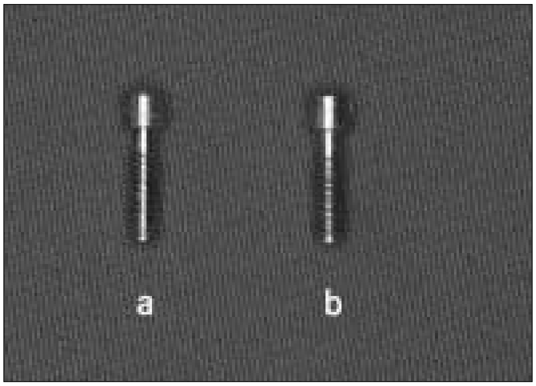


Fig. 1. The Steri-oss abutment screws selected for this study.(a:new, unused screw, b:old, used screw)

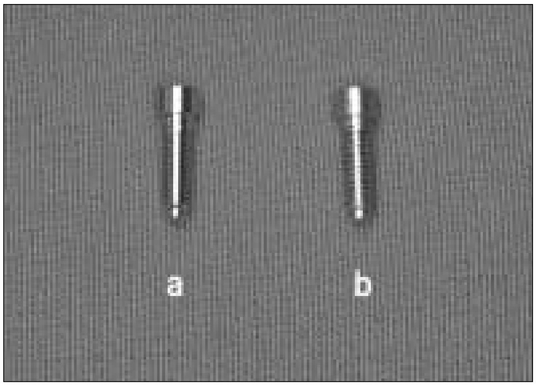


Fig. 2. The 3i abutment screws selected for this study. (a: new, unused screw, b: old, used screw)

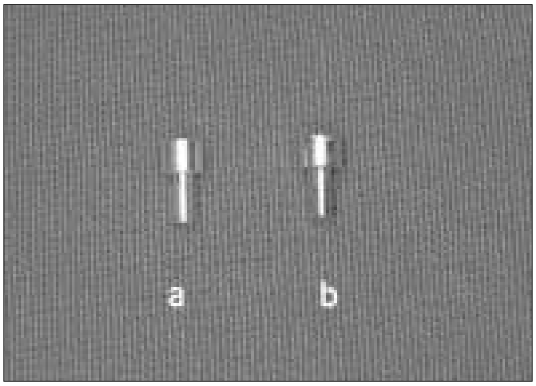


Fig. 3. The 3i gold retaining screws selected for this study. (a:new, unused screw, b:old, used screw)

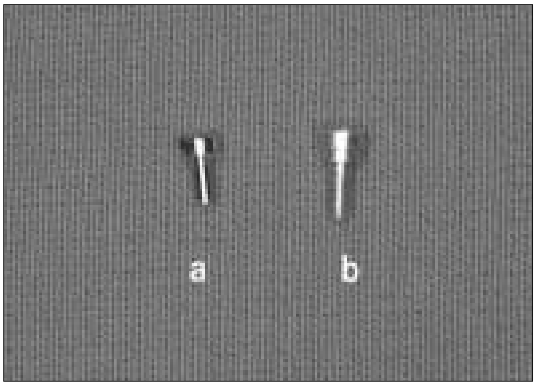


Fig. 4. The 3i titanium retaining screws selected for this study. (a:new, unused screw, b:old, used screw)

screwdriver. New, unused steri-oss and 3i abutment screws were prepared for control group(Fig. 1, 2).

2) Retaining screws

The 3i gold and titanium retaining screws retrieved from the other patient for this study. The loading time before retrieval was 1.6 years. New, unused 3i gold and titanium retaining screws were prepared for control group(Fig. 3, 4). Each of the old retaining screws was retrieved with a screwdriver.

3) Retrieved implant complex

The Steri-oss implant complex of the left first and

Fig. 5. Retrieved implant complex of Steri-oss system.

Table Ⅰ. Kinds of screw selected for this study

Kind of screw \ system & material	Implant system	screw material
Abutment screw (unused, used screw)	Steri-oss 3i	titanium titanium
Retaining screw (unused, used screw)	3i 3i	titanium gold
Retrieved implant complex(used screw)	Steri-oss	titanium

Steri-oss: Bausch & Lomb company
3i: Implant Innovations Incorporated ™

second molars was retrieved due to peri-implantitis from the patient(Fig. 5). The loading time before retrieval was 4.4 years. Implant complex was retrieved with a trephine. The abutment screws and retaining screws were not unscrewed. The retrieved implant complex and surrounding tissues were washed in saline solution and immediately fixed in 10% buffered formalin.

Methods

1) SEM investigation and EDS analysis of abutment and retaining screws.

The surfaces of new abutment screws and retaining screws as delivered by the manufacturer were investigated by scanning electron microscopy (SEM, XL 30s, Philips, Netherland) at magnifications of up to 1,000. A tungsten tip was used where micromanipulation of the specimens was carried out under SEM investigation. Care was taken not to touch the thread surfaces of abutment screws and retaining screws to avoid contamination of the surfaces.

Retrieved old abutment screws and retaining screws were also investigated by scanning electron microscopy. Then, old abutment screws and retaining screws were cleaned in liquid soap and water in an ultrasonic cleaner. After cleansing, theses old abutment screws and old retaining screws were also evaluated by scanning electron microscopy. And Energy-disperse spectrometry(EDS) was performed on abutment screws and retaining screws using an EDS(EDAX International, USA).

2) SEM investigation of cross-sectioned sample of retrieved implant complex.

① Cross-section of retrieved implant complex

Cross-section of the retrieved implant complex was made by mounting the sample in a translucent thermoses type liquid unsaturated polyester. The mounting media(Epovis, Cray Valley Inc) is a 2-part system made up of a resin and hardener. The two components were mixed together and poured over sample and allowed to cure overnight. Once the mount was hardened, sample was ground using a silicone carbide-type sandpaper(120 grit of finer). Mounts were ground through a series of progressively finer grit papers down to a 4000 grit finish. Final polishing was carried out with a plano cloth and 1㎛ Al_2O_3.

The retrieved implant complex was cross-sectioned until one retaining screw and one abutment screw were gone(Fig. 6).

Fig. 6. Cross-sectioned sample of retrieved implant complex.

② SEM investigation of cross-sectioned sample

The sample was cleaned in liquid soap and water in an ultrasonic cleaner. Then sample was evaluated in scanning electron microscopy.

RESULTS

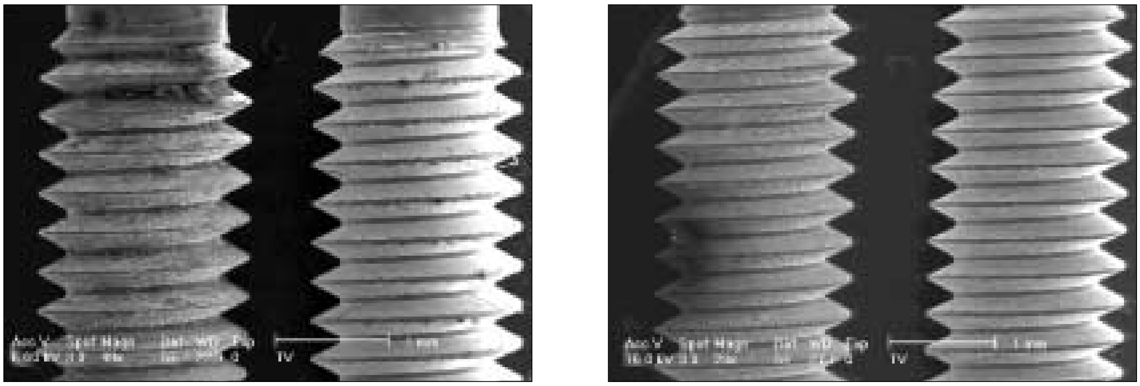
1. SEM investigation and EDS analysis of abutment screws.

Scanning electron microscopy of old abutment screw surfaces showed a lot of accumulation on the surfaces(Fig. 7). EDS analysis proved that these accumulation consisted of carbon and oxide. These organic substances consisted of plaque and corrosion product. After ultrasonic cleansing, EDS on old abutment screw surfaces proved that these abutment screws consisted of titanium(Fig. 8). Therefore, accumulation of the old abutment screw surfaces proved to be plaque and corrosion product.

In the case of old abutment screw surfaces, preexisting grooves of the new abutment screw surfaces appear to be randomly deepened and new scratches had appeared. The unused abutment screw surfaces presented a surface structure characterized by parallel circumferential machining grooves. The old abutment screw surfaces have the dull screw thread(Fig. 9, 10).

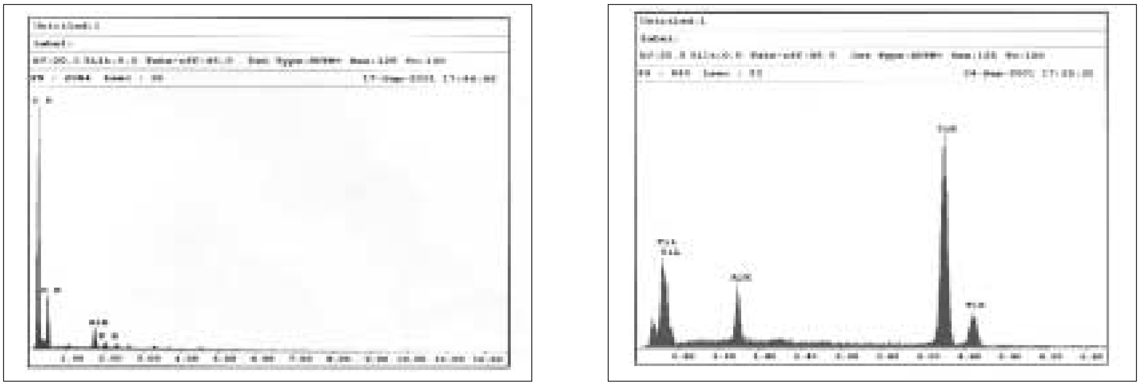
2. SEM Investigation and EDS Analysis of retaining screws.

Similar to the old abutment screw surfaces, circumferential grooves appeared to have been randomly deepened after use and new scratches appeared(Fig. 11, 12). SEM of old retaining screw



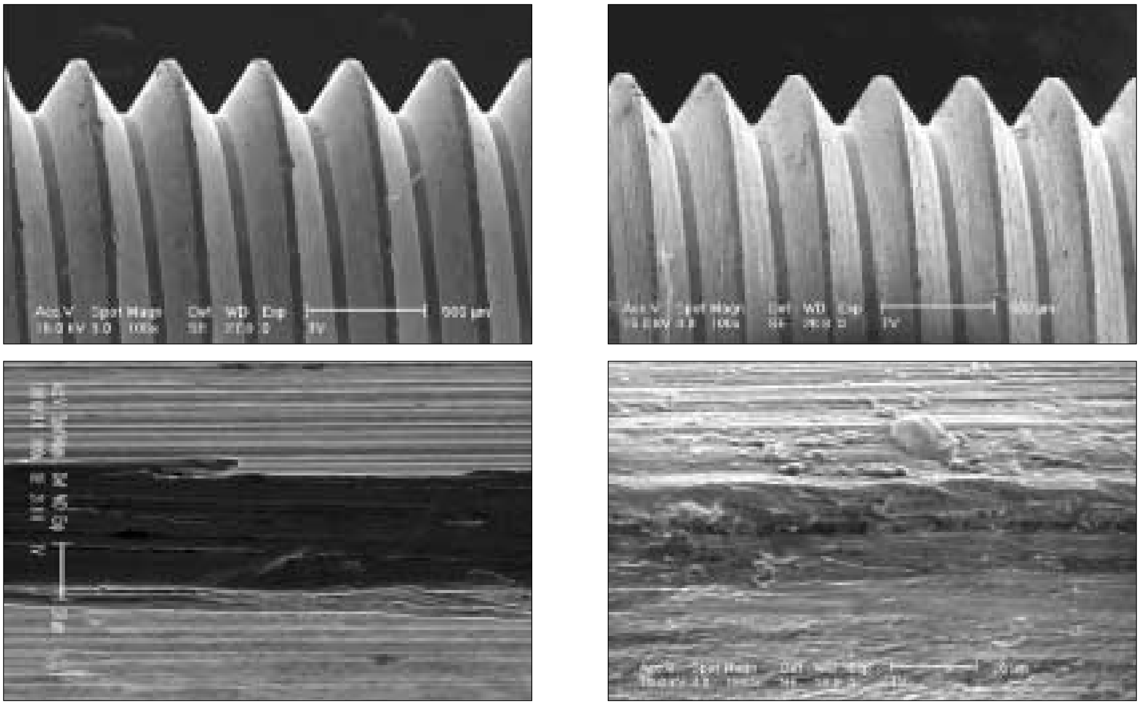
a　　　　　　　　b

Fig. 7. Used & unused abutment screw surfaces of Steri-oss system in SEM. (Magnification ×50, a:before ultrasonic cleansing, b:after ultrasonic cleansing)



a b

Fig. 8. EDS analysis on used abutment screw surfaces.(a:before ultrasonic cleansing, b:after ultrasonic cleansing)



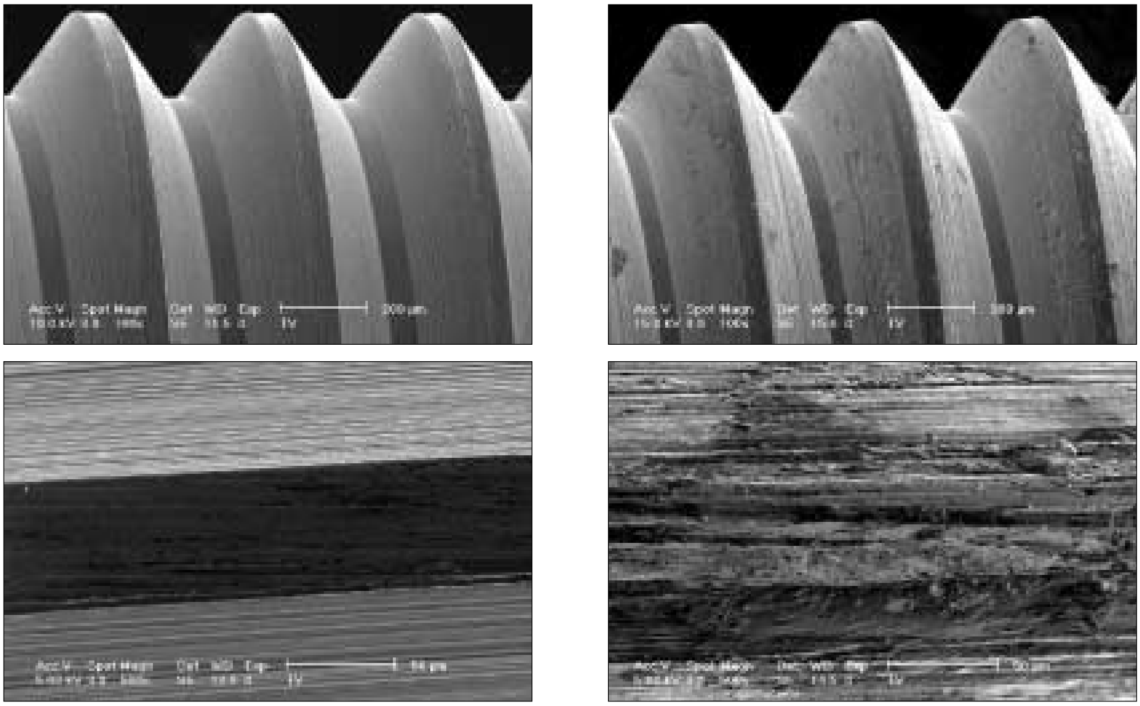
a b

Fig. 9. Abutment screw surfaces of Steri-oss system in SEM.(Magnification ×100, ×1000, a:unused screw, b:used screw)

surfaces showed a great deal of accumulation on the surfaces(Fig. 13). EDS analysis proved that these accumulations are plaque and corrosion product(Fig. 14).

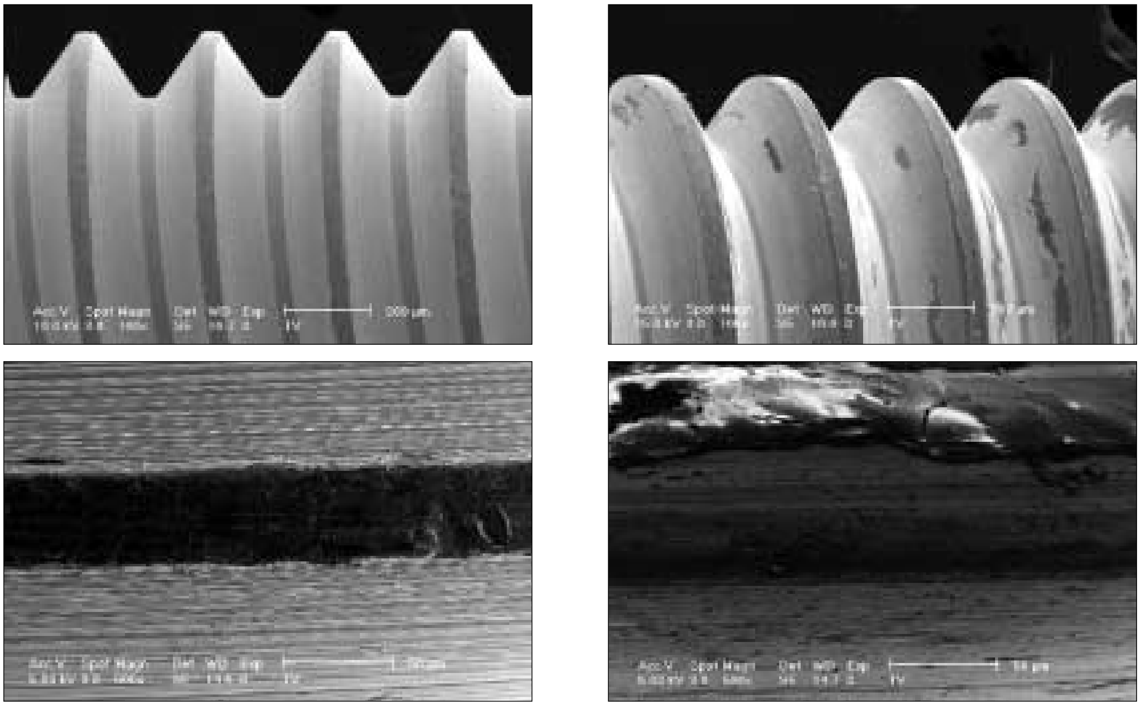
The case of old retaining screws had relatively larger plaque accumulation on the surface than the case of old abutment screws.

Surface alterations after use were more exam-



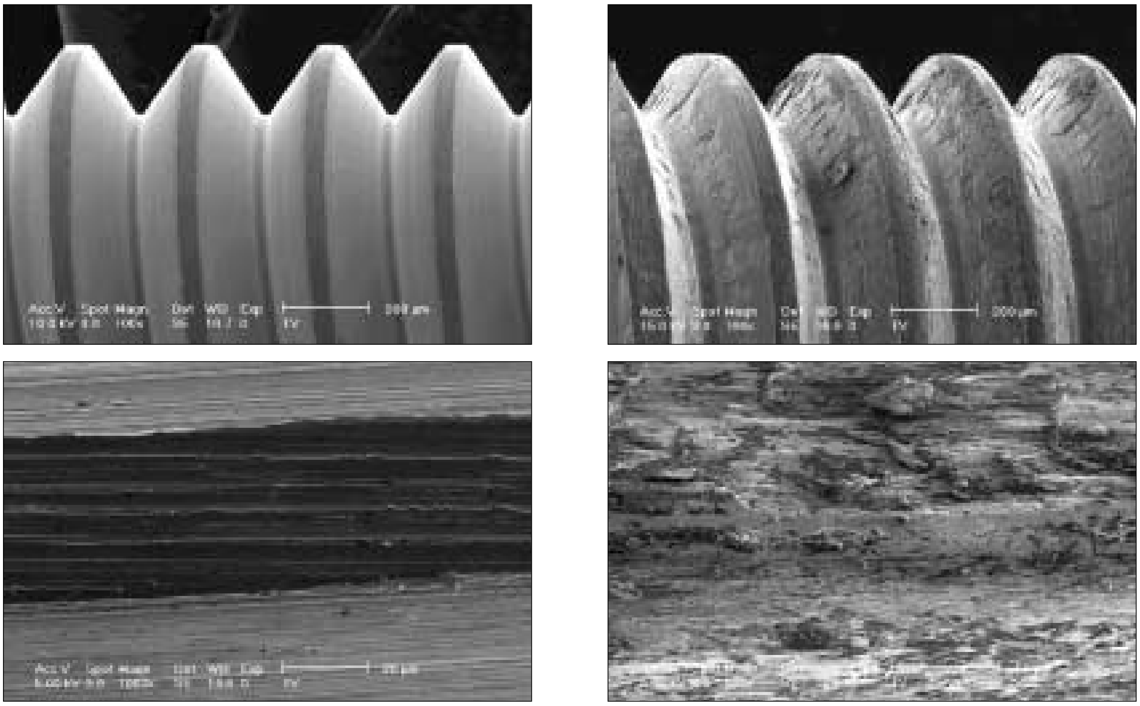
a **b**

Fig. 10. Abutment screw surfaces of 3i system in SEM.(Magnification ×100, ×1000, a:unused screw, b:used screw)



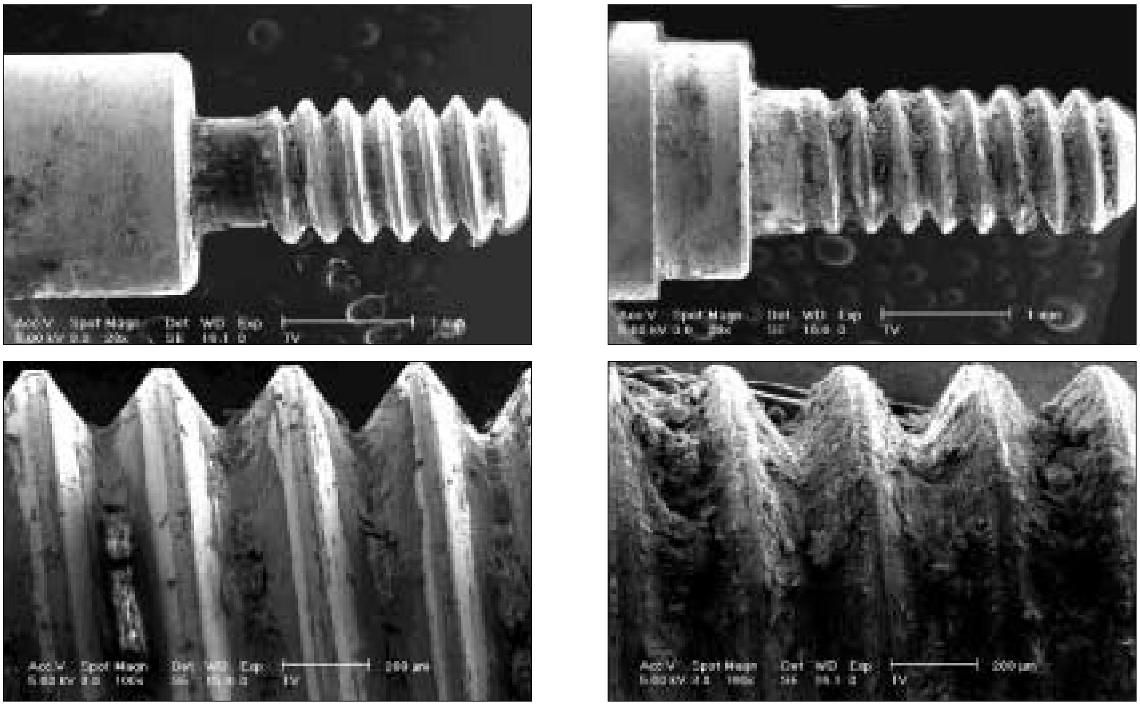
a **b**

Fig. 11. Gold retaining screw surfaces in SEM.(Magnification ×100, ×1000 a:unused screw b:used screw)



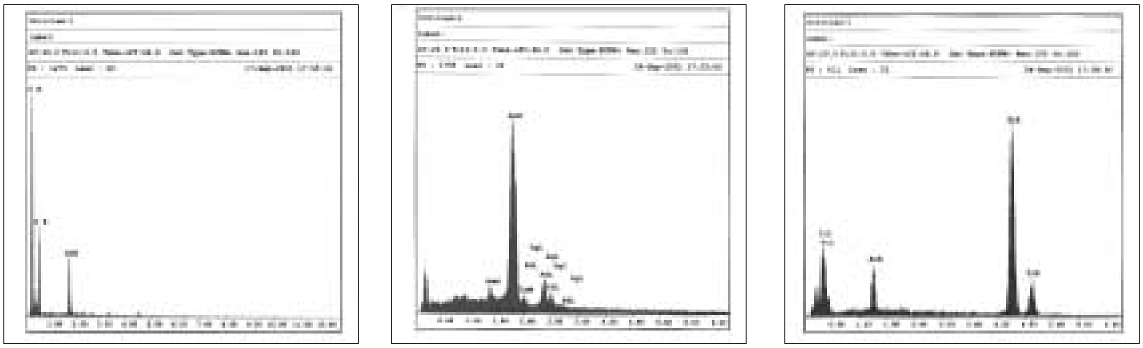
a b

Fig. 12. Titanium retaining screw surfaces in SEM.(Magnification ×100, ×1000 a:unused screw b:used screw)



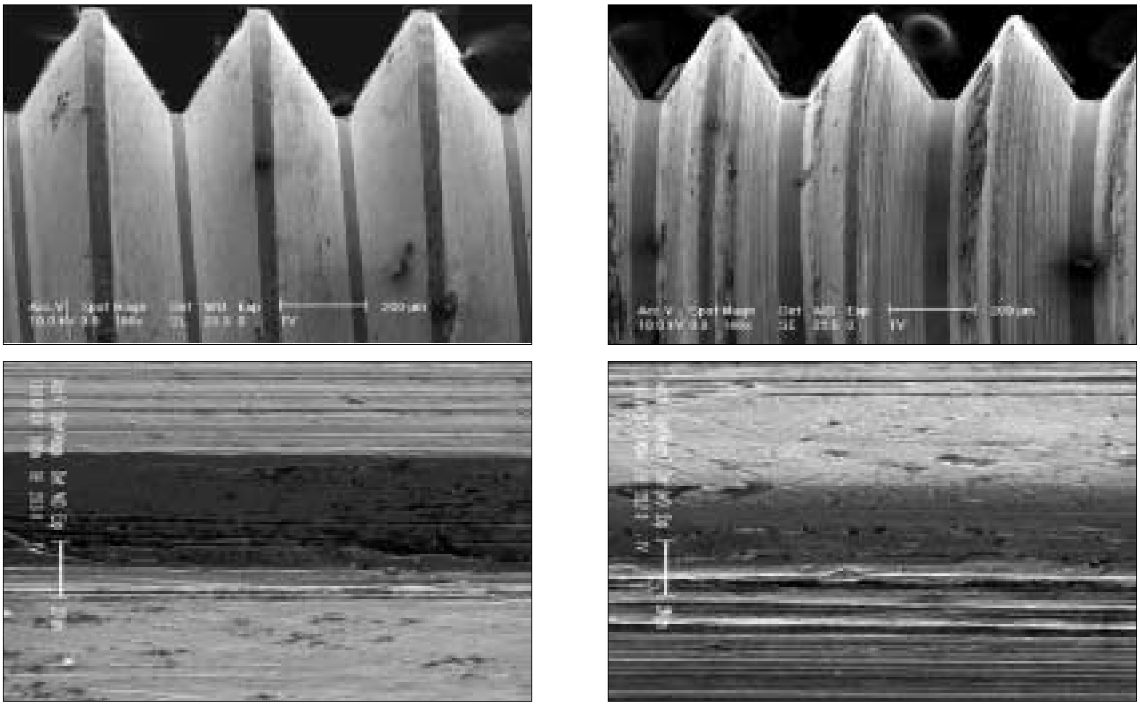
a b

Fig. 13. Used retaining screw surfaces before ultrasonic cleansing in SEM.(Magnification ×30, ×100 a:gold screw b: titanium screw)



a **b** **c**

Fig. 14. EDS analysis on retaining screw surfaces.(a:before ultrasonic cleansing b:after ultrasonic cleansing of gold screw c:after ultrasonic cleansing of titanium screw)



a **b**

Fig. 15. Screws of retrieved implant complex in SEM. (Magnification ×100, ×1000 a:abutment screw b:retaining screw)

ined in titanium screw than gold screw. And gold screw surfaces were smoother than the titanium screw surfaces.

3. SEM Investigation of cross-sectioned sample of retrieved implant complex.

In this study, cross-section sample which retrieved implant complex means that screws were not retrieved with screwdriver. Screw surfaces were not touched with manipulation and similar with in oral cavity. One retaining screw and one abutment screw were removed by cross-section. In the case of retrieved screws without screwdriver, the surface alteration after use are existed, but screw thread bluntting was not significant(Fig. 15).

DISCUSSION

Very high long-term success rates are reported for titanium osseointegrated implants.[12-14] In the study by Lekholm et al.,[15] found accumulative implant success rate of 93.3% as a mean for both jaws.

The changes in the surface structure observed on the thread of the screws after use are difficult to explain.[9] In the study by Rangert et al.,[16] found that the failure mechanism was fatigue. In the study by Takeshita et al.,[17] found that SEM analysis showed the presence of linear scratches indicating the development of fatigue cracks, due probably to repeated tensile stresses.[12,17]

Therefore, the purpose of this study was to evaluate surface alteration of implant screws after function through the examination of old and new screws in SEM.

We examined old and new screws in SEM and EDS was performed on screws. And retrieved screws without screwdriver were also examined in SEM.

It is a well-established fact that fatigue failures occur through crack formation, which then propagate through the specimen. All cracks in the present study seen under SEM began in notches on the surface of the components.[18]

In this study, the retaining screw surface alteration was more than the abutment screw surface alteration. This may be related to retaining screw fracture more often than the abutment screw.[10]

Patterson and Johns [19] provided a theoretical analysis of the fatigue life of retaining screws and concluded that applying the correct torque achieved a long fatigue life for the screw. Binon[20] promoted the concept of the weak link for components. The proposed weak link is the retaining screw, which connects the gold cylinder to the transmucosal titanium abutment. This retaining screw should fracture before any other component does. This concept is well accepted but has never been scientifically proven.[20]

In the study by Jo rneus et al.,[3] the design of screw head, screw material, and tightening torque were demonstrated to be significant parameters for screw joint stability.[3,21] The single most significant factor that determines the bolting characteristics of the screw is the construction material, and manufacturers have made numerous changes in that regard. The friction resistance between the titanium of the implant thread and the titanium of the screw threads, resulting in part from "galling," a form of adhesive wear that occurs during the intimate sliding contact of two like materials, limits the preload characteristics of titanium screws. Hence transition has been made to the gold-alloy screw. Gold-alloy screws have a lower coefficient of friction, can be tightened more effectively to higher preloads, and will not stick to titanium.[22,23]

In this study, old titanum retaining screw surfaces had more plaque accumulation, scratches and grooves than old gold retaining screw surfaces. And gold screw surfaces were smoother than the titanium screw surfaces.

The difference of surface defect between gold screw and titanium screw can be explained by formation of oxides, such as TiO and TiO_2. In the case of gold screw, surface was not activated for noble metals. Therefore gold screw surfaces can be protected without oxidation film. Whereas, in the case of Ti screw, Ti was formed oxides on the surface protecting against aggressive ion. But Ti screw will easily dissolute in the part of broken

TiO_2 layer which was formed for tightening and loosening process of screw due to act as activation sites. The formation rate of scratch and plaque was accelerated in the part of broken TiO_2 layer.[24]

In this study, gold screw better influence than titanium screw on surface alteration of implant screws after function. Therefore, We recommend the use of gold screws rather than titanium screws. Since it appears to be difficult to predict the longevity of implants, prevention can only be achieved by regular examination that includes cleansing, and the exchange of implant screws.

CONCLUSION

The purpose of this study was to evaluate screw surface alteration of implant screws after function through the examination of old and new screws in SEM(scanning electron microscope).

The results were as follows;

1. In the case of new, unused implant screws, as manufactured circumferential grooves are regularly examined and screw threadare sharply remained.
2. Before ultrasonic cleansing of old, used implant screws, a lot of accumulation and corrosion products were existed.
3. After ultrasonic cleansing of old, used implant screws, circumferential grooves as examined before function are randomly deepened and scratches increased. Also, dull screw thread was examined.
4. More surface alterations after function were examined in titanium screw than gold screw. And more surface alteration was examined when retrieved with driver than retrieved without driver.

These surface alteration after function may result in the screw instability. Regularly cleansing and exchange of screw was recommended. We recommend the use of gold screw rather than titanium screw, and careful manipulation of the driver.

REFERENCE

1. Cibirka R, Nelson S. Examination of the implant-abutment interface after fatigue testing. J Prosthet Dent 2001;85:268-275.
2. Gratton D, Aquilino S, Stanford C. Micromotion and dynamic fatigue properties of the dental implant-abutment interface. J Prosthet Dent 2001;85:47-52.
3. Jorneus L, Jemt T, Carlsson L. Loads and design of screw joints for single crowns supported by osseointegrated implants. Int J Oral Maxillofac Implants 1992;7:353-359.
4. Kallus T, Bessing C. Loose gold screws frequently occur in full-arch fixed prostheses supported by osseointegrated implants after 5years. Int J Oral Maxillofac Implants 1994;9:169-178.
5. McGlumphy E, Holloway J. Implant screw mechanics. Dental clinic of north America 1998;42:71-89.
6. Helsingen A, Lyberg T. Comparative surface analysis and clinical performance studies of Branemark implants and related clones. Int J Oral Maxillofac Implants 1994;9:422-430.
7. Mengel R, Buns C, Mengel C. An in vitro study of the treatment of implant surfaces with different insturments. Int J Oral Maxillofac Implants 1998;13:91-96.
8. Jaarda M, Razzog M, Gratton D. Geometric comparison of five interchangeable implant prosthetic retaining screws. J Prosthet Dent 1995;74:373-379.
9. Schliephake H, Reiss G. Metal release from titanium fixtures during placement in the mandible: An experimental study. Int J Oral Maxillofac Implants 1993;8:502-511.
10. Charles J. Clinical complications of osseointegrated implants. J Prosthet Dent 1999;81:537-552.
11. Laney W, Jemt T, Harris D. Osseointegrated implants for single-tooth replacement: Progress report from a multicenter prospective study after 3years. Int J Oral Maxillofac Implants 1994;9:49-54.
12. Piattelli A, Scarano M, Piattelli E. Hollow Implants Retrieved for Fracture: A Light and Scanning Electron Microscope Analysis of 4Cases. J Periodontol 1998;69:185-189.
13. Breeding L, Dixon D. Torque required to loosen single-tooth implant abutment screws before and after simulated function. Int J Prosthodont 1993;6:435-439.
14. Schulte J, Coffey J. comparison of screw retention of nine abutment systems: A pilot study. Implant Dent 1997;6:28-31.
15. Lekholm U, Van Steenberghe D, Herrman I. Osseointegrated implants in the treatment of par-

tially edentulous jaws: A prospective 5-year multicenter study. Int J Oral Maxillofac Implants 1994;9:627-635.
16. Rangert B, Langer B. Binding overload and implant fracture: a retrospective clinical analysis. Int J Oral Maxillofac Implants 1995;10:326-334.
17. Takeshita F, Matsushita Y, Ayukawa Y, Suetsugu T. Fractures of hydroxyapatite-coated blade implants connected with natural teeth. A histological study using SEM, light microscopy, and an image processing system. J Periodontol 1996;67:86-92.
18. Christoph H. Load fatigue preformance of two implant-abutment combinations. Int J Oral Maxillofac Implants 1996;11:522-528.
19. Patterson E, Johns R. Theoretical analysis of the fatige life of fixture screws in osseointegrated dental implants. Int J Oral Maxillofac Implants 1992;7:26-34.
20. Binon P, McHugh M. The effect of eliminating implant/abutment rotational misfit on screw joint stability. Int J Prosthodont 1996;9:511-519.
21. Boggan R, Strong J, Misch C. Influence of hex geometry and prosthetic table width on static and fatigue strength of dental implants. J Prosthet Dent 1999;82:436-440.
22. Binon P. Implants and Componennts: Entering the New Millennium. Int J Oral Maxillofac Implants 2000;5:76-94.
23. Haack J, Sakaguchk R. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac Implants 1995;10:529-536.
24. Revie R. Corrosion Handbook, Electrochemical Society Series: John Wiley& Sons Inc 2000 pp.870-871.

Reprint request to:
Dr. Chae-Heon Chung, D.D.S., Ph.D.
Department of Prosthodontics, College of Dentisity,
Chosun University
421, Seosuk-Dong, Dong-Gu, Gwangju, 501-759, Korea
Tel:+82-62-220-3820
E-mail: jhajung@mail.chosun.ac.kr