지대주 나사의 TiN 코팅이 풀림력에 미치는 영향

Effect of TiN coating of abutment screw on detorque force

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이 논문을 치의학 박사학위 신청 논문으로 제출함.

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김희중의 박사학위 논문을 인준함.

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본 연구의 목적은 타이타늄 임프란트 지대주 나사에 TiN 코팅을 하여 반복적인 착탈을 가한 후 풀림력에 어떠한 변화가 일어나는지를 알아보고자 하였다. 이 연구에 사용된 지대주 나사는 3i system의 금 지대주 나사(Gold-Tite)와 타이타늄 지대주 나사였으며, 각각 7개와 21 개씩 선택되었다. 21개의 타이타늄 지대주 나사중 14개의 나사에 TiN 코팅을 하였다. 28개의 지대주 나사는 다음과 같이 4개의 군으로 나뉘었다. 두 개의 군은 20 Ncm의 조임력을 가하는 7개의 타이타늄 지대주 나사군(Titanium abutment screw, Group A)과 7개의 TiN 코팅된 타이타늄 지대주 나사군(Titanium abutment screw with TiN coating, Group B)이며, 나머지 두 군은 32 Ncm의 조임력을 가하는 7개의 금지대주 나사군(Gold-Tite abutment screw, Group C)과 7개의 TiN 코팅된 타이타늄 지대주 나사 그룹(Titanium abutment screw with TiN coating, Group D)이였다. 임플란트 고정체는 3i사의 Osseotite(Hexlock 4.0 D×13 mm; 3i/implant Innovations Inc, USA)를 선택하였다. 지대주는 3i GingiHue™ Post abutment (4.1 mmD × 5 mmP × 2mmH;3i/implant Innovations Inc, USA)를 사용하였다. 임플란트 고정체와 지대주는 28개씩 선택되었다. 레진블록에 임플란트 고정체를 고정한 후 각각의 지대주를 연결하였고, electronic torque controller를 이용하여 지대주 나사를 조였다. 금지대주나사와 TiN 코팅된 타이타늄 지대주 나사는 32 Ncm의 조임력을 가하였고, 타이타늄 지대주 나사와 TiN 코팅된 지대주나사는 20 Ncm의 조임력을 가하였다. 모든 시료는 30회씩의 반복적인 착탈을 시행하였으며 매회 풀림력을 측정하였다. 각 풀림 횟수마다 토크 측정기(MGT 12®, Mark-10 Corp., U.S.A)를 이용하여 풀림

력을 관찰하여 다음과 같은 결론을 얻었다.

1. 지대주및 지대주나사의 착탈 횟수가 증가할수록 금지대주 나사(Group C) 군을 제외한 다른 모든 군에서 풀림력의 감소 경향을 보였으며, 타이타늄 지대주나사(Group A)에서 가장 뚜렷한 소실 양상이 나타났다.
2. 네 그룹의 30회의 평균 풀림력은 Group A에서는 14.69± 0.64 Ncm, Group B에서는 16.05± 0.59 Ncm, Group C에서는 20.43± 2.06 Ncm, Group D에서는 23.36± 1.13 Ncm 이었다.
3. 20Ncm의 조임력을 가한 Group A과 Group B의 풀림력 비교에서는, Group B가 Group A에 비해 통계학적으로 유의하게 높은 값을 나타내었다($P<0.05$, Repeated measure ANOVA).
4. 32Ncm의 조임력을 가한 Group C와 Group D의 풀림력 비교에서는, Group D가 Group C 보다 통계학적으로 유의하게 높은 값을 나타내었다($P<0.05$, Repeated measure ANOVA).
5. 각 그룹의 나사산 표면들을 실험 전후에 SEM으로 고찰한 결과에서는, Group A와 C가 뚜렷한 변화를 보였으며, Group B와 D는 거의 변화가 없었다.

이 실험의 결과에서 TiN 코팅을 한 타이타늄 지대주 나사군이 타이타늄 지대주 나사군과 금 지대주 나사군 보다 높은 풀림력을 나타내었다. 또한, TiN 코팅을 한 지대주 나사군이 타이타늄 지대주 나사군과 금 지대주 나사군 보다 마모 저항도 우수하였다. 따라서, 지대주나사의 TiN 코팅은 나사의 풀림 현상을 감소시키는데 도움이 되는 것으로 사료된다.

I. Introduction

Most of implant systems have more than one screw to connect the restoration or suprastructure to an implant fixture. Screw loosening in such systems has been reported as one of the most common complications.[1-3] In the study by Jemt et al,[2] abutment screw loosening was found to be as high as 45% with implant single crowns. Goodacre et al[3] reported abutment screw loosening was detected in 6% (365 of 6256 screws loosened) of the prostheses.

Factors related to screw loosening are various including poor tightening(inadequate preload), inaccurate fit of framework , poor component fit, flexure of framework, settling, debris trapped in screw receptor, screw design and bone elasticity.[4] However, the most frequent cause of screw loosening is the loss of preload.

Preload is tension within a tightened screw and is induced in a screw when torque is applied during tightening.[4,5] When torque is applied to new screw, about 90% of input torque is used to overcome friction and only 10% to induce preload.[6] For that reason, a few manufacturers have altered the surface of abutment screw to reduce the friction coefficient and obtain the higher preload. The most well-known abutment screws are the Gold-Tite of 3i(3i/implant Innovations Inc, USA) and TorqTite of Steri-Oss(Novel Biocare USA, Yorba Linda, Calif.). Martin et al[7] reported that Gold-Tite and Torqtite abutment screws with enhanced surfaces helped reduce the friction coefficient and generated greater rotational angles and preload values than conventional screw. Drago[8] reported that the use of Gold-Tite square abutment screws, torqued to 35 Ncm, maintained a stable implant/abutment connection that was successful in clinical practice for one year.

Extremely thin titanium nitride(TiN) coatings are the most general and popular coating method and used to improve the properties of metallic surface for industrial purposes. This layer of 2~3 ㎛ thickness renders the surface scratch-proof and is considered to be chemically stable. TiN is used as a hard coating for metal cutting tools like drills and burs, and forming tools such as dies and punches because it has high hardness, low friction coefficient(lublicity) and good resistance to adhesive wear[9)]. Additionally, it has a golden appearance and is useful for ornamental purposes. Such properties of TiN coating are also expected to increase the preload.

TiN coating has been applied to clinical dentistry long since. The clinical trials which coated crown, partial fixed denture and removable prostheses made from casting dental alloy with TiN had been performed by several dentists.[9)] At that time, most of researches focused on biological, mechanical and corrosive aspects of the coating. Recently, Scarano[10,11)] reported that TiN surfaces showed a significant reduction of the presence of bacteria and the bone healing around the TiN-coated implants was similar to that observed around the uncoated surfaces. However, the application of TiN coatings on abutment screw has not been reported yet.

The aim of this study is to evaluate the effect of TiN coating of abutment screw on the unscrewing torque.

II. Materials and Methods

1. sample preparation

Abutment screws that used for this experiment were titanium hexed uniscrews(3i/implant Innovations Inc, USA) and Gold-Tite abutment screws (3i/implant Innovations Inc, USA). Twenty eight abutment screws including 21 titanium and 7 Gold-Tite abutment screws were randomly selected. Seven titanium and Gold-Tite abutment screws were respectively divided into two groups, Group A and Group C (Fig . 1, Table 1). Group A and C were used as control groups. The rest of titanium abutment screws were coated with TiN and were also classified into two groups of seven implants each, Group B and Group D(Fig. 1, Table 1). Group B and D were used as experimental groups. Abutment screws of experimental groups had TiN coating by using radio frequency sputtering physical vapour deposition(RF sputtering). TiN film of 2-3 ㎛ thickness was deposited on the threads of abutment screw. Prior to deposition all abutment screws were cleaned ultrasonically, in detergent, methanol and finally distilled water , and presputtering was carried out for 20 min using an RF power of 200W . TiN coatings were produced by RF sputtering of a titanium target in an atmosphere of Ar and N_2. The TiN coatings were produced as a function of gas composition, basic and working pressure, substrate temperature, and coating thickness. The conditions for TiN coating of Group B and D were shown in Table 2.

Fig. 1. Kinds of abutment screws

Table 1. Classification of groups

Group	Abutment Screw	Number(n)	Applied torque (Ncm)
A*	Titanium Hexed Uniscrew	7	20
B**	Titanium Hexed Uniscrew with TiN coating	7	20
C*	Gold-Tite Abutment screw	7	32
D**	Titanium Hexed Uniscrew with TiN coating	7	32

*=control groups, **=experimental groups.

Table 2. Deposition conditions 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 ㎛

The implant fixtures selected in this study were external hexagonal extension threaded implants(OSSEOTITE Hexlock 4.0D×13 mm;3i implant Innovations Inc, USA, Fig. 2-a). Abutments for this experiment were 3i GingiHue^{TM} Post abument (4.1 mmD×5 mmP×2 mmH ;3i implant Innovations Inc, USA, Fig.2-b). Twenty eight pairs of implant fixture and abutment were selected respectively.

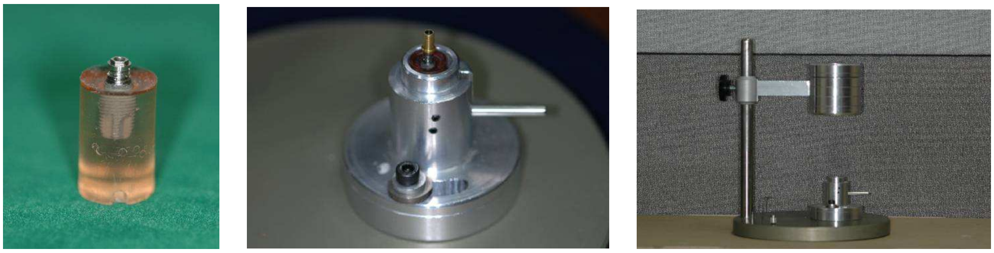
One fixture, one abutment and one abutment screw comprised a specimen.

a b

Fig. 2. Fixture and abutment for this study(a: Hexlock 4.0D×13 mm, b: 3i GingiHue^{TM} Post abument (4.1 mmD×5 mmP×2 mmH)).

2. measurement of detorque value

The implant fixtures were perpendicularly mounted in liquid unsaturated polyesther with dental surveyor. The mounting media (Epovia, Cray Valley Inc.) was a 2-part system made up of a resin and hardener. The two components were mixed together and poured and allowed to cure overnight. Mounted fixture block was fixed in the specially devised specimen-holding apparatus before closing and opening(Fig. 3-a, b, c).



a: mounted fixture

b: specimen fixed onto jig

c: customized jig

Fig. 3. Mounted sample and customized jig for measurement of detorque value.

Each abutment was secured to the implant fixture by each abutment screw with recommended torque value using finger screw driver(PHD02N, 3i/implant Innovations Inc, USA) and electronic torque controller(Brånemark system DEA 020 Torque controller, Fig. 4-a,b). Finger screw driver was used to fix the abutment screw till thread mating components were slightly contact. After that, electronic torque controller was used to tighten the screw to 20/32 Ncm. It was used to insure that an accurate and reproducible force was applied to each abutment screw(Fig. 4-b).

a: finger screw driver

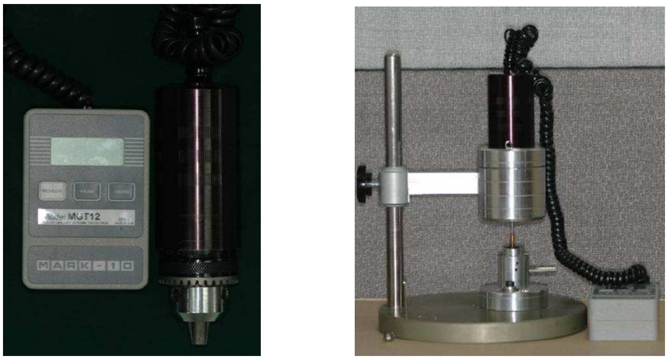
b: electronic torque controller

Fig. 4. Finger screw driver and electronic torque controller

According to manual of manufacturer, 20 Ncm tightening torque was applied for titanium abutment screw group(Group A) and 32 Ncm for

Gold-Tite abutment screw(Group C). Group B was torqued by 20 Ncm for the comparison with Group A and Group D was tested to 32 Ncm torque for the comparison with Group C. The abutment screws were repeatedly tightened and removed thirty trials. One operator who had experienced implant prosthetic restorations accomplished this operation.

Sample with abutment screw tighten was fixed in the customized jig for the measurement of opening force. Detorque values were measured with digital torque gauge(MGT 12®, Mark-10 Corp., U.S.A, Fig. 5-a). Identical measurements were repeatedly performed 30 times for each sample.



a: digital torque gauge   b: measurement of detorque value

Fig. 5. Digital torque gauge and measurement of detorque value.

3. Statistical analysis

SPSS statistical software for Windows(release 12.0, SPSS Inc., Chicago, IL, U.S.A.) was used for statistical analysis. Repeated measure ANOVA(analysis of variances) and Student t-test were used for the comparison of the detorque values measured from coating groups and non-coating ones. Hierarchical cluster analysis was used to find a statistical reduction point of detorque force of non-coating groups.

III. *Results*

Fig. 6 and Table 3 show the mean detorque values of each trial. As shown in Fig. 6, Group C and Group D that tested to 32 Ncm had a higher mean detorque force than Group A and Group B. Three groups except for Group C had a declining tendency of detorque value as the closing and opening were repeated, while Group C had a ascending tendency even if in minute. Cluster analysis revealed that the mean detorque values of only Group A were classified into two levels, high and low level, between 13th and 14th trial(Fig. 7).

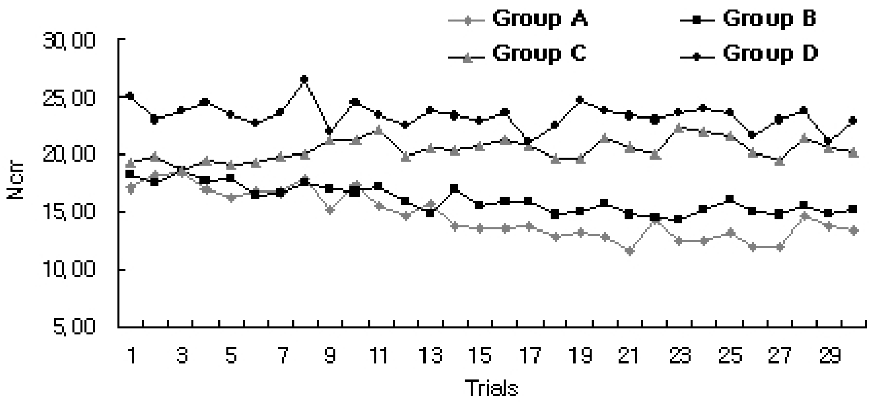


Fig. 6. Distribution of mean detorque value of all groups

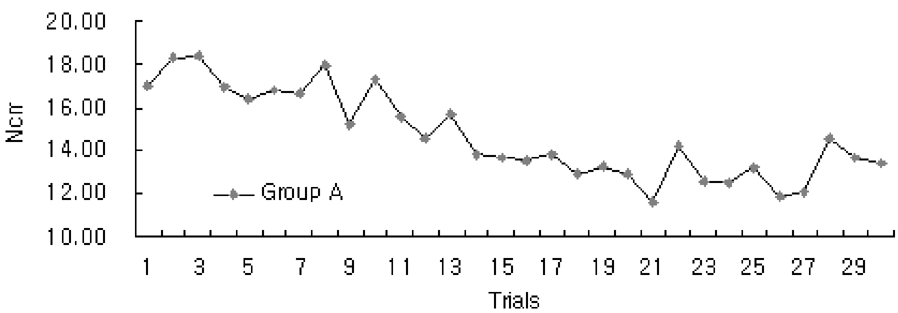


Fig. 7. Distribution of mean detorque value of Group A.

Table 3. Mean detorque value (Unit; Ncm)

Groups / Trials	Group A	Group B	Group C	Group D
1	17.04	18.27	19.29	25.01
2	18.36	17.44	19.81	22.94
3	18.41	18.51	18.54	23.87
4	16.96	17.66	19.39	24.51
5	16.36	17.96	19.20	23.43
6	16.81	16.40	19.29	22.71
7	16.67	16.63	19.87	23.64
8	17.97	17.47	20.03	26.53
9	15.23	16.96	21.21	21.94
10	17.31	16.73	21.27	24.57
11	15.56	17.19	22.21	23.43
12	14.61	15.90	19.73	22.64
13	15.69	14.83	20.46	23.71
14	13.80	16.94	20.39	23.36
15	13.66	15.46	20.74	22.80
16	13.53	15.89	21.24	23.63
17	13.79	15.99	20.73	21.19
18	12.93	14.76	19.66	22.47
19	13.24	15.01	19.64	24.67
20	12.94	15.74	21.54	23.79
21	11.59	14.67	20.69	23.31
22	14.26	14.51	20.01	22.94
23	12.56	14.20	22.34	23.66
24	12.47	15.10	22.04	23.99
25	13.21	16.10	21.67	23.54
26	11.89	14.96	20.14	21.57
27	12.07	14.77	19.54	23.00
28	14.56	15.47	21.54	23.89
29	13.71	14.84	20.50	21.10
30	13.39	15.26	20.13	22.87
Mean	14.69	16.05	20.43	23.36
SD	2.03	1.23	0.99	1.12

The results from the measurements of detorque value at 20 Ncm torque were shown in Fig. 8 and Table 4. There was a statistically significant difference between Group A and Group B($P<0.05$, repeated measure ANOVA). In the comparison of detorque values from 1st trial to thirteenth one, there was no statistically significant difference between group A and Group B(P>0.05, Student t-test) (Fig. 9). However, the comparison of detorque values from 14th to 30th trial revealed that Group B had statistically higher detorque values than Group A (P<0.05, Student t-test) (Fig. 9).

Table 4. Mean detorque value of Group A and B(Unit; Ncm)

Sample Number	Group A	Group B
1	14.74	15.65
2	14.05	17.09
3	14.54	16.23
4	15.18	15.57
5	15.65	15.34
6	14.87	16.22
7	13.78	16.28
Mean	14.69	16.05
SD	0.64	0.59

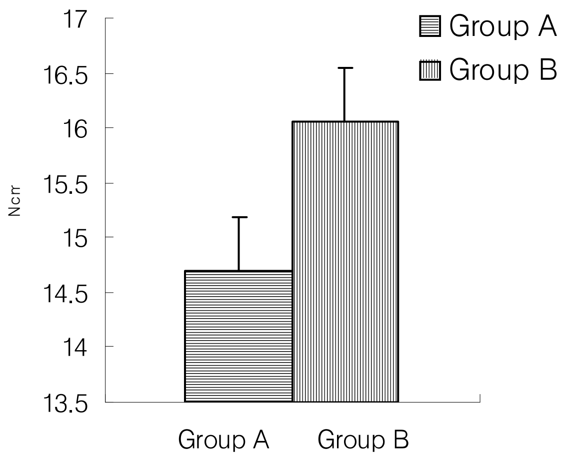


Fig. 8. Comparison of detoque value of Group A and Group B (P<0.05, ANOVA, n=7).

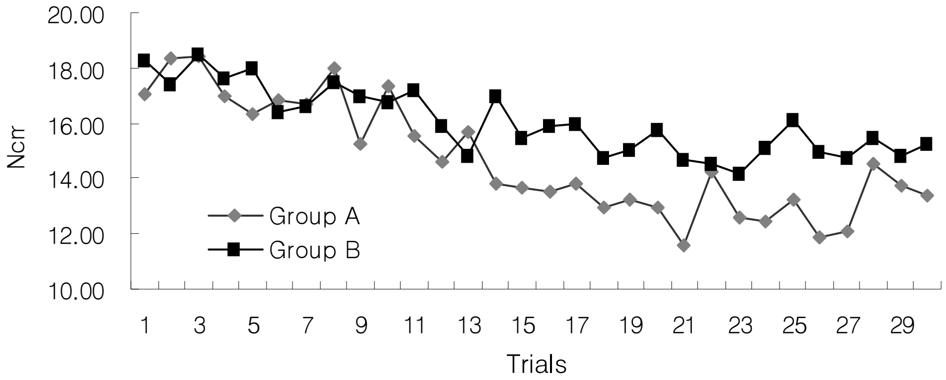


Fig. 9. Detorque value of Group A and B.

The results of detorque values measured at 32Ncm were reported in Table 5 and Fig. 10. There was a statistically significant difference between Group C and Group D(P<0.05, repeated measure ANOVA) (Fig. 10). Detorque values of Group D were statistically higher than those of Group C during every trial.

Table 5. Mean Detorque Value of Group C and D(Unit; Ncm)

Groups / Trials	Group C	Group D
1	21.02	23.16
2	17.83	22.25
3	21.47	24.88
4	17.59	21.76
5	20.70	23.08
6	21.01	24.37
7	23.38	24.00
Mean	20.43	23.36
SD	2.06	1.13

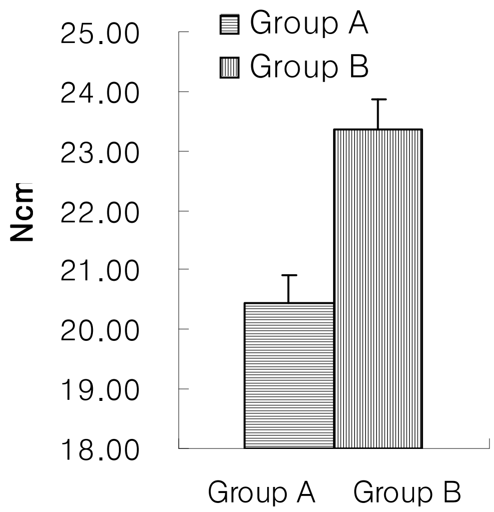


Fig. 10. Comparison of detoque value of Group C and Group D (P<0.05, ANOVA, n=7).

In the SEM analysis of Group A and Group B, Group A had noticeable changes in screw threads after test. The abutment screws of Group A showed a thinner width of thread crest and more severe wear of thread surface after experiment, while those of Group B had little changes (Fig. 11).

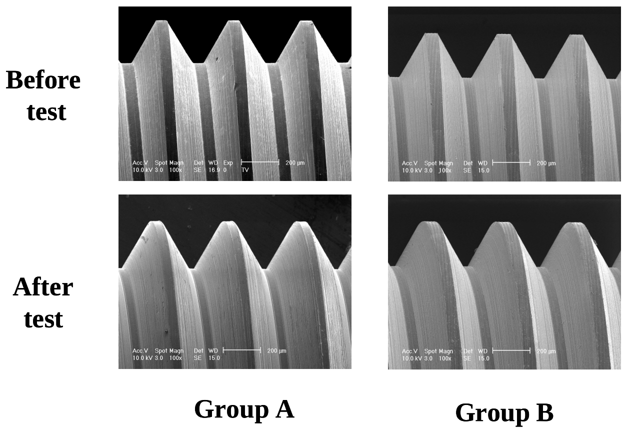


Fig. 11. Photomicrograph of abutment screw threads of Group A and

B in SEM(magnification ×100).

Fig. 12 showed the screw surface of Group C and Group D before and after test. The changes of screw surface were visually more remarkable in Group C than Group D. The screws of Group C had thinned width of thread crests, wear surface and scratches. Group D had a little changes in SEM view after experiment. The changes of Group D were much lesser noticeable than Group C but, a little more than Group B.

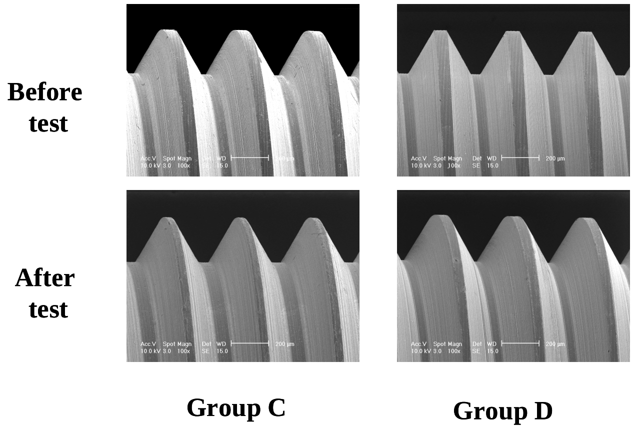


Fig. 12. Photomicrograph of abutment screw threads of Group C and D in SEM(magnification ×100).

IV. Disscussion

Screw loosening in implant dentistry has still been reported and remained as a potential problem. The prevalent method to reduce the screw loosening is the application of dry lubricant coating on abutment screw. The purpose of lubricant is to reduce a frictional coefficient and obtain a higher preload. The need for coating with lubricant has long since introduced.

When titanium slides in contact with other metals of similar hardness, the friction coefficient is initially fairly low. However, the values of friction coefficient gradually increase to that for titanium against titanium, as tightening and loosening are repeatedly performed[12). Abkowitz et al[12) found this increase in the frictional coefficient to be attributable to the galling and seizing tendency of titanium.

TiN film has low friction coefficient, high hardness and good wear resistance. Considering these properties of TiN coating, it seems to be an alternative coating method according to result.

In this study, all abutment screws were repeatedly closed and opened up to 30 trials. The number of trials included several try-in of abutment screw up to final setting and long follow-up once or twice a year.

As shown in Table 3, Group C and D tightened to 32Ncm had higher detorque values than Group A and B. Three groups except for Group C had a declining tendency of detorque value as the closing and opening were repeated, while Group C had a ascending tendency even if in minute. This may be attributed to malleability and ductility of gold. Gold has physical property such as the most malleable and ductile properties of any metal, resistance to corrosion[13), so space can be closed between screw and thread if pure gold is compressed slightly between titanium and gold alloy[14). Furthermore, high ductility leaded to decrease of friction and settling when screw is tightened[15]. It is considered that such properties make the detorque values ascending in minute.

In the comparison of detorque values of Group A and B, there was a statistically significant difference between Group A and Group B. Both Group A and B exhibited the gradual decrease of detorque values during the test. However, from the viewpoint of statistics, there was a remarkable reduction of detorque values from the measurement of 14th loosening in only Group A. It may be attributed to the severe decrease of friction coefficient due to wear between mating components. In the study of Weiss et al[16], they suggested that wear as a result of repeated closing/opening cycles may decrease the coefficient of friction of screw head, threads, and other mating components and consequently, resistance to opening force gradually decreases. As shown in Fig. 11, Group B with TiN coating had little changes in the thread surface of their abutment screws. It is considered that such properties of TiN coating as a high hardness and resistance to wear may prevent detorque values from going down. In this study, we found that the detorque value of titanium abutment screw in external hexed connection decreased from 14th trials. However, the number of specimen size was too small to suggest that the precise trial, from which detorque value starts to decline, be 14th. Further studies are needed to discover that.

Also in the comparison of Group C and D, Group D coated by TiN had a higher mean detorque value than Group C. Gold-Tite screws showed lower mean values than the screws with TiN coating in all trials, even though their detorque values maintained a stable and regular level. This may be attributed to the difference of friction coefficient and the surface treatment between pure gold and TiN.

Abutment screws of Group C and D were coated by pure gold and TiN, respectively. Gold-Tite abutment screw has a friction coefficient of 0.15[17] against titanium and is gold alloy with a 0.76㎛ pure gold coating. In the SEM view after test, there were noticeable changes on the threads of screw(Fig. 11). A typical friction coefficient is 0.65 for TiN against steel. In the study of Pihosh et al[18], friction coefficient of TiN prepared by RF magnetron sputtering against steel ranged from 0.14~ 0.3 according to nitrogen gas consistence. Recently, Oh et al[19] reported that friction coefficient of TiN prepared by RF magnetron sputtering against titanium was 0.39. We could not find a friction coefficient of TiN coated screw(Group B and D) because of too small size of screw. It was assumed that a friction coefficient of TiN by sputtering against titanium might be higher than that of Gold-Tite and lower than(or equal to) that of titanium alloy. SEM observation of Group D showed that there were little changes in the thread surface of screw like as Group B.

The most common method that gains a higher preload is to reduce the friction coefficient of screw using a dry lubricant. Apropriate decrease of a frictional coefficient enables abutment screw to gain a higher preload and consequently, decrease the possibility of screw loosening. However, excessive decrease of a frictional coefficient may cause the decrease of detorque force and more frequent screw loosening. Hagiwara and Ohashi[20] reported that the preload distributed throughout the screw joint increased as the friction coefficient of friction between the threads decreases and abutment screw removal torque values decrease with a reduction in the coefficient of friction. About this phenomenon, Martin et al[7] mentioned that further studies are needed to test for the point at which the reduction in friction was too high and thus might promote screw loosening. Although there are numerous factors affecting a friction coefficient, further studies are needed for such a optimal friction coefficient that can obtain a higher preload and prevent the decrease of detorque force.

Beside friction coefficient, surface hardness and resistance to wear also are seemed to be important factors that decrease the loss of detorque. Above all, it is considered that such properties can prevent settling or embedment relaxation to cause the loss of preload. SEM view in Group B and D coated by TiN showed little changes in the threads of screw.

There were several potential limitations to this study. The specimens were randomly selected and tested by one researcher. The number of sample is too small and we could not find the friction coefficient because of too small size of screw. Finally, test was performed under only repeated closing and opening without occlusal loading.

Ⅴ. Conclusion

The purpose of this study was to evaluate the effect of TiN coating of abutment screws on loosening force. Titanium(3i/implant Innovations Inc, USA) and Gold-Tite abutment screws(3i/implant Innovations Inc, USA) were classified into two groups, Group A and C respectively, as control groups. Titanium abutment screws with TiN coatings were also classified into two groups, Group B and D, as experimental ones. Each group had seven samples. Each sample was composed of one abutment screw, one abutment and one fixture. Group A and B were tightened to 20 Ncm input torque, and Group C and D were tightened to 32 Ncm torque. Electronic torque controller(Brånemark system DEA 020 Torque controller) and driver(PHD02N, 3i/implant Innovations Inc, USA) were used for tightening. Detorque values were measured with digital torque gauge(MGT 12®, Mark-10 Corp., U.S.A). Detorque values of titanium abutment screws with TiN coatings(Group B and D) were compared with those of titanium and Gold-Tite abutment screws(Group A and C) after thirty times of repeated closing and opening test respectively.

The results were as follows ;

1. As the number of closing and opening was increased, there was a progressive decrease in the detorque values of Group A, B and D except for Group C.
2. Mean detorque value of four groups was 14.69± 2.06 in Group A , 16.05± 1.13 in Group B, 20.43± 0.99 Ncm in Group C and 23.36± 1.12 Ncm in Group D.
3. In the comparison of detorque values of Group A and B tested to 20 Ncm, there was a statistically significant difference between

Group A and Group B($P<0.05$, Repeated measure ANOVA).

4. In the comparison of detorque values of Group C and D tested to 32 Ncm, Group D revealed a statistically higher mean value than Group C($P<0.05$, Repeated measure ANOVA).
5. In the SEM observation of abutment screws after test, Group A and C revealed more remarkable changes than Group B and D. Group B and D showed little changes.

Above the results of this study, titanium abutment screw coated with TiN scored a higher mean detorque value than both titanium abutment screw and Gold-Tite abutment screw. Additionally, abutment screws with TiN coatings showed more resistant to wear than titanium screw and Gold-Tite screw. Therefore, it is suggested that TiN coating of abutment screw help to reduce the risk of screw loosening and improve the stability of screw joint.

References

1) Taylor TD. Prosthodontic problems and limitations associated with osseointegration. J Prosthet Dent 1998;79:74-78.

2) Jemt T, Pettersson P. A 3-year follow-up study on single implant treatment. J Dent 1993;21:203-208.

3) Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JYK. Clinical complications with implants and implant prostheses. J Prosthet Dent 2003;90:121-132.

4) Binon PP, Sutter F, Beaty K, Brunski J, Gulbransen H, Weiner R. The role of screws in implant systems. Int J Oral Maxillofac Implants (supplement) 1994;9:8-63.

5) Haack JE, Sakaguchi RL, Sun T, Coffey JP. Elongation and preload stress in dental implant abutment screws. Int J Oral Maxillofac implants 1995;10:529-536.

6) Motosh N. Development of design charts for bolts preloaded up to the plastic range. J Eng Ind 1976;98:849-851.

7) Martin WC, Woody RD, Miller BM, Miller AW. Implant abutment screw rorations and preloads for four different screw materials and surfaces. J Prosthet Dent 2001;86:24-32.

8) Drago CJ. A clinical study of the efficacy of gold-tite square abutment screws in cement-retained implant restorations. Int J Oral Maxillofac Implants 2003;18(2):273-278

9) Mezger PR, Creugers NH. Titanium nitride coatings in clinical dentistry. J Dent 1992;20(6):342-344

10) Scarano A, Piattelli M, Vrespa G, Petrone G, Iezzi G, Piattelli A.

Bone healing around titanium and titanium nitride-coated dental implants with three surfaces: an experimental study in rats. Clin Implant Dent Relat Res 2003;5(2):103-111.

11) Scarano A, Piattelli M, Vrespa G, Caputi S, Piattelli A. Bacterial adhesion on titanium nitride-coated and uncoated implants: an in vivo human study. J Oral Implantol 2003;29(2):80-85.

12) Abkowitz S, Burke JJ, Hiltz RH. Titanium in industry. New York (NY): Van Nostrand Co Inc; 1955.

13) William JD. Dental Materials and Their selection. 2nd Edition. 1997:16-17.

14) Jeong YT, Chung CH, Lee HT. Screw joit stability according to abutment screw materials. J Korean Acad Prosthodont 2001;39: 297-305.

15) Park CI, Choe HC, Chung CH. Effect of surface coating on the screw loosening of dental abutment screws. Metal and materials International 2004;10:549-553.

16) Weiss EI, Kozak D, Gross MD. Effect of repeated closures on opening torque values in seven abutment-implant systems. J Prosthet Dent 2000;84:194-199.

17) Bowden FP, Young L. Influence of interfacial potential on friction and surface damage. Research. 1950;3(5):235-237.

18) Pihosh Y, Goto M, Kasahara A, Oishi T, Tosa M. Influence of reacting nitrogen gas consistence on the properties of TiN films prepared by rf. magnetron sputtering. Applied Surface Science 2005;244:244-247

19) Oh DJ. Chung CH. A study on mechanical properties of TiN, ZrN, WC coating in titanium alloy. J. Korean Acad. Prosthodont 2006. In Press

20) Hagiwara M, Ohashi N. A new tightening technique for threaded fasteners. Mater Eng ASME 1992;371-376.