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치의학석사 학위논문

Screw loosening study of a internal zirconia implant abutment reinforced with a titanium insert

타이타늄 인서트에 의해 강화된 내부연결형 지르코니아 임플란트 지대주의 나사 풀림력 연구

2015년 2월

서울대학교 대학원

치의학과

이 소 피 아

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이 소 피 아

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Abstract

Screw loosening study of a internal zirconia implant abutment reinforced with a titanium insert

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Objectives

Secondary component, titanium insert was developed to reinforce the implant-abutment connection, known as the weakest part of an internal zirconia abutment. The aim of this study was to evaluate the effect of titanium insert under cyclic loading on screw loosening in internal friction connection structure; titanium abutments and zirconia abutments using titanium inserts were compared.

Material and methods

Two different type of abutment with internal friction connection were assessed: titanium abutment-titanium abutment screw

assemblies (Ti-Ti group) and zirconia abutment-titanium insert-titanium abutment screw assemblies (Zr+Ti-Ti group). Fourteen abutments and fourteen implants were used and divided into two groups of seven specimens. Pre-load removal torque values (RTVs) were measured after each assembly was tightened to 35 Ncm with a digital torque gauge. A cyclic load of 300N at a 30 degree angle in reference to the loading axis was applied at a frequency of 15Hz until failure or 1 million cycles by universal testing machine, Instron (E300, Instron, Canton, MA, USA). After cyclic loading, post-load RTVs were measured again.

Results

1) The pre-load RTVs for Ti-Ti group and Zr+Ti-Ti group were 26±0.8 7Ncm and 25.14±0.75 Ncm. The post-load RTVs for each groups were 18.43±1.17 Ncm and 17.50±1.08 Ncm.
2) The mean removal torque difference for Ti-Ti group and Zr+Ti-Ti group were -7.57±1.61 Ncm and -7.64±1.18 Ncm. Statistical analysis by the independent t-test revealed that RT difference of both groups were not significantly different from each other ($P>0.05$).
3) For all specimens, there was no screw loosening identified by visual or tactile inspection during cyclic loading or after loading.

Conclusion

The internally connected zirconia implant abutment reinforced with a titanium insert shows similar resistance to screw loosening under cyclic loading compared to internally connected titanium implant abutment.

Keywords : Implant abutment, Cyclic loading, Zirconia, Titanium insert, Screw loosening

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Introduction

In the search for the esthetic restorative materials, the ceramics are replacing the metals in prosthetic restorations; crowns, bridges and even implant abutments because of its optical qualities. When using ceramic abutments, soft tissue color seems more similar to the natural and bluish appearance of cervical soft tissues as encountered with metal abutments can be avoided.[1] Among the ceramic materials, zirconia shows the most adequate properties for dental applications. With esthetic advantages, Zirconia has high fracture and fatigue resistance and compatible biological properties.[2-4] Zirconia implant abutments are reported clinically success in some studies however but further studies are needed to validate their applications.

When using internally connected zirconia abutments, the implant-abutment connection area is vulnerable to crack or fracture.[5] A secondary component, titanium insert is developed to be placed between an abutment and implant. It is reported such an assembly can be an alternative method to avoid fracture at the weak point of internally connected zirconia abutment. In one study, superior strength was achieved by means of internal connection via a secondary metallic component.[6] However, there is no study on the assembly that it maintain the advantage on screw loosening, the most common complication of implant restoration.

Screw loosening is a renown complication in implant restoration. Although it is not a serious complication itself, it may lead to component failure, demanding more extensive repair.[7] There are several factors that can play critical roles in screw joint stability, including preload, and screw geometry (implant interface geometric design and precision of fit of mating components). Screw joint preloading is one important mechanical factor to prevent screw loosening which is built up in the abutment screw as a product of screw tightening. When preload falls below a critical level, joint stability may be compromised, and the screw joint may fail.[8-9]

The purpose of this study was to evaluate the effect of a titanium insert under cyclic loading on abutment screw loosening in the internal friction connection structure; titanium abutments and zirconia abutments using titanium inserts were compared. For this purpose, the reverse torque value (RTV) of abutment screw was measured before and after loading.

Methods and materials

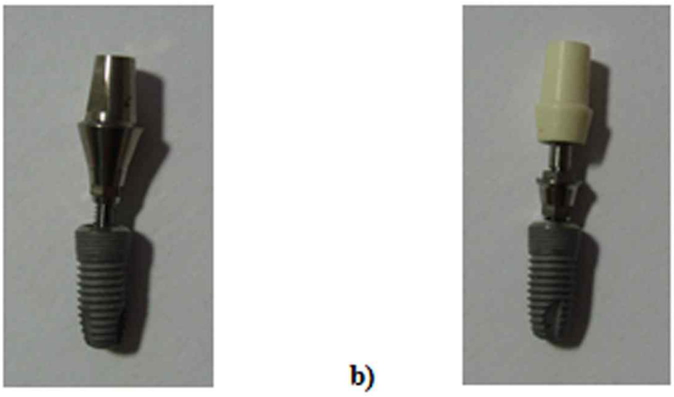
Preparation of specimen and test set-up was performed according to the ISO 14801:2007 protocol. Specimen preparation and testing were performed by the same operator and completed in random sequence to avoid potential errors.

Preparation of specimen

Two types of internal friction connection implant abutments with the anti-rotational hex structure were selected for this study and were divided into two groups: titanium abutments (Dual Abutment [Hex], Dentium Co., Ltd., Seoul, Korea) and titanium abutment screws for Ti-Ti group and zirconia abutments (ZirAce

External, Acucera, Inc., Seoul, Korea) with titanium inserts (Z socket Dentium Regular, Osung MND Co., Ltd., Seoul, Korea) and titanium abutment screws for Zr+Ti-Ti group (Fig.1, Table 1). Both groups were all internally connected. For Zr+Ti-Ti group, titanium insert has both external and internal structure to fit both external zirconia abutment and internal titanium implant.

Fourteen screw-shaped titanium implants (Implantium, Dentium Co., Ltd., Seoul, Korea), which were 4.5 mm in platform diameter, 4.3 mm in body diameter, and 10.0 mm in length, were used in this study. The sample size of the abutments was seven for each group. All the abutments were adjusted to the same 8 mm length from the implant-abutment junction to the top of the abutments and assembled onto the implants through the titanium abutment screws.



a) b)

Fig. 1. Two types of implant-abutment systems used in the study. (a) Group Ti-Ti. Internally connected one-piece titanium abutment with titanium screw and titanium implant. (b) Group Zr+Ti-Ti. Internally connected two-piece zirconia abutment with titanium insert and titanium screw, and titanium implant.

Table 1. The abutment specimens used in this study

Groups	Items	Product name (product code)	Properties
Ti-Ti	Titanium abutment	Dual abutment [hex] (DAB5535HL)	Width: ϕ5.5 Height: 5.5 mm Collar height: 3.5 mm
Zr+Ti-Ti	Zirconia abutment	ZirAce external (ZAR535)	Width: ϕ5.0 Height: 5.5 mm Collar height: 3.0 mm
	Titanium insert	Z socket Dentium Regular (23SASRD-07H1)	Insert width: ϕ4.1

Testing Protocols

In this study, initial preload was considered to be the reverse torque value, measured immediately after tightening with the recommended torque. RTV following cyclic loading was also measured. The effect of cyclic loading was evaluated by examining the changes in RTV. A digital torque gauge (MGT50, Mark-10 Co., Hicksville, NY, USA) was used to ensure that torque was accurately applied to each abutment screw. Using the torque guage, 35 Ncm was applied for both Ti-Ti group and Zr+Ti-Ti group.

Cyclic loads were applied by a universal testing machine, Instron (E3000, Instron, Canton, MA, USA) The specimens were mounted in metal holder, which inclined 30° angle in reference to the loading axis. (Fig. 2) For all specimens, loads of 300N at a frequency of 15Hz were applied until failure or 1 million cycles. Hemispherical metal caps were fabricated and were placed on the abutment during testing.

After 1 million cycles of loading, the implant assembly was measured for post-loading reverse toque using the same digital torque gauge (MGT50, Mark-10 Co., Hicksville, NY, USA). (Fig. 3) The changes on surface morphology of implant-abutment used in the study were observed using scanning electron microscopy(SEM).

Fig. 2. a) Cyclic loading test of implant assembly with metal capping by Instron test machine based on ISO 14801:2007. b) Schematic drawing of the cyclic loading test in this study

a) 

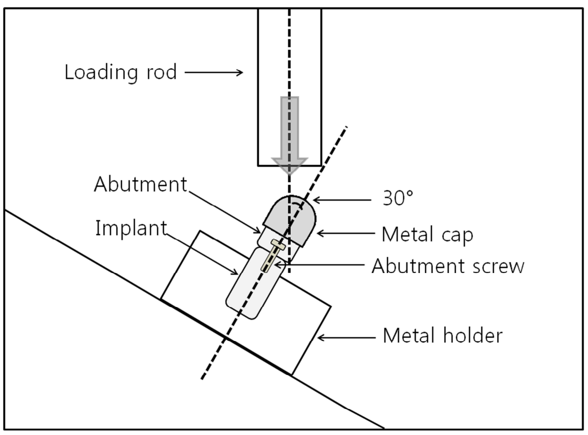
b) 

Fig. 3. Digital torque gauge (MGT50)

Statistical Analysis

The data were analyzed using SPSS 22.0 for Windows (IBM, New York, USA). To compare RTVs in group Ti-Ti and Zr+Ti-Ti, independent t-test was conducted.

Results

For all specimens, there was no screw loosening identified by visual or tactile inspection during cyclic loading or after loading. Table 2 lists the preload and postload reverse torque values (RTV), mean values, and the RT difference. (Fig.4) In Table 2, negative reverse torque difference were shown from all specimens, indicating loaded screws required less loosening torque. Group Ti-Ti had the lower mean RTD value (-7.57±1.61 Ncm) than Group Zr+Ti-Ti (-7.64±1.18 Ncm). Statistical analysis by the independent t-test revealed that RT difference of both groups were not significantly different from each other (P>0.05). (Table 3)

Table 2. Test groups with the preload and postload reverse torque values (RTV), mean values, and the RT difference

Group	Specimen No.	Pre-load RTV (Ncm)	mean Pre-load RTV (Ncm)	Post-load RTV (Ncm)	mean Post-load RTV (Ncm)	RT difference (Ncm)
Ti-Ti	1	26.5	26	17	18.43	-9.5
	2	25.5		18		-7.5
	3	24		20		-5
	4	27		18.5		-8.5
	5	27		19.5		-7.5
	6	25		19		-6
	7	26		17		-9
Zr+Ti -Ti	1	25	25.14	19	17.50	-6
	2	26		18		-8
	3	25.5		16		-9.5
	4	26		18.5		-7.5
	5	24		17.5		-6.5
	6	24.5		17		-7.5
	7	25		16.5		-8.5

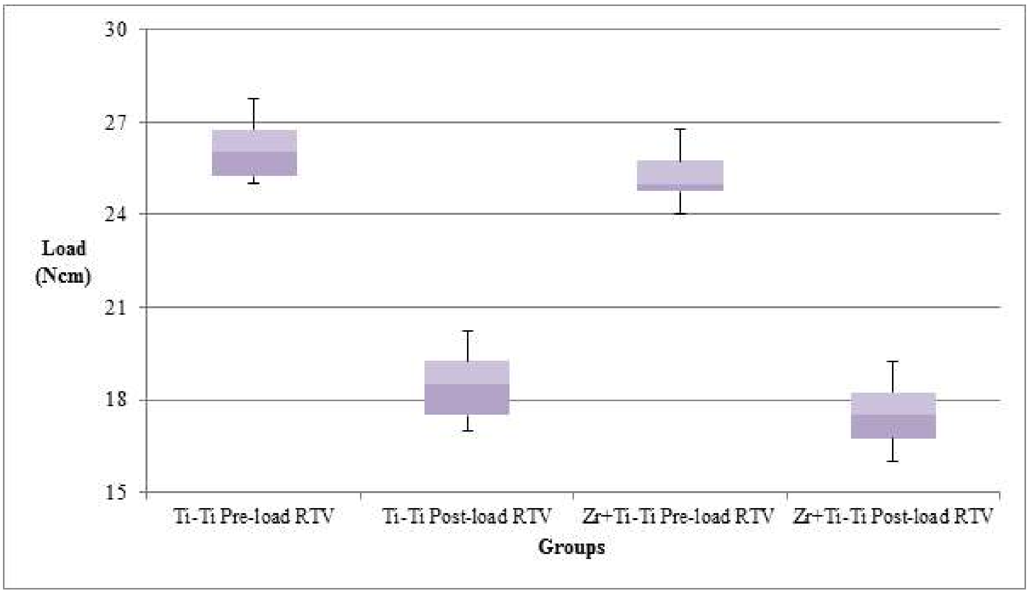


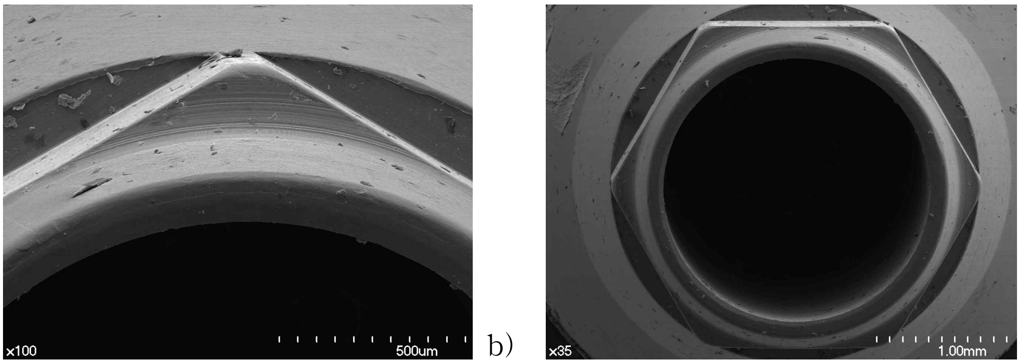
Fig.4 Boxplot of Test groups with the preload and postload reverse torque values

Table 3. t-test of RT difference (Ncm)

Group	N	Mean	SD
Ti-Ti	7	-7.57	1.61
Zr+Ti-Ti	7	-7.64	1.18
t=.094	df=12	P=0.926	

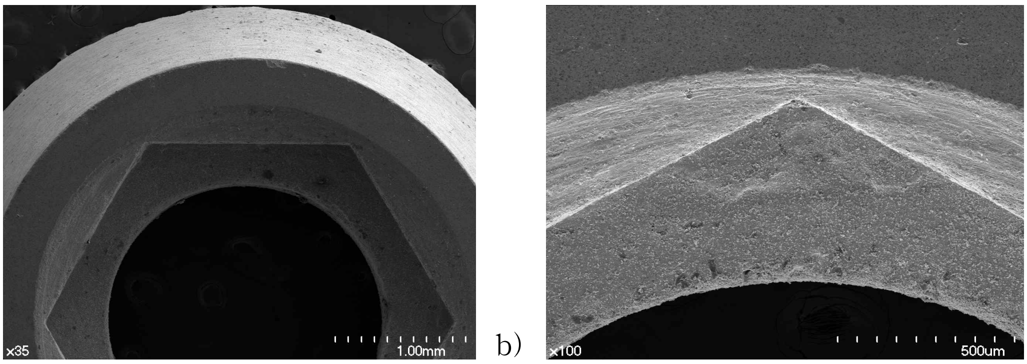
All specimens were observed using SEM at a high magnification. SEM analysis revealed that both group Ti-Ti and Zr+Ti-Ti had clean wear surface on abutments and showed no burnshing or scuffing of surfaces. No abnormal damage or wear due to cyclic loading was not observed on abutment surface in all groups. (Fig. 5, 6)

Fig. 5 SEM micrographs of surfaces of group Ti-Ti abutment (original magnification X35, X100)



a) b)

Fig. 6 SEM micrographs comparing surfaces of group Zr+Ti-Ti abutment (original magnification X35, X100)



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Discussion

A common complication of single or multiple implant restoration is the screw loosening.[10] Screw loosening occasionally may require mechanical repairs. Currently, there are insufficient studies on abutment screw loosening in zirconia abutments with secondary titanium insert. In this study, the effect of cyclic loading on screw loosening was evaluated by examining the changes in RTVs in group Ti-Ti and Zr+Ti-Ti.

From this investigation, RTVs were less than torque used for initial placement for before and after cyclic loading in both groups. Before cyclic loading, despite the screws were tightened to 35Ncm, the initial preload were lower than 35Ncm. Initial preload was approximately 25.7% lower in group Ti-Ti and approximately 28.7% lower in group Zr+Ti-Ti compared to the applied torque. After cyclic loading, all sample groups showed decreased RTVs compared to measurement recorded before cyclic loading. For both groups, post-load RTVs were approximately 29.1% and 30.4% lower compared to pre-load RTVs. RTD values were higher in group Zr+Ti-Ti (-7.64±1.18 Ncm) than group Ti-Ti (-7.57±1.61 Ncm).

Stability of implant-abutment depending on type of connection has been investigated in many former studies. In several studies, more screw loosening were reported for externally connected implant system than internally connected implant system.[11] In this study, a separate titanium insert was mounted on the implant together with zirconium abutment and assembled by one abutment screw. This titanium insert has both external and internal structure to fit both external zirconia abutment and internal titanium implant. It may induced that external structure of titanium insert had influenced on the decrease of post-load RTV values compared to internally connected titanium implant.

From analyzed result, both groups were not significantly different from each other, indicating stability of the implant-abutment connection of internally connected zirconia abutment with titanium insert is similar to that of internally connected titanium abutment. However, to be a true alternative of widely used titanium abutments, the mechanical qualities of reinforced zirconia abutment with titanium insert should be equal or better. To ensure clinical result of two piece zirconia abutment, additional experiments and studies are needed.

In this study, the load was set to normal mastication of premolar region (300N). One million cycles of loads were applied to the implant-abutment assemblies in this study. However, simulating the clinical setting involves multiple factors, such as oral environment and variable masticating loads and patterns. Additional experiments with more realistic loading conditions would be necessary. Moreover, to obtain more accurate results, greater sample size should be obtained.

Conclusion

In this study, removal torque values (RTVs) of two groups, internally connected one piece titanium abutment and internally connected two piece zirconia abutment with titanium insert were compared before and after dynamic cyclic loading simulation. The following conclusions were withdrawn from this study.: There were no significant differences in RTVs between both groups. The result of this study indicates that the internally connected zirconia implant abutment reinforced with a titanium insert shows similar resistance to screw loosening under cyclic loading compared to internally connected titanium implant abutment. Additional and further studies are required to ensure clinical result of two piece zirconia abutment.

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국문초록

타이타늄 인서트에 의해 강화된 내부연결형 지르코니아 임플란트 지대주의 나사 풀림력 연구

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목적

지르코니아 지대주는 매식체와의 연결부위가 파절에 약하다는 단점을 보인다. 이를 보완하기 위해 연결부위를 타이타늄 인서트로 강화된 지르코니아 지대주가 개발되었다. 본 연구에서는 타이타늄 인서트에 의해 강화된 지르코니아 지대주와 전체가 타이타늄으로 이루어진 두 가지 내부연결형 지대주의 반복하중에 대한 나사풀림력을 비교하여 타이타늄 인서트의 강화 효과를 분석하는 것이 목적이다.

방법

타이타늄 지대주와 타이타늄 인서트로 강화된 지르코니아 지대주를 각각 7개씩 준비하였고, 이를 14개의 동일한 내부연결형 매식체에 연결한 후, 그룹 Ti-Ti와 Zr+Ti-Ti로 분류하였다. 디지털 토크게이지를 사용하여 일정한 토크, 35Ncm의 토크로 연결한 후 반복하중 시험 전후의 나사풀림력을 측정하였다. 반복하중은 동적 만능재료시험기인 Inston

(E300, Instron, Canton, MA, USA)을 시용하여 시편의 장축과 30도 각도를 이루도록 적용하였다. 준비된 시편에 하중의 크기는 300N, 적용속도는 15Hz, 100만번의 반복 하중이 가해졌다.

결과

1) 그룹 Ti-Ti와 그룹 Zr+Ti-Ti의 반복 하중 시험 전의 평균 나사풀림력은 각각 26±0.87Ncm, 25.14±0.75Ncm이고 반복하중 시험 후의 평균 나사풀림력은 각각 18.43±1.17Ncm, 17.50±1.08Ncm이었다.
2) 그룹 Ti-Ti와 그룹 Zr+Ti-Ti의 반복하중 시험 전후의 평균 나사풀림력 차이는 각각 -7.57±1.61 Ncm, -7.64±1.18 Ncm으로 서로 통계적으로 유의미한 차이를 보이지 않았다. ($P>0.05$).
3) 모든 시편은 반복 하중 시험 도중 또는 시험 후 나사풀림현상이나 파절현상을 보이지 않았다.

결론

본 실험 결과, 타이타늄 인서트로 강화된 지르코니아 지대주는 전체 타이타늄 지대주와 비슷한 나사풀림력에 대한 저항성을 보였다.

주요어 : 임플란트 지대주, 반복하중, 지르코니아, 타이타늄 인서트, 나사풀림력
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