새로운 타이타늄 구성요소를 사용한 내부연결 임플란트용 지르코니아 지대주의 동적하중 후 나사 제거력

이주희*
울산대학교 의과대학 서울아산병원 치과보철과

Removal torque of a two-piece zirconia abutment with a novel titanium component in an internal connection implant system after dynamic cyclic loading

Joo-Hee Lee*
Department of Prosthodontics, College of Medicine, University of Ulsan, Asan Medical Center, Seoul, Republic of Korea

Purpose: The aim of this study was to evaluate screw removal torque of the two-piece zirconia abutment with the novel titanium component compared to the conventional one-piece titanium abutment in the internal connection implant before and after dynamic cyclic loading. **Materials and methods:** Two types of the abutment assemblies with internal connection were prepared and divided into the groups; titanium abutment-titanium abutment screw assemblies as control, and zirconia abutment-titanium socket-titanium abutment screw assemblies as experimental group. A total of 12 abutments and implants were used of six assemblies each group. Each assembly was tightened to 30 Ncm. A cyclic load of 300 N at an angle of 30 degrees in reference to the loading axis was applied until one million cycles or failure. The removal torque values (RTVs) of the abutment screws were measured with a digital torque gauge before and after cyclic loading. The RTVs of the pre load and post load were analyzed with t-test, and P-values < .05 were considered statistically significant. **Results:** The assemblies of both groups survived all after the dynamic cyclic loading test without screw loosening. The statistically significant differences were found between the mean RTVs before and after the cyclic loading in both groups ($P < .05$). The RTV differences for the control and the experimental group were -7.25 ± 1.50 Ncm and -7.33 ± 0.93 Ncm, respectively. Statistical analysis revealed that the RTV differences in both groups were not significantly different from each other ($P > .05$). **Conclusion:** Within the limitation of this study, the two-piece zirconia abutment with the titanium component did not show a significant RTV difference of the abutment screw compared to the titanium abutment after dynamic cyclic loading. *(J Korean Acad Prosthodont 2017;55:151-5)*

Keywords: Abutment screw; Dynamic loading; Zirconia; Titanium; Removal torque

Introduction

Various ceramic materials have been replacing metals in prosthetic fields, including crowns, fixed partial dentures and implant restorations, because of their biocompatibility and optical qualities. When these ceramics were used, the soft tissue appeared more similar to the natural color and the bluish appearance of cervical soft tissues as encountered with metal restorations would be avoided.[1] As the esthetic demands of dental patients increase, attempts to use zirconia materials for fabricating monolithic crowns in the posterior region have been widely accepted because of their mechanical properties and biocompatibility. However, when selecting implant abutments for the posterior region, zirconia abutments were not preferred over titanium abutments.[2-4] When using internal connection zirconia abutments, the implant-abutment connection area was vulnerable to cracking or fracture.[5] The development of various zirconia

*Corresponding Author: Joo-Hee Lee
Department of Prosthodontics, College of Medicine, University of Ulsan, Asan Medical Center, 88 Olympic-ro 43 gil, Songpa-gu, Seoul 05505, Republic of Korea
+82 (0)2 3010 5803: e-mail, ljhl11911@hanmail.net
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abutments for internal connection type implants was a major breakthrough in overcoming this weak joint between the abutment and the implant connections. Nowadays, even in-office milling of customizable zirconia abutments is available using a simple cementation process with a secondary titanium component. Because of this practicality of two-piece zirconia abutments, many *in vitro* studies have been performed. In one study, superior strength, compared to one-piece zirconia abutment, was achieved by means of an internal connection via a secondary metallic component.[6]

Another component can be placed between an abutment and the implant. There have mainly been two ways to connect these secondary components to zirconia abutments; using friction fitting and using bonding with luting cement.[7] The novel titanium socket used in this study had dual hexes; a hex which went into an internal connection implant fixture, and an opposite hex which connected to the zirconia abutment. The zirconia abutment, titanium socket and the implant fixture were all fixated with a single abutment screw without cementation or a friction fitting process.[8] This type of novel abutment assembly design offers many advantages over other types of two-piece zirconia abutments. Since the abutment and the secondary component are screw retained, a cementing procedure is not necessary. Screw loosening was a well-known complication in prosthetic restoration.[9] It might lead to a component failure that demanded a more extensive repair.[10,11] There are several factors that can play critical roles in screw joint stability, including the preload and screw geometry. Screw joint preloading, an important mechanical factor in preventing screw loosening, accumulated in the abutment screw as a product of screw tightening.[12] When the preload falls below a critical level, joint stability may be compromised, and the screw joint may fail.[13,14]

Because of the unique dual hex design connecting both the implant fixture and the zirconia abutment, screw loosening is of utmost importance in abutment and prosthetic survival. However, the author was unable to identify any studies evaluating abutment screw loosening and preload reduction on two-piece zirconia abutments with titanium sockets. Therefore, the purpose of this study was to evaluate abutment screw removal torque of the two-piece zirconia abutments with titanium sockets compared to one-piece titanium abutments in internal connection systems by measuring torque values before and after cyclic loading.

Materials and Methods

Different types of internal connection implant abutments with anti-rotational structure were selected and divided into two groups; internal connection titanium abutments (Dual Abutment, Dentium Co., Ltd., Seoul, Korea) and titanium abutment screws for control group, and external connection zirconia abutments (ZirAce External, Acucera, Inc., Seoul, Korea) with titanium sockets (Z socket Dentium Regular, Osung MND Co., Ltd., Seoul, Korea) and titanium abutment screws for experimental group (Fig. 1). In the experimental group, the titanium sockets were 4.1 mm in width and had dual hex design; a hex which connected into the implant and an opposite hex which connected to the zirconia abutment. The zirconia abutment, the titanium socket and the implant were all fixated with the single screw.

12 internal connection 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 prepared. The sample size of the abutments was 6 for each group. Assembly preparation and testing setup were performed basically according to the ISO 14801:2007 protocol. Using the torque gauge, 30 Ncm was applied for the assemblies of both groups. A digital torque gauge (MTT03-12, Mark-10 Co., Hicksville, NY, USA) was used to investigate torque values applied to remove the abutment screws. The initial pre-reverse torque value (RTV) was defined as the

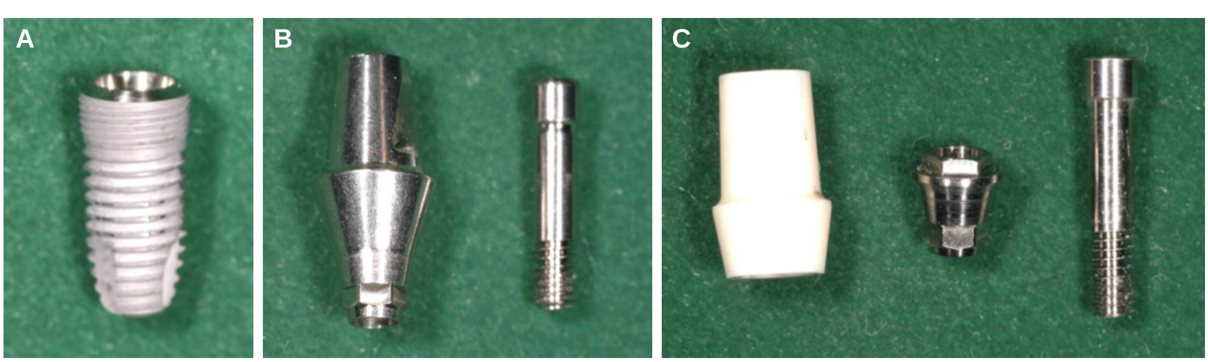

Fig. 1. The implant/abutment assemblies used in the study, (A) internal connection type titanium implant, (B) control group: internally connected titanium abutment with a titanium screw, (C) experimental group: externally connected zirconia abutment with a titanium socket and a titanium screw.

RTV measured after tightening with the recommended torque before dynamic cyclic load. The RTV following cyclic loading was also measured and defined as post-RTV. The effect of cyclic loading was evaluated by examining the change in the RTVs. Cyclic loading was applied by a universal test machine (8871, Instron, Canton, MA, USA). The assemblies were tightened in the metal holder, which was inclined at a 30 degrees angle in reference to the loading axis. For all assemblies, loads of 300 N were applied until one million cycles, which represented 40 months of simulated function.[15] After one million cycles of the loading, the assembly was measured for post-RTV using the digital torque gauge.

The data were analyzed using SPSS 12.0 for Windows (IBM, New York, NY, USA). Data normality was tested using the Kolmogorov-Smirnov test, which revealed the possibility of parametric statistical analyses. Paired t-tests were used to compare the RTVs before and after the dynamic cyclic loading of each group. To compare the RTV differences between the groups, independent t-tests were conducted. A difference was considered significant when $P < .05$.

Results

The assemblies of both groups survived all after the dynamic cyclic loading test without screw loosening. Table 1 shows the pre load and post load RTVs and the RTV differences. As shown in Table 1, means of the RTVs after repeated load stress tended to be smaller than the values before the cyclic loading. The means and standard deviations of the pre- and post-loading RTVs of the control were 25.92 ± 0.58 Ncm and 18.67 ± 1.13 Ncm, respectively. The means and standard deviations of the pre- and post-loading RTVs of the experimental group were 25.08 ± 0.74 Ncm and 17.75 ± 0.88 Ncm, respectively. The statistically significant differences were found in the mean RTVs before and after the cyclic loading of both groups ($P < .05$). The control group showed a lower mean RTV difference value (-7.25 ± 1.50 Ncm) than the experimental group (-7.33 ± 0.93 Ncm). Statistical analysis revealed, however, that the RTV differences between the groups were not significantly different ($P > .05$).

Discussion

In this study, a constant stress test was used, which has been used to simulate masticatory function in *in vitro* studies.[16] As for the cyclic loading, there were articles, in which various loads were applied at 50 - 450 N.[14,15,17-19] A dynamic load of 300 N was used in this study because 300 N represents the maximal physiological occlusal forces on the anterior teeth. The evaluations for screw loosening were reported by measuring RTVs before and after cyclic loading.[14,18] One million cycles were used in several studies, in which load was applied to the specimen 1.0×10^6 cycles which represented 40 months of simulated function.[14,18,19] Within the limitations of this *in vitro* setting, both titanium abutments and two-piece zirconia abutments with a titanium socket survived cyclic loading without screw loosening. The results implied that the screw retained two-piece zirconia abutment assembly with the titanium socket could successfully withstand dynamic functional loading when compared to the conventional titanium abutments.

More screw loosening has been reported for externally connected implant systems than for internally connected implant systems.[20] In the study, the separate titanium socket was mounted on the implant together with the zirconium abutment and fixed by one abutment screw. When the one-piece zirconia abutments were compared to the one-piece titanium abutments in an internal connection system, the one-piece zirconia abutments were less fracture-resistant than the one-piece titanium abutments.[21] This may be due to high stress concentration at the internal connection part of the zirconia abutment and the brittle characteristics of zirconia.

Various designs of two-piece zirconia abutments have been tested *in vitro*, and all of these studies have reported consistent results where two-piece titanium reinforced zirconia abutments had higher fracture and fatigue resistance than one-piece zirconia abutments, regardless of differences in design.[20-23] The two-piece zirconia abutments also showed competitive results when compared to conventional titanium abutments.[22] A common complication of single or multiple implant restoration is screw loosening.[23]

Screw loosening may occasionally require mechanical repairs. Currently, there is a lack of studies with regard to abutment screw loosening in zirconia abutments with a secondary titanium component. In this study, the effect of cyclic loading on screw removal was evaluated by examining the changes in RTVs in the groups. Abnormal damage or wear due to cyclic loading was not observed on the abutment surfaces in either group. From this investigation, it was

Table 1. Pre- and post-cyclic load reverse torque values (RTVs), and RTV differences

Group	Pre-cyclic load RTV (Ncm)	Post-cyclic load RTV (Ncm)	RTV difference (Ncm)
Control	25.92 ± 0.58	18.67 ± 1.13	-7.25 ± 1.50
Experimental	25.08 ± 0.74	17.75 ± 0.88	-7.33 ± 0.93

found that the RTVs were less than the torque used for the initial placement before and after cyclic loading in both groups. Before cyclic loading, despite the fact that the screws were tightened to 30 Ncm, the initial preloads were lower than 30 Ncm. After cyclic loading, both sample groups showed decreased RTVs compared to the measurements recorded before the cyclic loading. Based on the analyzed results, the RTV differences between the groups were not significantly different, which indicating that the implant-abutment connection with the zirconia abutment and the titanium socket would not be harmful to the stability of the internally connected implant. However, an additional experiment using larger sample size is necessary to ensure the stability. Further studies about resistance to persistent thermal stress and clinical evaluations will be needed.

Conclusion

In this study, the titanium socket had dual hex design needed to fit both the external connection zirconia abutment and the internal connection titanium implant. The means of RTVs after repeated loading were smaller than the RTVs before the cyclic loading. The RTVs before and after the cyclic loading showed statistically significant differences of both groups. However, there were not statically significant differences in the RTV differences between the groups.

ORCID

Joo-Hee Lee *http://orcid.org/0000-0002-7907-3098*

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새로운 타이타늄 구성요소를 사용한 내부연결 임플란트용 지르코니아 지대주의 동적하중 후 나사 제거력

이주희*

울산대학교 의과대학 서울아산병원 치과보철과

목적: 이 연구의 목적은 새로운 타이타늄 구성요소를 가진 지르코니아 지대주의 나사 제거력의 변화에 대해 알아보는 것이다. 내부연결 임플란트를 위한 새로운 지르코니아 지대주의 동적하중 후 지대주 나사의 제거력을 기존의 타이타늄 지대주와 비교하여 분석하였다.

재료 및 방법: 내측연결 임플란트와 타이타늄 지대주, 타이타늄 구성요소를 가진 지르코니아 지대주를 준비하였다. 12개의 내부연결형 임플란트에 6개의 타이타늄 지대주를 연결하고(대조군), 6개의 타이타늄 구성요소를 가진 지르코니아 지대주(실험군)를 30 Ncm의 토크로 연결한 후 동적하중 전후의 나사 제거력을 측정하였다. 동적 만능재료시험기를 사용하여 연결체의 장축과 30도 각도를 이루도록 하고 300 N 하중크기로 100만번의 하중이 가해졌다. 동적하중 전후의 지대주 나사 제거력을 t검정을 통해 신뢰구간 95%로 통계적 유의성을 검증하였다.

결과: 두 그룹 모두에서 동적하중 후 나사 풀림을 보이지 않았다. 동적 하중 전후의 나사 제거력은 두 그룹 모두에서 통계적으로 유의한 차이가 있게 나타났다($P < .05$). 동적 하중 전후의 나사 제거력 차이는 대조군에서 -7.25 ± 1.50 Ncm, 실험군에서 -7.33 ± 0.93 Ncm 로 나타났다. 통계분석 결과 두 군간에 나사 제거력 차이에서는 유의한 차이를 보이지 않았다($P > .05$).

결론: 이 실험의 결과에 한하여 타이타늄 구성요소를 사용한 지르코니아 지대주의 동적하중 후 지대주 나사 제거력의 변화는 타이타늄 지대주와 통계학적으로 유의한 차이를 보이지 않았다. *(대한치과보철학회지 2017;55:151-5)*

주요단어: 지대주나사; 동적하중; 지르코니아; 타이타늄; 나사 제거력

*교신저자: 이주희
05505 서울 송파구 올림픽로 43길 88
울산대학교 의과대학 서울아산병원 치과보철과
02 3010 5803: e-mail, ljhl11911@hanmail.net
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