전치부 지르코니아 지대주의 축벽 두께

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Axial wall thickness of zirconia abutment in anterior region

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Purpose: The purpose of this study was to evaluate the proper axial thickness of zirconia abutment applied to implant in the anterior region. **Materials and methods:** Zirconia abutments were prepared at different axial wall thickness by processing pre-sintered zirconia blocks via CAD/CAM to obtain equal specimens. The abutments were each produced with a thickness of 0.5 mm (Group 1), 0.8 mm (Group 2), 1.2 mm (Group 3), or 1.5 mm (Group 4). The implant used in this study was a external connection type one (US, Osstem, Pussan, Korea) product and the zirconia abutment was prepared via replication of a cemented abutment. The crowns were prepared via CAM/CAM with a thickness of 1.5 mm and were cemented to the abutments using RelyX™ UniCem cement. A universal testing machine was used to apply load at 30 degrees and measure fracture strength of the zirconia abutment. **Results:** Fracture strength of the abutments for Group 1, Group 2, Group 3, and Group 4 were 236.00 ± 67.55 N, 599.00 ± 15.80 N, 588.20 ± 33.18 N, and 97.83 ± 98.13 N, respectively. Group 1 showed a significantly lower value, as compared to the other groups (independent Mann-Whitney U-test. $P<.05$). No significant differences were detected among Group 2, Group 3, and Group 4 (independent Mann-Whitney U-test. $P>.05$). **Conclusion:** Zirconia abutment requires optimal thickness for fracture resistance. Within the limitation of this study, > 0.8 mm thickness is recommended for zirconia abutment in anterior implants. *(J Korean Acad Prosthodont 2015;53:345-51)*

Key words: Zirconia abutment; Fracture strength; Axial wall thickness

Introduction

Aesthetic restoration of the maxillary anterior teeth using implant is a challenge to clinicians. Methods and materials for the fabrication of abutment have evolved for better aesthetic results of the anterior region. Materials used for implant abutments are titanium alloy, gold alloy, ceramics and the various methods introduced include abutments of natural tooth root form, production of individual abutments, and production of ceramic abutments.[1-4] However, unaesthetic results occur frequently in the maxillary anterior region with implant restoration as the abutment below the prosthetic is exposed or the metal color is reflected in the gingiva due to the thin labial bone and gingiva.[5-8] Application of ceramic abutments are attempted to overcome these problems. Ceramic abutments allow light transmission on the cervical area preventing the blue or grayish discoloration of the cervical soft tissue caused by metal abutments.[8,9] Moreover, additional advantages were obtained with the use of ceramic abutments as it promotes biological adhesion with gingiva,[1,10] and minimizes Galvanic corrosion.

The first ceramic abutment used was the CerAdapt (CerAdapt, Nobel Biocare, Gothenburg, Sweden) in 1993,[3,9,11] an aesthetically favored alumina abutment. However, its hardness makes it difficult to

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modify its form and occasionally leads to fracture due to its low fracture toughness resulting in limited use in single tooth restoration. Abutments using zirconia with high fracture toughness and biocompatibility while maintaining esthetic, are developed to overcome these disadvantages.[12]

Zirconia is a general term for zirconium oxide (ZnO_2) that has chemical and volumetric stability, high flexural strength, and fracture strength, as compared to conventional ceramics. However, its high strength made it difficult for processing and prevented its use in ceramic restoration. Recently methods for cutting and processing presintered-zirconia blocks using the computer-aided design/manufacturing (CAD/CAM) system have been developed in the fabrication of abutments, as well as dental restorations.[13,14]

Ceramic abutments are fabricated not only as external but more especially as internal connection type abutments, since the part connected to the inside of the implant is too thin and recognized as a fragile area.[15] Zirconia abutment fracture is mainly found at the labial cervical area where the thickness is reduced due to the lingual angulation of abutment caused by the thinness of the internal connection area and excessive preparation or thin lateral walls. The thickness for zirconia abutment is typically estimated as 0.3 - 0.6 mm and 0.5 - 0.7 mm, but there is no clear evidence in the literature.

Therefore, we evaluated the axial thickness of the zirconia abutment that can be applied for the external connection type implant restoration via measurement and analysis of fracture strength of the zirconia specimens.

Materials and Methods

1. Production of zirconia abutment and crown

The implant fixture was the external connection type implant (US, Osstem, Pussan, Korea) product of Osstem co. and the zirconia abutment was prepared via replication of the cemented abutment (CAR525, 4.0 mm D $\times$ 2 mm GH $\times$ 5.5 mm H, Osstem, Pusan, Korea). The zirconia abutment was made by increasing the thickness of the abutment lateral wall, and the emergence profile was

increased with increased axial wall thickness to maintain a fixed form of the finish line (Fig. 1).

The Zirkonzhan CAD/CAM system was used for the production of abutments to create specimens of equal form and thickness for each group. The zirconia abutment was designed on consideration of shrinkage after sintering, and prepared by processing pre-sintered zirconia blocks(Transblock, Zirkonzhan, Gais/South Tyrol, Italy) (Fig. 2).

Four different axial wall thickness zirconia abutments were produced (Fig. 3) i.e., 0.5, 0.8, 1.2, and 1.5 mm. Five abutments were made for each thickness with a total of 20 zirconia abutments. Each abutment was sorted to Group 1 (0.5 mm), Group 2 (0.8 mm), Group 3 (1.2 mm), and Group 4 (1.5 mm), based on its lateral wall thickness. Zirconia crowns were made for each abutment. The crowns were produced using the CAD/CAM system by scanning the zirconia abutments. Five per group with a total of 20 crowns were created with a thickness of 1.5 mm (Fig. 3). Prettau was the zirconia block (Prettau, Zirkonzhan, Gais/South Tyrol, Italy) used for the crowns .
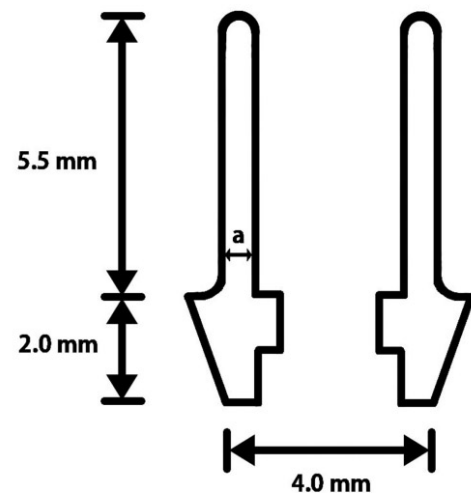

Fig. 1. Abutment design used in the study (a: thickness of axial wall of abutment).
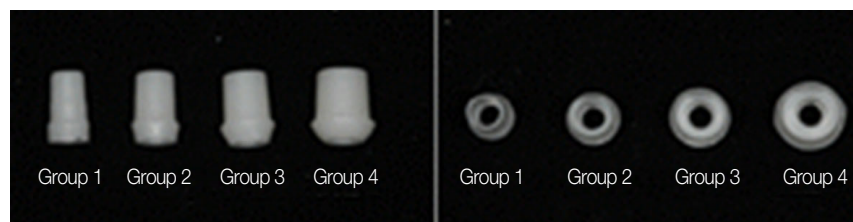

Fig. 2. Zirconia abutment for this experiment. (A) frontal view, (B) incisal view.
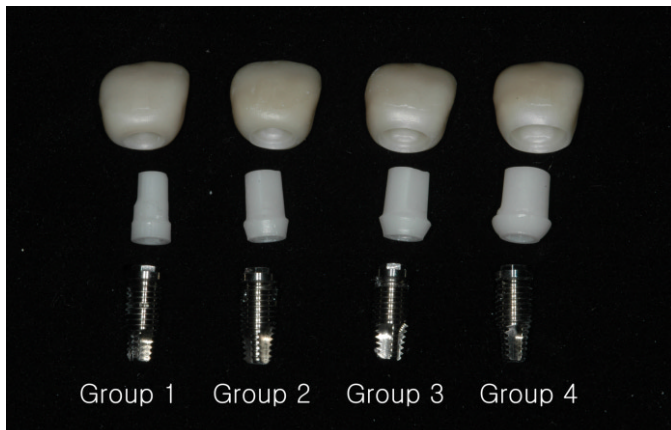
Fig. 3. Implant, zirconia abutment and zirconia crown used in the study.

Fig. 4. Measurement of fracture strength. The load was applied 3mm below the incisal edge at an angle of 30°.

The zirconia abutments were connected to the implant using the abutment screw and a tightening force of 20 N was applied with a torque driver. After connecting the abutment, a 2 - 2.5 mm area of the screw hole was filled with 0.5 mm of silicon (Easyseal, Megagen, Gyeongbuk, Korea) and Caviton (Caviton, GC Corp, Tokyo, Japan) and with light-curing resin (Spectrum, Dentsply, Konstanz, Germany) for the remaining space. The abutment screw holes were filled and polymerized with light curing unit; and zirconia crowns were cemented to the abutment using resin cement (RelyX™ UniCem, 3M ESPE AG, Seefeld, Germany).

2. Measurement of zirconia abutment fracture strength

A universal testing machine (EXH 750, Lloyd instrument Ltd, Fareham Hants, England) was used to measure fracture strength of the zirconia abutment. A supporting device connected the implant-abutment-crown complex to the tester, as it was designed to apply load at 30 degrees to the long axis of the crown (Fig. 4). Subsequently, it was fixed such that the load was applied to the 3 mm lingual area below the incisal surface (Fig. 4). The amount of load was measured at a rate of 0.5 mm/min until the specimens were fractured.
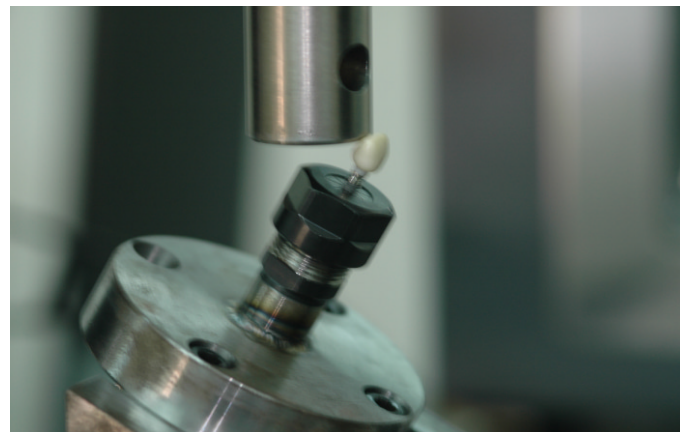
3. Statistics

IBM SPSS (IBM SPSS Statistics for windows, version 20.0, Armonk, NY, USA) was used for statistical analysis. The Kruskal-Wallis test was performed to compare group-wise statistical significance. Independent Mann-Whitney U-test was used for the post-hoc test when significant differences were found among the groups. The level of significance was 0.05.

Results

1. Zirconia abutment fracture pattern to load

The measurement of fracture strength for each group was shown on the following graphs (Fig. 5). Each graph showed the fracture pattern for each group over time. All groups showed a certain change in the pattern to load. A crack of the zirconia abutment appeared at point a, which shows a gradual decrease in applied load, and a deformation of the abutment screw and implant appeared at point b, which shows a sudden decrease in load. At the highest value, point c, the crown cemented to the zirconia abutment was separated from the
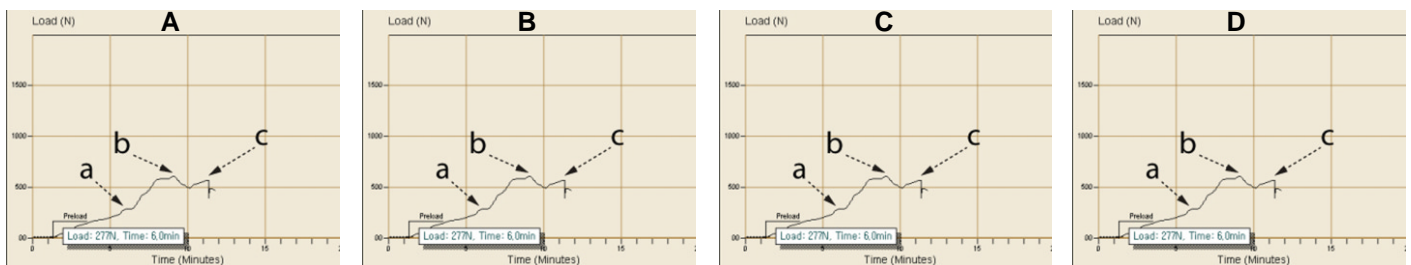

Fig. 5. Fracture aspect of zirconia abutment according to static loading. (A) Group 1: axial wall thickness of 0.5 mm; (B) Group 2: axial wall thickness of 0.8 mm; (C) Group 3: axial wall thickness of 1.2 mm: (D) Group 4: axial wall thickness of 1.5 mm.

Table 1. Mean fracture strength of zirconia abutment

Group	Fracture strength (N)	
1	236.00 ± 67.55	a
2	599.00 ± 15.80	b
3	588.20 ± 33.18	b
4	597.83 ± 98.13	b

* A different alphabet denotes statistically significant difference.

implant. None of the groups showed a fracture of the crown. All fractures were observed at the lateral wall area below the abutment screw.

2. Zirconia fracture strength

The fracture strength of the abutments of Group 1, Group 2, Group 3, and Group 4 was 236.00 ± 67.55 N, 599.00 ± 15.80 N, 588.20 ± 33.18 N, and 597.83 ± 98.13 N, respectively (Table 1).

A statistical difference was found between the 4 groups (Kruskal-Wallis test, P<.05). Group 1 showed a significantly lower value, as compared to the other groups (independent Mann-Whitney U-test. P<.05). No significant differences were shown among Group 2, Group 3, and Group 4 (independent Mann-Whitney U-test. P>.05).

Discussion

In this study, zirconia abutments were produced with a lateral wall thickness of 0.5 mm, 0.8 mm, 1.2 mm, and 1.5 mm. Prior to the experiment, an abutment with a lateral wall thickness of 0.25 mm was planned but was too thin to be processed with a pre-sintered zirconia block. Group 1 had the fracture strength of 236.00 ± 67.55 N that was significantly lower, as compared to Group 2, Group 3, and Group 4. There is no significant difference among Group 2, Group 3, and Group 4. Based on other studies reporting the average anterior biting force of 60 - 200 N with a maximum force of 90 - 370 N,[12,16] 0.5 mm thick zirconia abutments are not stable at anterior occlusal force since the fracture strength is lower than the maximum biting force. However, abutments with a thickness of ≥ 0.8 mm show the fracture strength higher than maximum occlusal force. This indicates that the zirconia lateral wall thickness should be at least 0.8 mm in order for the abutments to be applied at the anterior teeth.

Thicker abutments are expected to have a higher fracture strength, but we showed that fracture strength of zirconia abutments with a thickness of > 0.8 mm did not increase significantly with increased thickness. Fracture strength showed a decrease at 1.2 mm thickness, and fracture strength at 1.5 mm was higher than at 1.2 mm, but lower than at 0.8 mm. Similar results were reported by Adatia *et al*.[15] In

their study, internal connection type zirconia abutments were prepared using a diamond bur with a margin of 0 mm (control group), 0.5 mm, and 1 mm. The group with a 0.5 mm chamfer margin showed the highest fracture strength and the margin-free zirconia abutment showed the lowest fracture strength, although the lateral wall thickness of the abutment was not measured accurately as compared to our study. These results seem to indicate the possibility that optimal thickness could produce high fracture strength.

The strength-load graph that represents the fracture pattern of the abutment starting from when the load is applied, shows that the load does not constantly increase. A pattern of a decrease after an increase was observed 2 - 3 times. Load at a rate of 0.5 mm/min resulted in a gradual increase in fracture strength. However, we observed a sudden decrease in load for 5 - 10 seconds. Some factors for the decrease in fracture strength may be fracture of the abutment, deformation and fracture of the screw, and deformation and fracture of the implant.[15] Deformation of the screw and implant would occur after a fracture of the abutment. Even though the screw may deform within its range of elasticity, since the load does not decrease without a fracture in the abutment, the first decrease (point a) in load would be due to a crack from the abutment. The following decrease (point b) in load was observed as a deformation of the screw or implant. A displacement of the zirconia crown-cemented abutment was observed visually, and the load started to increase again even after a certain time of displacement. Load was continually applied even after the deformation of the implant and screw, in order to observe the final failure pattern. A fracture pattern in which the crown cemented to the abutment was separated from the implant, was observed on the final load decrease (point c). However, since the load direction and the point of load application changed with the displacement of the zirconia crown and abutment caused by the deformation of the screw and implant, it may not be associated with the fracture strength of zirconia.

The fracture pattern of the zirconia abutment was formed at the cervical area of the abutment close to the contact surface of the abutment and implant. Att *et al*.[6] and Yildirim *et al*.[16] reported that the cervical part is an area concentrated with high stress by tightening the abutment screw. The area concentrated with stress as load increases is also the cervical part of the abutment. Previous studies reported that fracture was observed at the cervical area of the abutment adjacent to the abutment screw and implant platform.[6,16] Yildirim *et al*. reported that 40% of zirconia abutments were fractured before the fracture of the all-ceramic crown or the deformation of the gold screw with an Empress crown installed on a zirconia abutment.[16] Similar to previous studies, abutment fracture was the first to occur in this study. This indicated that the abutment is where stress is concentrated due to the lever phenomenon and

takes on the highest load. According to the study by Adatia *et al*.[15] on internal connection type zirconia abutment, fracture was observed in all groups showing that the area of the abutment connecting to the internal part of the implant is where stress is concentrated, as compared to the other areas.

The fracture strength of the zirconia abutment varies based on the connection type with implant, fabrication method, and load applying methods. Adatia *et al*.[15] reported fracture strength of 429 - 576 N for the internal connection type zirconia abutment; Butz *et al*.[17] reported that the fracture strength of an abutment of titanium based zirconia was 281 N; and Yildirim *et al*.[16] reported fracture strength of 788.1 N for the external connection type zirconia abutment. The zirconia abutment prepared in this study was identical to the external hexagon abutment used by Yildirim *et al*. Based on the results of the 2 studies, the value of fracture strength was higher than the other studies. Yildirim *et al*. and our research group studied the crown-abutment-implant complex after crown cementation, whereas Adatia *et al*. used internal connection type zirconia abutment without making a crown. Despite these differences, the results indicated that the external connection type abutment, which has ease in thickness control, has the higher fracture strength than the internal connection type abutment. Likewise, Glauser *et al*.[12] reported a fracture strength of 276 N for the external connection type zirconia abutment and 182 N for the internal connection type zirconia abutment. Moreover, in support of the possibility that crown installation on the zirconia abutment increases fracture strength, Adatia *et al*. reported that fracture strength of implant abutment increased after crown cementation since the crown functioned to protect the abutment. The fracture strength of 281 N reported by Butz *et al*.[17] shows a significant difference from Yildirim *et al*., and the current study, even though the same external connection type abutment was used. The reason may be due to measurement of fracture strength with static load after occlusal load of 1,200,000 times at 30 N according to Butz *et al*. Gehrke *et al*.[18] compared the strength of a zirconia abutment applied only with static load and a zirconia abutment applied with static load after occlusal load was applied 80,000 times. The results showed that the fracture strength of the abutment applied only when static load (672 N) was twice the value of the abutment applied static load after occlusal load. Based on these results, the fracture strength will decrease when occlusal forces are applied to the zirconia abutment.

We prepared zirconia crowns from zirconia abutments using CAD/CAM. Thus, full zirconia crowns were prepared under equal conditions ruling out the effects of core thickness, core material, veneer porcelain thickness, and margin design. The crowns were made with zirconia (Prettau) of 1.5 mm thickness to avoid fracture. No crown fracture was observed during the actual measurement of fracture strength in each specimen.

Since the study was not performed inside the oral cavity, factors that may decrease the strength of zirconia inside the oral cavity were excluded. Saliva or change in blood and temperature inside the oral cavity decreases bond strength of zirconia restoratives.[19,20] In addition, forces inside the oral cavity are not static. Dynamic forces act in various directions intra-orally. Further study is needed to observe the change in fracture strength of the dynamic load by applying static load after dynamic forces are applied.

Conclusion

The results of the study suggested that the axial wall of the zirconia abutment should be prepared with a thickness of at least 0.8 mm to facilitate clinical application of zirconia abutments of external connection type.

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전치부 지르코니아 지대주의 축벽 두께

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목적: 이 실험의 목적은 전치부 임플란트에 적용되는 지르코니아 지대주의 적절한 축벽의 두께를 평가하는 것이었다.

재료 및 방법: 시편들은 4가지의 서로 다른 두께로 제작되었으며, 일정하게 제작하고자 CAD/CAM 시스템을 이용하여 소결전 지르코니아 블록을 가공한 후 소결하였다. 가공된 시편들은 두께에 따라 Group 1 (0.5 mm), Group 2 (0.8 mm), Group 3 (1.0 mm), Group 4 (1.2 mm)의 4가지 그룹으로 분류되었다. 임플란트 시스템은 외부연결형(US, Osstem, Pussan, Korea) 을 이용하였다. 지대주 시편들은 시멘트 유지형 지대주를 복제하여 제작되었다. 크라운은 1.5 mm 의 두께로 CAD/CAM을 이용하여 제작되었다. 제작된 지대주 시편들을 임플란트에 고정시킨 후 레진시멘트(RelyX™ UniCem, 3M ESPE AG, Seefeld, Germany)를 이용하여 크라운을 합착하였다. 지르코니아 지대주의 파절을 측정하기 위해 만능시험기로 임플란트 장축에 30도의 각도로 힘을 가하였다.

결과: Group 1, Group 2, Group 3와 Group 4의 파절강도는 각각 236.00 ± 67.55 N, 599.00 ± 15.80 N, 588.20 ± 33.18 N, 97.83 ± 98.13 N이었다. Group 1이 다른 그룹에 비해 통계학적으로 유의성 있게 낮은 강도를 보여주었다(independent Mann-Whitney U-test, $P<.05$). 나머지 Group 2, Group 3와 Group 4는 서로 통계학적으로 유의성을 보여주지 않았다(independent Mann-Whitney U-test, $P>.05$).

결론: 지르코니아 지대주는 파절에 저항하기 위해 적절한 두께를 필요로 한다. 이 실험의 결과로 판단할 때, 지르코니아 지대주가 전치부 임플란트에 적용되기 위해서는 0.8 mm 이상의 두께를 가져야 된다고 추천된다. *(대한치과보철학회지 2015;53:345-51)*

주요단어: 지르코니아 지대주; 파절 강도; 축벽 두께