The Precision Between Implant Fixture and Titanium Base Abutment Connection and Cement Gap between Titanium Base Abutment and Zirconia Crown

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Abstract

The purposes of this study were to verify the precision between implant fixture and internal abutment connection and to compare the cement gap between commercial titanium base abutment (Osstem TS link abutment, Osstem®, Korea) and customized titanium base abutment produced by third party (Zirkonzahn parallel cemented titanium base HEX, Zirkonzahn, Italy). The implant-abutment connection gap between titanium base abutment and fixture analog, and cement gap between titanium base abutment and zirconia crown were recorded with light body silicone. The thickness of the gap, obtained by imprinted silicone, was stabilized and cross-sectionally cut and then measured in 4 different levels, i.e., (1) at a middle level of internal connection gap, (2) at a middle level of upper part of abutment surface, (3) at a middle level of lower part of abutment surface in which antirotations were presented, and (4) at antirotations gap, by using polarized microscope. All measurement points were re-evaluated 3 times and the mean value was calculated by independent T-test. The statistical analysis revealed that, for the connection gap, the mean gap value of customized titanium base abutment (88.48 $\pm$ 6.64 micrometers) was significantly lower than that of the commercial titanium base abutment (124.67 $\pm$ 16.26 micrometers) ($P<0.05$), while, for the cement gap at the antirotation points, the mean cement gap value of customized titanium base abutment (76.19 $\pm$ 21.23 micrometers) was significantly higher than the commercial titanium base abutment (24.83 $\pm$ 12.96 micrometers) ($P<0.05$). It can be concluded that the customized titanium base abutment could be used as an alternative option as it can provide a comparable connection with the commercial one.

Keywords: *Titanium base abutment/ Implant internal connection gap/ Cement gap*

Introduction

Implant abutment is a component part which connects to the implant fixture in order to support the prosthesis. It could be either the cement-retained or screw-retained restoration, based on the retention of prosthesis to implant fixture. The screw-retained prosthesis is the superstructure that combines the abutment and crown restoration[1], and is directly connected to the implant fixture by a retaining screw. This type of restorations provides a convenient, hygienic and predictable retention and it is easily removed without any damage to the crown.[2] The screw-retained prosthesis is very useful in several situations, such as a limited interocclusal space, in which it may not be possible to achieve adequate retention with a cement-retained prosthesis. As a completely cement-free solution, it is recommended in immediate loading cases as it can eliminate the difficulty of excess cement removing from the peri-implant area that may interfere with healing and osseointegration.[3] The residual cement has been indicated to cause peri-implantitis and implant failure.[4] In such a situation when patients are predicted to lose their teeth in the near future, a screw-retained prosthesis is also preferred due to the ease of removal and the restoration can be modified.[5] However, the fabrication of

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screw-retained prosthesis is required a casting process by waxing the castable plastic patterns such as the universal clearance limited abutment (UCLA). The wax pattern is developed on this plastic pattern and burned out before casting with a noble metal.[6] Therefore, it is costly and time consuming. If the screw-retained prosthesis is made of a whole metal, the esthetic outcome may be compromized.

As a consequence, the need for a screw-retained restoration, which can mimic tooth colour, has dramatically increased especially in the esthetic zones such as in anterior region. Previously, the customized zirconia abutment was introduced by companies in various designs for both single and multiple restorations to support the all ceramic prostheses. Recently, the abutment and crown could be combined together as a single unit by using titanium base abutment and monolithic zirconia restoration through cementation technique.

Up to date, the screw-retained restoration with titanium base abutment design becomes more popular due to a high clinical success and less complications.[7] The morse taper connection, in which the internal anti-rotation design is provided, can distribute the lateral loading force through the implant which could lead to a better-shielded abutment screw. Moreover, it also can create a stiff, unified body from a long internal wall engagement which provides a resistance of joint opening.[8, 9] As many implant manufacturers have produced their own titanium base abutment, so, some laboratories have milled titanium base abutment themselves to use instead of the commercial titanium base which can reduce the cost in some companies. The differences between commercial and customized titanium base abutment can be occurred due to various design and the accuracy of milling machine. Therefore, the internal connection between titanium base abutment and implant fixture should be verified, since its geometrical passive fit plays an important role for joint strength and stability as well as the rotational and locational stability.[10] According to the recently study, an absolutely passive fit cannot be obtained.[11] There were some studies indicated that the acceptable fit varied between 10-300 micrometers, was recommended.[12-16] If the misfit is presented, several studies indicated that the interface between alveolar bone and implant is threatened with microbial colonization as well as many complications, *i.e.*, screw loosening, screw fracture, plaque accumulation, poor soft tissue reaction and bone loss.[17-22] Another problem which could be occurred with titanium base abutment, is the dislodgement of crown from titanium base abutment by insufficiency retention. To solve this problem, it is recommended to attach the crown to the titanium base abutment with mechanical and chemical methods including a sandblasting technique combined with a proper cementation system. For a proper seating and adequate retention between titanium base abutment and zirconia crown, the cement space should be adequate but not too large to avoid excessive cement thickness. The recommendation of cement gap was about 20-40 micrometers.[23-25] The increasing of cement space from 30 to 60 micrometers could enhance a harmful effect on cement durability and lead to air bubbles and void in the cement.[26] However, the clinical studies about titanium base abutment are limited. Therefore, the objectives of this study are to verify the precision between implant fixture and abutment internal connection and to determine the zirconia crown cement gap, whether using customized titanium base abutment could be an alternative option to achieve the success outcome.

Materials and methods

Eighteen posterior single tooth implant restorations were prepared by using customized titanium base abutment produced by third party (Zirkonzahn parallel cemented titanium base HEX, Italy) (Figure 1A) with multilayer monolithic zirconia crowns as a sample group. Whereas two commercial titanium base abutment (Osstem TS link abutments, Korea) (Figure 1B) with multilayer monolithic zirconia crowns were prepared as a control group. There were some differences of the design between customized and commercial titanium base abutments at antirotation points as shown in Figure 1 and 2. The internal connection gap width was measured between titanium base abutments and an implant fixture analog, while the cement gap was measured between titanium base abutments and the internal surface of multilayer monolithic zirconia crowns (Figure 3).

1. Specimen preparation

To obtain the connection gap specimen, the light body addition silicone (Elite® HD, Zhermack, Badia Polesine RO, Italy) was injected on the connection part of titanium base abutment before seated into implant analog and the retentive screw was torqued 30 Ncm with torque wrench according to the company guideline. Only one implant fixture analog was randomly chosen and represented of an implant fixture for both control and experimental groups. After the polymerization was completed, the titanium base abutment was removed. The thin film of light body addition silicone was presented inside the implant analog (Figure 4A). To stabilize this thin silicone film, a regular body addition silicone (Provil® Novo, Heraeus kulzer GmbH, Hanau, Germany)

was injected inside the analog over the silicone imprint. After the polymerization, the replica impression was removed and the external side was then stabilized with the regular body silicone within the acrylic block with dimension of 10 x 10 x 8 mm (Figure 4B), in order to construct the silicone model (Figure 4C). Eighteen replica impression specimens from 18 customized titanium base abutments were prepared for experimental group. While in a control group, there were 2 replica impression specimens which were replicated from 2 commercial titanium base abutments. Only two commercial titanium base abutments were randomized chosen because of the quality assurance from the manufacturer.

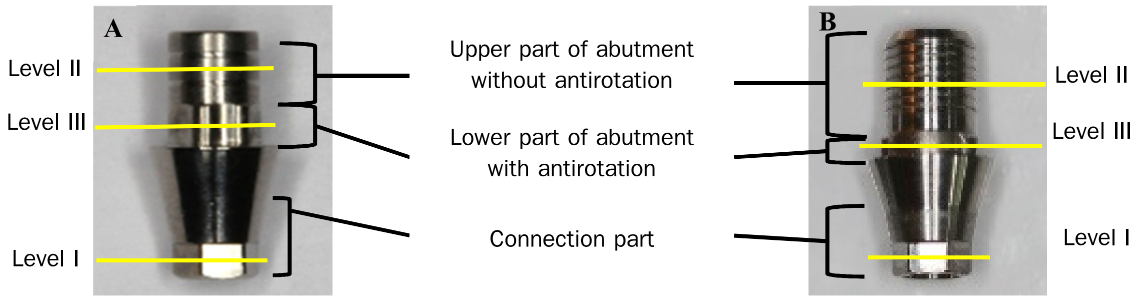

Figure 1 (A) Customized titanium base abutment, and (B) Commercial titanium base abutment with three segmented levels.

Figure 2 (A) Occlusal view of customized titanium base abutment with 2 adjacented antirotation points, and (B) The 3 distributed antirotation points of the commercial titanium base abutment.

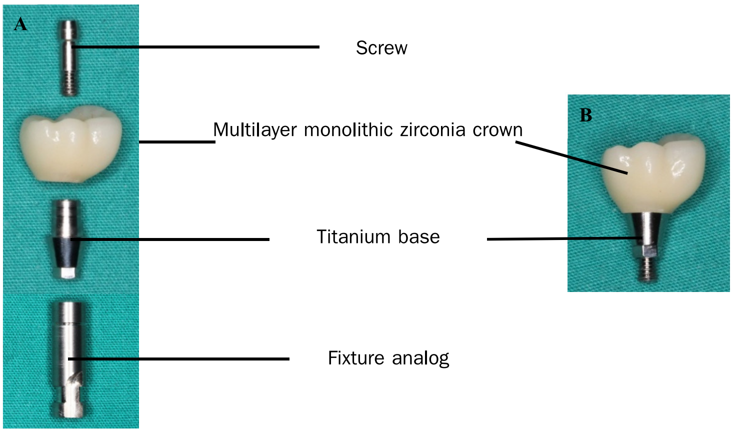

Figure 3 (A) The restoration component before assembly, and (B) After cementation of the zirconia crown on the titanium base abutment.

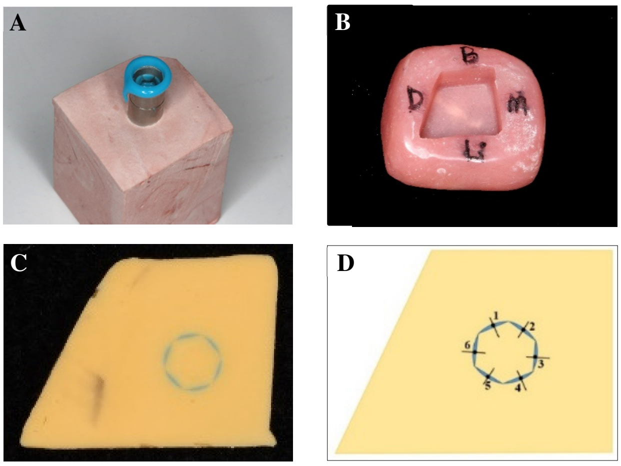

Figure 4 (A) The replica impression of connection gap was obtained with light body silicone. (B) An acrylic block was used as a template for stabilization. (C) The cross-sectionally cut of silicone model after the stabilization of replica impression. (D) The diagram of 6 measurement sites.

To obtain the cement gap specimen, twenty multilayer monolithic zirconia crowns were fabricated in the laboratory (Zirkonzahn M1 Wet Heavy, Zirkonzahn, Italy), 18 for Zirkonzahn titanium base abutments and 2 for Osstem titanium base abutments. Cement space were set up at 30 micrometers in the CAD software of milling machine. The internal surface of zirconia crown and outer surface of titanium base abutment were sandblasted with 110 micrometers aluminum oxide (Al_2O_3) particles under 0.2 MPa (2 bar) pressure. The preparation of the cement gap specimen was similar to the connection gap. After the light body addition silicone was injected on the external surface of abutment, the crown was put on top until it was completely seated on abutment with a stable pressure 50 N. After the polymerization was completed, the crown was removed and then regular body addition silicone was injected over the thin film of light body silicone inside the crown (Figure 5A). After the polymerization, the replica impression was removed from the crown and the external side was stabilized with the regular body silicone by using the acrylic block. Finally, the silicone model was constructed.

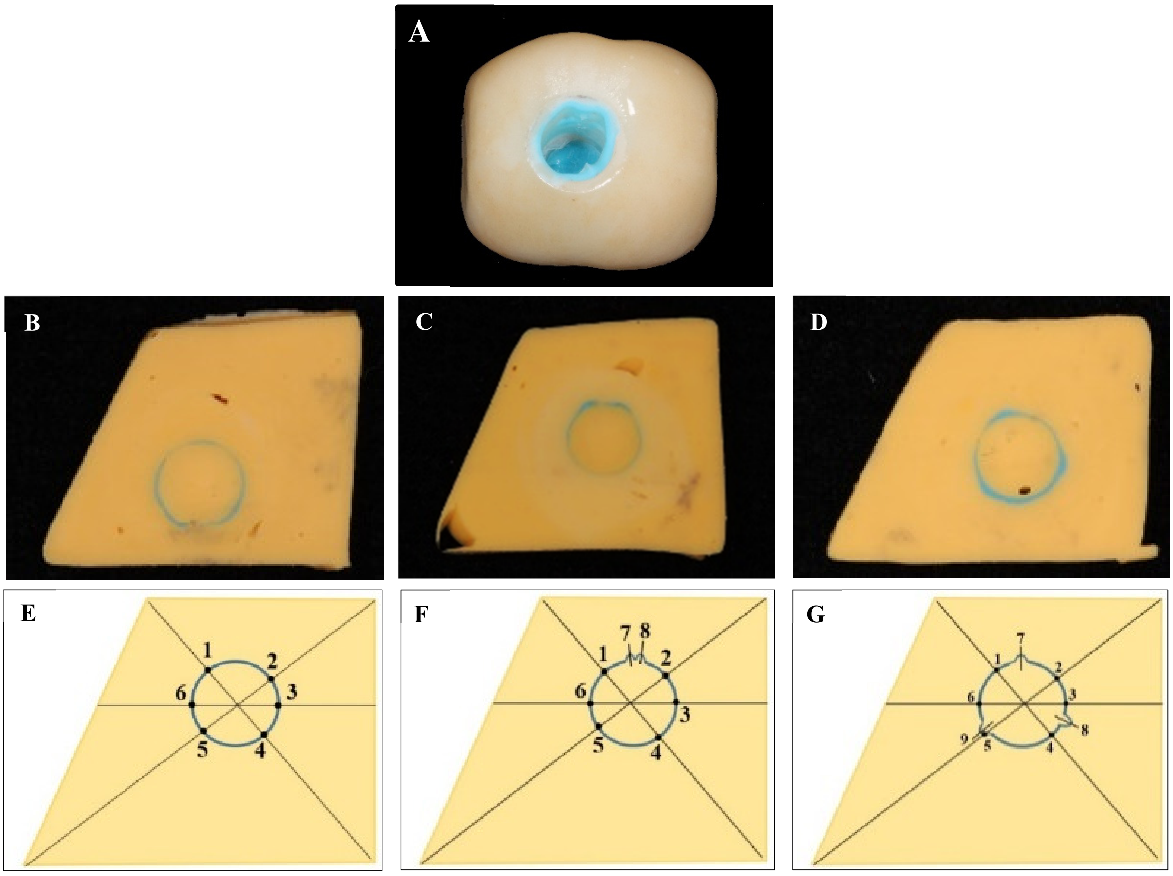

Figure 5 (A) The replica impression of cement gap obtained with light body silicone. (B) The cross-sectionally cut of silicone model at the middle of upper part. (C and D) The cross-sectionally cut of silicone model at the middle of lower part in which the antirotations were presented, obtained from customized and commercial titanium base abutment, respectively. (E, F and G) The diagram of the measurement sites at the upper part (E), at the lower part of customized titanium base abutment (F), and at the lower part of commercial titanium base abutment (G).

2. Measuring and statistical analysis

The silicone model were cross-sectionally cut with razor blade (Gillette, Gillette Co., Massachusetts, USA) as shown in Figure 4C and 5B, 5C, and 5D. The sectional positions were at 3 different levels, (1) level I, at a middle level of connection gap, (2) level II, at a middle level of upper part of abutment surface, and (3) level III, at a middle level of lower part of abutment surface, in which the antirotations were presented (Figure 1). Every sections were measured, by a single operator, with the polarized microscope (Nikon ECLIPSE LV100POL, Melville, USA) at a magnification of x50. For measuring a connection gap, 6 measurement points (Figure 4D) were verified by drawing the lines perpendiculary cut through the thickest part of all 6 sides of replica impression that was embedded in the silicone model. Each point was re-evaluated 3 times, hence, there were 18 measurements for each specimen. Then, the mean connection gap value was calculated.

For measuring a cement gap, 3 parts were distinguishably defined due to its antirotated configuration, *i.e.*, the first measurement points were obtained from the upper part by drawing 3 intersecting lines cut through the replica impression as shown in the diagram in Figure 5E. The second measurement points were obtained from the lower part, which were measured the same as the upper part (no.1-6 in Figure 5F and 5G). The last measurement points were the antirotation points, which their configuration were different between commercial and customized titanium base abutments. The commercial titanium base abutment presents 3 distributed antirotation points, while there are 2 adjacent antirotation points on customized titanium base abutment (Figure 2). These antirotation measurement points of customized titanium base abutment were shown at point no.7-8 in Figure 5C and 5F, whereas, the antirotation measurement points of commercial titanium base abutment were shown at point no.7-9 in Figure 5D and 5G, respectively. Independent T-test was used (SPSS 19.0, SPSS Inc., Chicago, USA) to verify the significant difference at P-value 0.05.

Results

The data for both connection gap and cement gap were taken for normality test with Shapiro-Wilk, and they were non-normally distributed, therefore Mann-Whitney U test was used with 95% confidence interval.

Implant fixture and titanium base abutment internal connection gap

The results showed that the means value of internal connection gap of the customized titanium base abutment (88.48 ± 6.64 micrometers), compared to the commercial titanium base abutment (124.67 ± 16.26 micrometers), was significantly lower (P=0.023).

Cement gap between titanium base abutment and zirconia crown

The mean value of cement gap obtained from the upper part and lower part of customized titanium base abutment (51.04 ± 16.86 and 42.22 ± 16.45 micrometers, respectively) were lower than the commercial

Table 1 Mean and standard deviation of connection gap (micrometer) when comparing between commercial and customized titanium base abutment.

Group	Number	Mean ± SD
Commercial titanium base abutment	2	124.67±16.26*
Customized titanium base abutment	18	88.48±6.64*

Note: Mann-Whitney U test p = 0.023

Table 2 Mean and standard deviation of cement gap (micrometer) when comparing between commercial and customized titanium base abutment.

Group	Number	Mean ± SD		
		Upper cement gap	Lower cement gap with antirotation	Antirotation points
Commercial titanium base abutment	2	64.33±10.84	68.00±13.44	24.83±12.96*
Customized titanium base abutment	18	51.04±16.86	42.22±16.45	76.19±21.23*

Note: Mann-Whitney U test *p = 0.027

titanium base abutment (64.33 ± 10.84 and 68.00 ± 13.44 micrometers, respectively), but there was no statistically significant different. In the contrary, the means value of cement gap obtained from antirotation point of customized titanium base (76.19 ± 21.23 micrometers) was significantly higher than the commercial titanium base (24.83 ± 12.96 micrometers) (P=.027).

Discussion

The titanium base abutment is a superstructure component of dental implant that plays an important role for treatment outcome. The internal connection gap between titanium base abutment and implant fixture and the cement gap between titanium base abutment and zirconia crowns, are crucial factors, since it could affect to the longevity of restoration and also could lead to implant failures.[7, 17-20, 22]

The results from previous studies revealed that clinical level of acceptable connection fit was about 10–150 micrometers.[14-16] A clinical study was also confirmed that they cannot find the relation between marginal bone level and prosthesis misfit at a mean discrepancy of 111 micrometers,[13] while another study indicated that the clinical acceptable marginal gaps could be varied between 30–200 micrometers.[12] In this study, the thickest points of the connection gap were chosen for measurement, both connection gap of the customized and commercial titanium base abutment did agree well with the previous studies. Interestingly, the customized titanium base abutment provided a narrower gap than the commercial one, *i.e.*, 88.48 ± 6.64 and 124.67 ± 16.26 micrometers, respectively. These significantly different value may come from the different setting protocol of the laboratory and implant company or the precision of milling process of different milling machine, *e.g.*, four or five axis of rotation. In addition to the three spatial dimensions in 3 axis milling device, the addition rotatable tension bridge in 4 axis and rotating milling spindle in 5 axis milling devices provide the milling possibility which can cope with undercut, increase efficiency of milling machine and improve their tool life.[27] Moreover, the difference tolerance values during the CAD/CAM process might cause the difference connection gap, these machining tolerance is determined as permissible limit from ideal measurement between the components when these components are held in place by their screws. There are two factors that contribute to machining tolerances, dimensional variation and surface roughness. The dimensional tolerance allows the range that a machine components can vary from its definite dimension while the surface roughness after machining process affects the fit of the contact surface. There was a study reported that the machining tolerance measurement of various implant component was 22–100 micrometers.[28] While another study indicated that the discrepancy at the implant interface was 34–119 micrometers.[29] Although the most desirable situation was passive fit between implant components, these tolerances alone was not sufficient to provide the passive fit because the screw torquing can certainly create stress in the implant, framework, and surrounding bone. However, these tolerance data can be useful as it can be a guidance information of the amount of the displacement which occurred during prosthesis fabrication.

Another weak point of titanium base abutment and its restoration is the adhesive connection between the titanium base abutment and the zirconia superstructure which is essential for long-term clinical success.[26] For the abutment height, an additional 4–7 mm of abutment height, increases retention by 67%[30], and at least 5 mm of abutment height is needed to ensure the retention of a cement-retained restoration.[31] While another study recommended that the minimum abutment heights, necessary to provide adequate retention, were 3 mm for narrow platform and 4 mm for wide platform in single cement-retained restorations.[32] In this study, the height of titanium base abutment was 4 mm, which is acceptable for providing adequate retention for zirconia crown. For the cement space evaluation, the proper internal cement gap of the conventional fabricated all ceramic crown, *e.g.*, slip casting or hot pressing technique, are within a range of 25-50 micrometers. A space of 25-30 micrometers is provided for the cement and space of 20 micrometers is compensated for distortion of the wax pattern. [23-25] If all ceramic crown is constructed with CAD/CAM technique, several step, *i.e.*, scanning, designing, and milling step, are involved and each step should be well controlled, as to provide the overall fit of the crown. One study recommended that the optimal cement gap must be more than 30 micrometers[33], while the others indicated that a range could be varied from 20 to 40 micrometers.[34-37] There was a significant higher retention if a luting gap between zirconia and titanium component was set at 30 micrometers.[26] Therefore, the cement gap in this study was initially set at 30 micrometers in the CAD software of milling machine. However, the mean gap value that were measured in this study, was higher than the setting value, which might come from the uncontrollable sandblasting process. The sandblasting process of internal surface of zirconia crown with 110 micrometers aluminum oxide (Al_2O_3) particles can remove a significant amount of material from restorations. This process is recommended to enhance the retention of the luting cement to the crown surface, despite it might affect to the mechanical properties and phase transformation of zirconia by introducing flaws and reshaping the surface.[38, 39]

Another interesting point was the mean value of antirotation gap which was statistically significant different between these two groups. This can be described by the position of antirotation configuration. The antirotation part of customized titanium base abutment are located in the adjacent position (Figure 2A), which may lead to the difficulty for accessing of milling machine burs on the connected surface. Hence, the wider cement gap in antirotation area could be occured, when compare to the commercial antirotation part which are distributed in three different position and it might easier for accessing of the milling process. Moreover, the cutting tool diameter which is used in machine process could also affect to the gap width. As in the limited access area, even when the narrowest bur diameter is used, the internal substance might be excessively removed than necessary. However, the misfit of the cement gap at the antiroration part of both customized and commercial groups are within the clinical acceptable range.[33, 34, 37]

Conclusion

Within the limitation of the present study, it can be concluded that the customized titanium base abutment can be chosen as an alternative option when the commercial titanium base abutment is not available. However, the effect of different antirotation part of titanium base abutment on the retention and resistance form of the crown and the prospective clinical study need to be verified.

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ความแนบสนิทของส่วนต่อระหว่างฐานไทเทเทียมกับรากเทียมและความหนาชั้นซีเมนต์ระหว่างฐานไทเทเนียมกับครอบฟันเซอร์โคเนีย

ดาราพร แซ่ลี้ พิศเพลิน ชนาเทพาพร* สุบิน พัวศิริ** วราภรณ์ สุวรรณรงค์*** ชลพร เรืองเลิศปัญญากุล*****

บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อตรวจสอบความแนบสนิทระหว่างหลักยึดฐานไทเทเนียมกับส่วนต่อภายในของรากเทียม และวัดความหนาชั้นซีเมนต์ที่ใช้ยึดครอบฟันบนหลักยึดฐานไทเทเนียม ศึกษาเปรียบเทียบระหว่างหลักยึดฐานไทเทเนียมจากบริษัทผู้ผลิต (Osstem TS link abutment, Osstem®, Korea) กับหลักยึดฐานไทเทเนียมที่ผลิตขึ้นในห้องปฏิบัติการโดยบริษัทที่ไม่ใช่ผู้ผลิตโดยตรง (Zirkonzahn parallel cemented titanium base HEX, Zirkonzahn, Italy) ใช้วัสดุพิมพ์ซิลิโคนชนิดหนืดน้อยบันทึกขนาดช่องว่างบริเวณรอยต่อระหว่างหลักยึดฐานไทเทเนียมกับรากเทียมจำลองและความหนาชั้นซีเมนต์ระหว่างหลักยึดฐานไทเทเนียมกับครอบฟันเซอร์โคเนีย คงสภาพชิ้นงานที่ได้ด้วยวัสดุพิมพ์ซิลิโคน นำไปตัดขวางและวัดความหนาที่ระดับต่างๆ 4 ระดับ คือ (1) ที่ระดับกึ่งกลางของรอยต่อระหว่างหลักยึดฐานไทเทเนียมกับรากเทียมจำลอง (2) ที่ระดับกึ่งกลางของผิวชั้นบนของหลักยึด (3) ที่ระดับกึ่งกลางของผิวชั้นล่างของหลักยึดที่เป็นบริเวณที่มีจุดต้านต่อการหมุน และ (4) ที่จุดต้านต่อการหมุน วัดขนาดช่องว่างด้วยกล้องจุลทรรศน์โพลาร์ไรซ์ไมโครสโคปโดยวัดซ้ำ 3 ครั้ง คำนวณค่าเฉลี่ยและวิเคราะห์ผลด้วยสถิติทดสอบที ผลการวิจัยพบว่าหลักยึดฐานไทเทเนียมที่ผลิตในห้องปฏิบัติการมีความแนบสนิทมากกว่าหลักยึดฐานไทเทเนียมจากบริษัทผู้ผลิต โดยมีค่าเฉลี่ยขนาดช่องว่างน้อยกว่าอย่างมีนัยสำคัญทางสถิติ (88.48 ± 6.64 ไมครอน และ 124.67 ± 16.26 ไมครอน ตามลำดับ) สำหรับค่าความหนาของชั้นซีเมนต์ที่บริเวณจุดต้านต่อการหมุนพบว่าหลักยึดฐานไทเทเนียมจากบริษัทผู้ผลิตมีค่าเฉลี่ยความหนาชั้นซีเมนต์น้อยกว่าหลักยึดฐานไทเทเนียมที่ผลิตขึ้นในห้องปฏิบัติการ (24.83 ± 12.96 ไมครอน และ 76.19 ± 21.23 ไมครอน ตามลำดับ) จากการศึกษานี้สรุปได้ว่าฐานไทเทเนียมที่ผลิตในห้องปฏิบัติการสามารถใช้เป็นทางเลือกหนึ่งแทนฐานไทเทเนียมที่ผลิตจากบริษัทได้ โดยมีความแนบสนิทที่ใกล้เคียงกัน

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