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Finite Element Analysis of a New Sealing-Type Abutment Inserted with a Gold Ring

Dae-sun Hong, Jeong-min Kim, and Seung-young Lee

***Abstract*—When chewing forces are repetitively applied to a dental implant, gap is often generated at the interface surfaces between the abutment and the fixture, and results in some deteriorations such as loosening of fastening screw, dental retraction and fixture fracture. To cope with such problems, a sealing-type abutment having a number of grooves along the conical-surface circumference was previously developed, and shows a better sealing performance than conventional ones. To enhance the sealing performance, a new model in which a gold ring is inserted into the top groove of the sealing-type abutment has been recently developed, and this study carries out finite element analysis on the stress and deformation of this new model in consideration of external chewing force. The analysis result shows that the gold ring gives sealing effect with its maximum capacity.**

***Keywords*-abutment, fixture, gold ring, dental implant, FEM analysis**

I. Introduction

A dental implant is currently used as a reliable way of dental treatments since the concept of osteolysis, which is a direct defect between a living body and metal, was reported by Branemark of Sweden in 1969[1], and has gone through continuous development through many experiments and clinical applications. Fig. 1 shows a shape of a dental implant consisting of a crown, an abutment and a fixture. The fixture plays a role of the tooth root implanted in the bone, while the abutment, a pillar that comes out through the fixture, plays a role of the support of the crown.

Fig. 1. Constitution of a dental implant

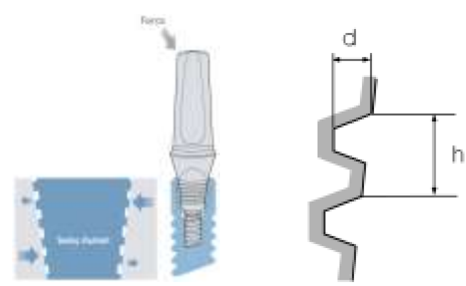
A dental implant, which plays a role of tooth, may generate some problems in view of biomechanics since it is implanted in the oral cavity, special environment, and receives static load and dynamic load repeatedly. The most common phenomena among such problems are the loosening of the prosthesis and bone loss on the part of the dental implant fixture due to the fracture of the screw and the fixture. As a result the function of the dental implant can be destroyed. Thus, to prevent such phenomena, many research works on the dental implant have been made in various ways [2]-[4].

A sealing-type abutment having a number of grooves along the outer conical surface was previously developed[5], and the analysis result shows better sealing performance than conventional ones. To enhance the sealing performance, a new model in which a gold ring is inserted into a groove of the sealing-type abutment has been developed, and this study carries out finite element analysis for this model. Specifically, the deformation and stress distribution in the gold ring of the abutment and fixture assembly is analyzed. The analysis result shows that the gold ring successfully plays a role of sealing with its maximum capacity.

II. Concept of a Sealing-Type Abutment

A. Sealing-type Abutment

In common abutments, loosening of the abutment from the fixture occasionally occurs since the perfect contact between two components is practically unrealizable, and the contact surfaces between the abutment and the fixture come to deform from repetitive chewing forces. As a result, gap is generated at the interface surfaces. Because of such gap, foreign substances can pass through it, and result in various deteriorations such as loosening of the fastening screw, dental retraction and fixture fracture.



(a) Sealing-type abutment (b) The groove shape

Fig. 2. The sealing abutment and the Groove shape

To alleviate such phenomena, a sealing-type abutment is provided with a number of grooves along the outer conical surface of the abutment so that the contact pressure at the interface surface is more evenly distributed [5]. Fig. 2 shows such a sealing-type abutment and its groove shape.

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Professor Dae-sun Hong and Mr. Jeong-min Kim are with School of Mechanical Department, Changwon National University, Gyongnam, 641-773, Rep. of Korea

President Seung-young Lee is with T.Strong,Inc

B. Abutment Inserted with a Gold ring

As described in the above, the sealing-type abutment has a number of grooves at the outer conical surface of the abutment. The number of grooves is six, and a new model is developed in such a way that a gold ring is inserted into the top groove to enhance the sealing performance. Here, the dimension of depth(d) and height(h) of the groove should be determined so as to fit to the size of the gold ring.

In this model, gold is selected as the sealing material, because gold has been known as medically safe material to human oral cavity. The shape of the gold ring is shown in Fig. 3. The outer diameter of the ring is 3mm to be fitted to the abutment groove and the diameter of the wire is determined to be 0.05mm.

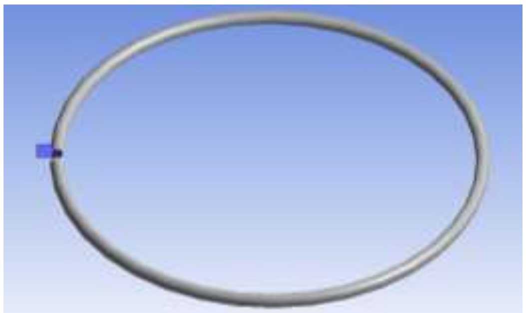


Fig. 3. The shape of a gold ring

III. Finite Element Analysis

In this section, structure analysis on the gold ring and the abutment is carried out to verify the effectiveness of the new abutment model. ANSYS Workbench[6] is used in this study as the analysis software.

A. Analysis of the Gold Ring

The gold wire used in this product is same as the one for wire bonding in the manufacture of semiconductors. The mechanical property of the gold wire is shown in Table 1.

The gold ring is inserted into the top groove, and make contact with both the abutment and the fixture. To provide sealing effect, the diameter of wire is chosen to be slightly larger than the cavity between the abutment and the fixture. When the wire diameter is chosen as too large, large deformation occurs at the gold ring in the assembly of the product. As s result, large stress is generated in the material so as to lead to fracture. Thus, the wire diameter should be chosen in such a manner that the maximum stress of the wire does not exceed the ultimate stress.

TABLE I. Mechanical Propery of the Gold Wire

Item	Property
Density	19,320kg/m^3
Tensile Yield Strength	115MPa
Tensile Ultimate Strength	130MPa
Young's Modulus	81GPa
Poisson's Ratio	0.42

For such purpose, finite element analysis is carried out for the gold wire. In this analysis, a gold wire is inserted into the top groove of the abutment, then external force is applied to the wire to the radial direction of the abutment. As the force is increased, the deformation of the wire also increases. Accordingly, the stress proportional to the deformation can be successively found. This simulation stops when the maximum stress exceeds the yield strength shown in Table I.

The analysis results are shown in Figs 4 and 5; Fig. 4 shows the stress distribution, while Fig. 5 is the deformation one.

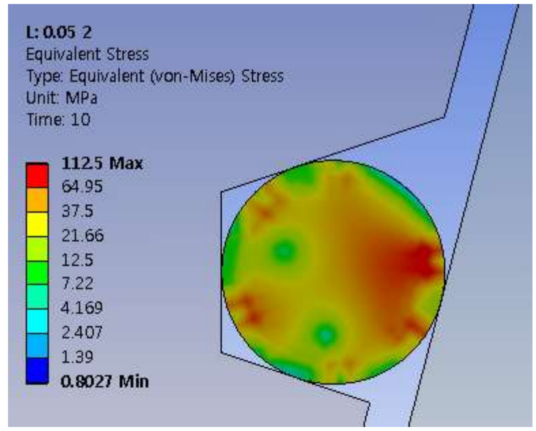


Fig. 4. The stress distribution in the 0.05mm gold wire

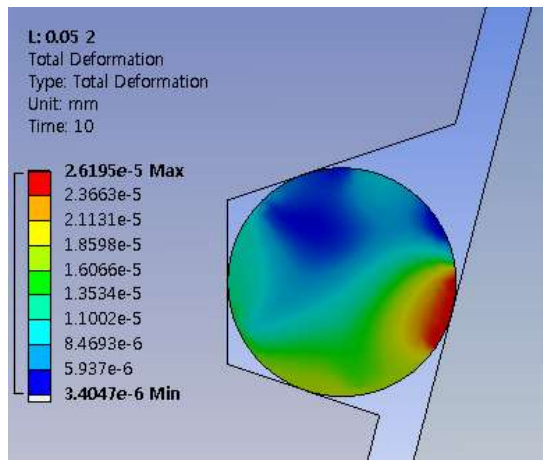


Fig. 5 The deformation in the 0.05mm gold wire

It can be seen from the figures that the maximum deformation is $2.6x10^{-5}$ mm when the maximum stress of the wire reaches 112.5 MPa, slightly below the yield strength. The wire diameter is 0.05mm, thus the ratio of the deformation to the diameter is calculated to be only 0.05%. This means that the gold wire undergoes plastic deformation under very small deformation.

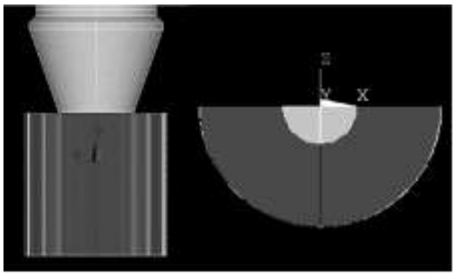
B. Analysis of the Abutment

The gold ring described in the above is inserted into the top groove at the outer surface of a sealing abutment. This new model is called the gold-ring-inserted sealing abutment. The material of the abutment and the fixture is a titanium alloy, and the mechanical property is shown in Table II. While, the property of the gold ring is the same as in the Table I.

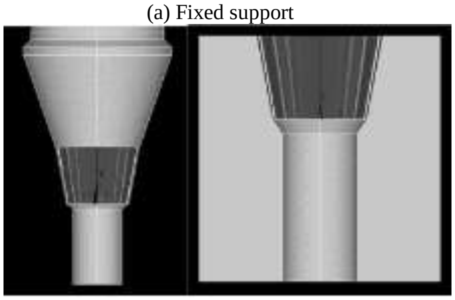
TABLE II. Mechanical Propery of the Gold Wire

Item	Property
Density	4430 kg/m^{-3}
Poisson’s Ratio	0.342
Tensile Yield Strength	880 MPa
Tensile Ultimate Strength	950 MPa
Compressive Yield Strength	970 MPa

As the boundary conditions, the outer surface of the abutment is regarded as the fixed support, as show in Fig. 6(a). Also, contact condition is applied at the surfaces between the outer of the abutment and the inner of the fixture as shown in Fig. 6(b), and the friction coefficient is assumed to be 0.2. In this assembly, a gold ring is inserted into the top groove, thus the ring contacts with both the abutment and the fixture, as show in Fig. 7. The friction coefficient is also 0.2.



(a) Fixed support



(b) Contact surface

Fig. 6. Boundary conditions

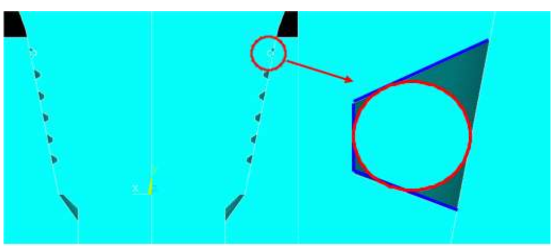


Fig. 7. Gold ring in contact with the abutment and the fixture.

As the force condition, downward chewing force is applied to the top of the abutment with the slope of 30° to the vertical direction. In the assembly the abutment and fixture, the lower part of the abutment is fastened to the fixture with the abutment screw, thus two components are initially undergoes pretension to a degree. Here, the pretention, calculated by a screw theory [7], is found to be 177.4N.

The analysis results are shown in Fig 8 and 9; Fig. 8 shows the stress distribution, while Fig. 9 is the contact pressure in the gold ring.

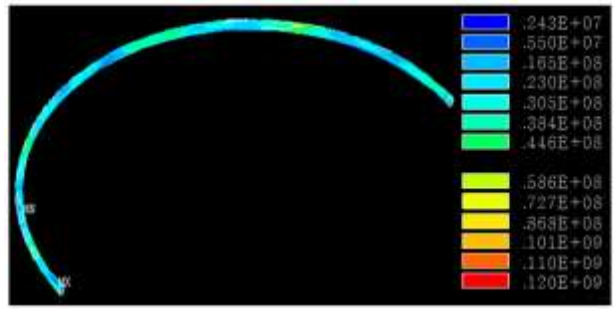


Fig. 8. The stress distribution in the gold wire of the abutment and fixture assembly

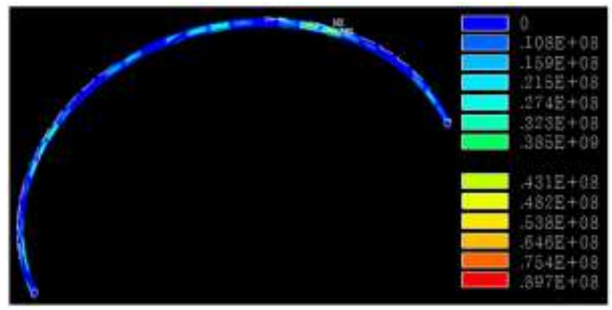


Fig. 9. The contact pressure in the gold wire of the abutment and fixture assembly

It can be seen from the figures that the maximum stress in the gold ring is found to be 120MPa, while the maximum contact pressure is 89.7MPa. The maximum stress is shown to be slightly larger than the yield strength, while it is lower than the ultimate strength. It is noticed that the gold ring undergoes plastic deformation in the assembly, however it does not reach its fracture. This means that the gold ring successfully plays a role of sealing with the maximum capacity of the gold wire. This sealing effect is to be verified in the near future through relevant experiment.

IV. CONCLUSION

In conventional dental implants, gap occurrence between the abutment and the fixture is a serious problem, because foreign substances can pass through it, and results in various deteriorations such as loosening of the fastening screw, dental retraction and fixture fracture.

To overcome such problems, a sealing-type abutment having a number of grooves along the outer conical surface was previously developed. To enhance the sealing performance, a new model in which a gold ring is inserted into the top groove of the abutment has been developed, and this study carries out finite element analysis for this new model to verify its effectiveness. From this analysis, the maximum stress is shown to be slightly larger than the yield strength, while it is lower than the ultimate strength. Thus, it is concluded that the gold ring successfully gives sealing effect with the maximum capacity of the gold wire.

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Dae Sun Hong was born in Korea, 1959, received his M.S and Ph.D degrees from KAIST (Korea Advanced Instute of Science and Technology), Korea, in 1986 and 1995, respectively. He is currently a chief and professor in School of Mechanical Engineeing of Changwon Naitonal University, Gyongnam, Korea. He worked as dean in College of Mechatronics Enigneeing in 2013-2015. His research interests include automation system design, design of implant parts, and mechnical design optimization.

Seung Young Lee was born in Korea, 1959, received his M.S and Ph.D degrees from KAIST (Korea Advanced Instute of Science and Technology), Korea, in 1986 and 1994, respectively. He is currently a representative in T-Strong Inc., Gyongnam, Korea. T-Strong Inc. produces dental implant system and related surgical instruments.