The Effect of Titanium on the Castability of Cobalt-Chrome Alloy

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Purpose of this experiment is to evaluate the effect of titanium on the castability when the titanium is added to the Co-Cr alloy. Raw materials Cobalt, Chrome, Molybdenum, Silicon, Manganase, Carbon, Nitrogen, Titanium were weighted and prepared. Biosil^{F} (Degudent, Germany) was the control group. To the experimental group, different weight percent of titanium was added from 1 wt% to 4 wt%. The wax pattern is 30 X 40 cm in size, rectangular in shape and has total of 160 grids. Centrifugal machine (Neutrodyne Easy Ti: Manfredy) was used for casting. For evaluation of the castability, the number of complete grids was counted by visual inspection and X-ray inspection. The test showed similar castability with the control group in the titanium addition of 1 wt% to 3 wt%. The titanium addition of 4 wt% showed poor result. With titanium lower than 4 wt%, the experiment metals showed proper castability with high expectation of successful clinical use.

Key words: castability, cobalt-chrome alloy, grid, partial denture, titanium
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INTRODUCTION

As for dental alloy, precious metal alloy[1] shows good corrosion resistance and biocompatibility. But it is very expensive and has an esthetic problem because of its distinctive color. Thus, usage of non-precious metal alloy is increasing. It is economic as well as good mechanical properties and corrosion resistance. However, non-precious metal alloy[2] is needed special equipments for melting and casting.

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In addition, non-precious metal alloy forms oxide layer during melting and casting, the laboratory procedure of non-precious metal alloy is very delicate. Thus castability of non-precious metal alloy is very important properties to select dental material for removable partial denture.

Among non-precious metal alloy, cobalt-chrome (Co-Cr) alloy[3] is widely used in manufacturing partial denture. Cobalt-chrome alloy shows good elongation property[2]. It is about 2 times better than that of gold alloy. Therefore partial dentures can be made thinner and lighter than the other alloys. It also shows excellent corrosion resistance and biocompatibility. Those characteristics lead to the most successful result in framework casting. Co-Cr alloy was used for a long time and shown good clinical success. However, sometimes deformation and fracture of Co-Cr alloy occurs, and abrasion and shearing of Co-Cr alloy occurs in patient with bruxism or hypermusculature[4].

Previous research in our laboratory is reported that addition titanium into Co-Cr alloy improves mechanical properties. In tensile strength, yield strength and elongation of fracture, the new alloy showed better performance than Co-Cr alloy did. Only in the melting range, the new alloy needs higher range of melting point because of its titanium contents. But thermal expansion rate shows that new alloy is more stable in volumetric change during heating and casting procedures than Co-Cr alloy. (Table I) But, the research about castability of Co-Cr alloy with titanium is not reported. The aim of this study is to evaluate the effect of titanium on the castability of Co-Cr alloy.

MATERIALS AND METHODS

Basic elements- Cobalt, Chrome, Molybdenum, Silicon, Manganase, Carbon, Nitrogen, Titanium- were weighed, melted, and casted. Cobalt-Chrome alloy (Biosil^{F}, Degudent,Germany) was the control group. For experimental groups, different weight percent of titanium were added from 1 wt% to 4 wt% (Table Ⅱ)

To test the castability, a wax pattern(Grids RNII, Dentarum, Germany) was made in a mesh type of 40 mm(horizontal) by 30 mm(vertical) which consists of 165 numbers of squares. Sprues(Kerr, 10 gauge, 2.6mm) with diameter of 2.6 mm were attached in a crow's feet-like fashion with a height of 15 mm. 3 wax patterns were used for each experimental group.(Fig. 1) After investing, it was bench set for 1 hour. The temperature in the furnace was elevated by 6℃ per minute up until 400℃ then by 10℃ per minute till it reached to 900℃. The investment were on hold for 30-60

Table I. Results of the mechanical properties

Criteria	Co-Cr alloy (Biosil^{F})	Co-Cr-N-Ti (2 %)
Tensile strength (MPa)	819	1007
Yield strength (MPa)	308.4	355.8
Elongation of fracture (%)	5	7
Melting range (℃)	1320 ~ 1380	1410 ~ 1480
Thermal expansion rate	15.2	14.5

Table Ⅱ. Composition of the control group and experimental groups

Group	Composition (wt%)
Group 1	63.2 Co -28Cr -6Mo -0.6Si -0.6Mn -0.3C -0.3N -1Ti
Group 2	62.2 Co -28Cr -6Mo -0.6Si -0.6Mn -0.3C -0.3N -2Ti
Group 3	61.2 Co -28Cr -6Mo -0.6Si -0.6Mn -0.3C -0.3N -3Ti
Group 4	60.2 Co -28Cr -6Mo -0.6Si -0.6Mn -0.3C -0.3N -4Ti
Control	64.8Co -28.5Cr -5.3Mo -0.5 Si -0.5 Mn -0.4 C

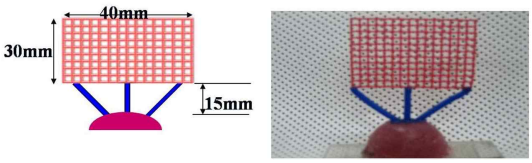

Fig. 1. Schematic representation and digital photo image of wax pattern

minutes in the 900℃ before casted. For casting procedure, Neutrodyn Easy Ti (Manfred, Italy) was used for centrifugal environment for Titanium alloy.

To see the result, two methods were used. The one is using X-ray to see casting defects, air bubbles and cracks. The other is visual inspection by which number of the integrate squares can be counted[5]. It can be said the more number of integrate squares with their four sides intact, the better the fluidity of the fused metals.

RESULTS AND DISCUSSIONS

There has been a great interest in the use of titanium for removable prostheses recently because of its excellent biocompatibility and mechanical properties. Previous research is reported that addition titanium into Co-Cr alloy improves mechanical properties. In tensile strength, yield strength and elongation of fracture, the new alloy showed better performance than Co-Cr alloy did. The role of titanium in Co-Cr alloy is fixing carbon and nitrogen by creating interstitial solid solution. Interstitial solid solution is not a mixture of element metals but a newly created type of metal which has a different unit cell during the melting and casting procedure. Titanium alloy with oxygen, carbon, nitrogen and hydrogen atoms dissolved interstitially. Whenever a solute atom substitutes for a solvent atom in the crystal structure of a metal, the different size of the solute atom results in a localized distortion, and the movement of dislocations becomes more difficult. The strength, proportional limit, and hardness are increased, and the ductility is usually decreased. Thus solid solution alloying can be a highly efficient means of strengthening a metal[6]. Only in the melting range, the Co-Cr alloy with titanium needs higher range of melting point because of its titanium contents. But thermal expansion rate shows that new alloy is more stable in volumetric change during heating and casting procedures than Co-Cr alloy.(Table I) But, the research about castability of Co-Cr alloy with titanium is not reported. The aim of this study is to evaluate the effect of titanium on the castability of Co-Cr alloy.

In this study, the control group, group 1, group 2 and group 3 showed similar castability. Only the

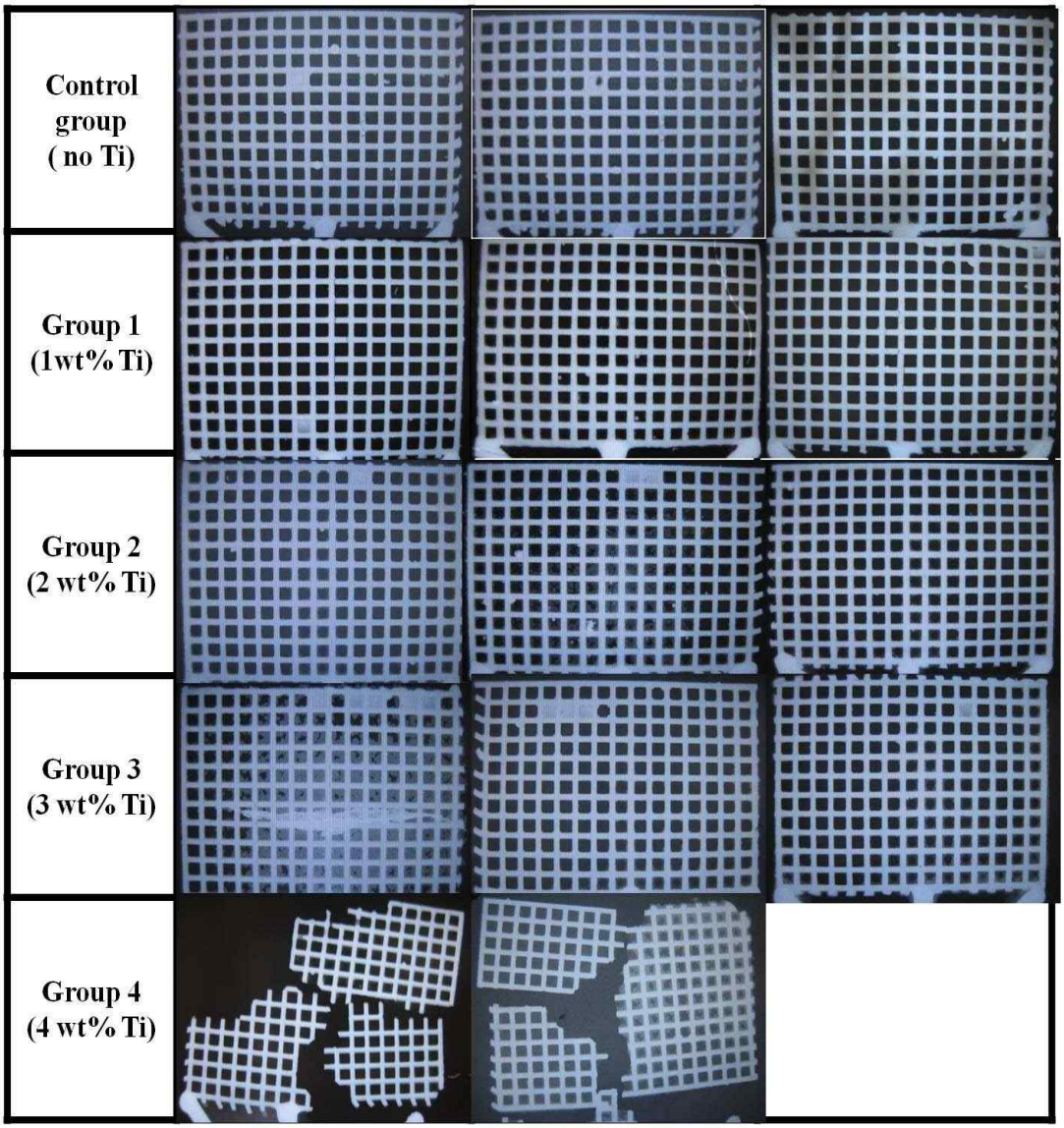

Fig. 2. The results of X-ray inspection.

group 4 with 4 wt% of titanium showed defects in castability.(Fig. 2,3) Irregular shaped projections in the middle of the mesh model of group 3 are not actually came from the casting defect, but from the investment procedure. Therefore those squares are included to the total number of successful mesh. Among the three specimen for this 4 wt% Ti experimental group, one sample end up to be an uneven mass just right before the entrance of the sprue. It seemed that the fused liquid metal of 4

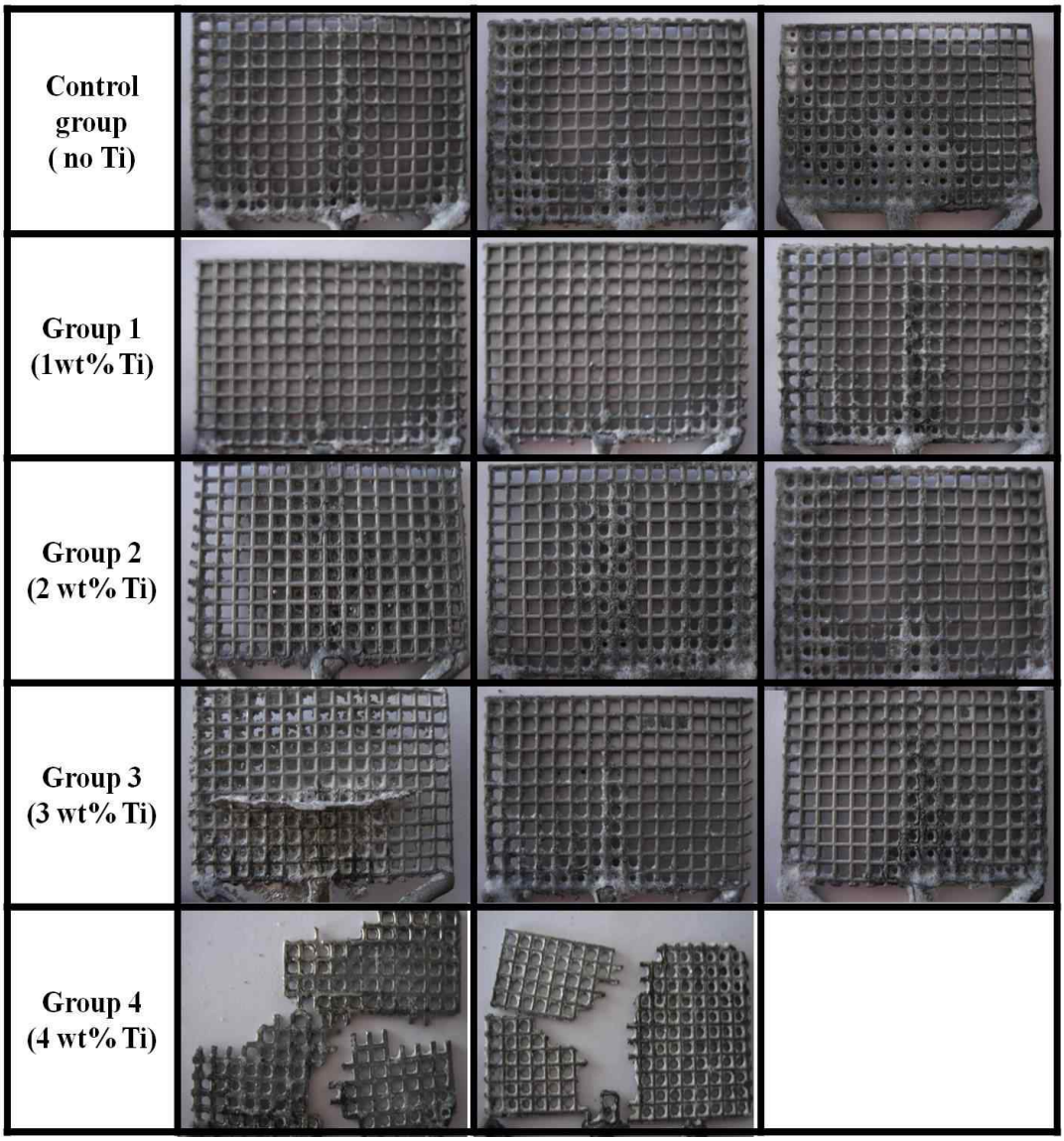

Fig. 3. The results of visual inspection

wt% Ti had failed to be poured into the sprue of the lost wax investment. The number of the integrate squares are counted as a standard to compare the castability of the test models. Fig. 4 is showed the number of meshes.

As for the reason of the castability failure in the test model of 4 wt% of titanium, it can be guessed the main culprit is the oxidized titanium shield (TiO_2) that is to be created during the melting procedure. When titanium content is below 4 wt%,

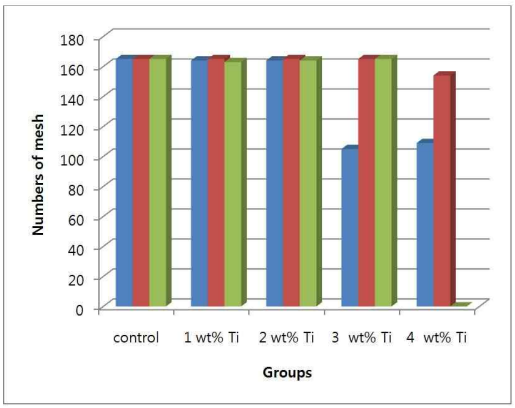

Fig. 4. The number of meshes according to group

the effect of oxidation is negligible. But when Titanium exceeds 4 wt%, it seems the amount of oxidized titanium shield which may act as an impurity, a direct cause of the low fluidity, influences the castability. However, for the definite explanation of this, more studies will be needed.

CONCLUSION

With titanium lower than 4 wt%, the Co-Cr alloy with titanium showed similar castability and better mechanical properties with high expectation of successful clinical use.

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코발트 크롬 합금의 주조성에 미치는 타이타늄의 효과

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연구의 목적은 타이타늄이 함유된 코발트 크롬의 주조성에 타이타늄이 어떠한 영향을 미치는지 평가하기 위함이다. 원재료에는 코발트, 크롬, 몰리브덴, 실리콘, 망간, 탄소, 질소, 티타늄이 사용되었고 이것들을 정량계량하였다. Biosil^{F} (Degudent, Germany)를 대조군으로 하였고, 실험군에는 티타늄을 1 wt% 에서 4 wt% 까지 각기 다른 함량으로 첨가하여 주조성을 평가하였다. 왁스 패턴은 30 X 40 cm 크기의 직사각형 모양으로, 총 160개의 격자를 함유하고 있다. 원심주조기 (Neutrodyne Easy Ti: Manfredy)를 사용하여 왁스패턴을 주조하였다. 주조성의 평가는 왁스패턴의 4면이 완전한 격자의 수를 육안과 X-ray를 이용하여 검사하였다. 1 wt%에서 3 wt%의 티타늄을 함유한 금속은 대조군과 비슷한 주조성을 나타냈다. 4 wt%의 티타늄을 함유한 금속은 좋지 않은 결과를 보였다. 4 wt% 미만의 티타늄 함유한 실험군의 주조성은 대조군과 비슷하면서도 기계적인 물성은 증가됨을 보였으며 임상에서의 성공적인 사용을 가능케 한다.

주요어: 격자, 국소의치, 주조성, 코발트-크롬 합금, 타이타늄

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