A Change in Attractive Force of a Keeper Fabricated using a Reuse Metal of Castable Magnetic Alloy

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Introduction

In clinical practice, a root cap with a ready-made stainless steel keeper is placed to a non-vital tooth, and a magnetic assembly is embedded in the denture base. The size of a magnetic attachment has become smaller along with a reduction of the magnet size in recent years. However, there is often a case when a commercially available magnetic attachment cannot be placed due to the limited space, inclined dental root, and the influence of adjacent teeth. A magnetic alloy root-cap was developed to be replaced by a conventional root-cap with a keeper. This root-cap was fabricated using a castable magnetic alloy, and, therefore, attachable to the magnetic assembly. The development of the root-cap expanded the application of magnetic attachments in the limited space compared with a conventional root-cap with a keeper. Hearth formed by casting using a lost-wax method is essential to prevent casting defects.

A mixture of hearth and virgin metal is used for casting in clinical practice. It is necessary to evaluate an influence of casting using hearth of dental magnetic alloy on the attachment force between a keeper and a magnetic assembly.

Objective

The present study examined attractive force of a keeper and magnetic assembly fabricated using a hearth of dental magnetic alloy, and analyzed the constituent elements for verification.

Materials and Methods

1. Materials

Castable magnetic alloy Attract P (TOKURIKI-HONTEN Co.) was used. Attract P is the only commercially available dental cast magnetic alloy. Figure 1 and Table 1 show an ingot image and properties of Attract P. The main component of the alloy is Ag-Co-Pd. It also includes Au, Zn, and In.

Fig1. 「Attract P」（TOKURIKI HONTEN）

Table1. Composition and Properties of Attract P

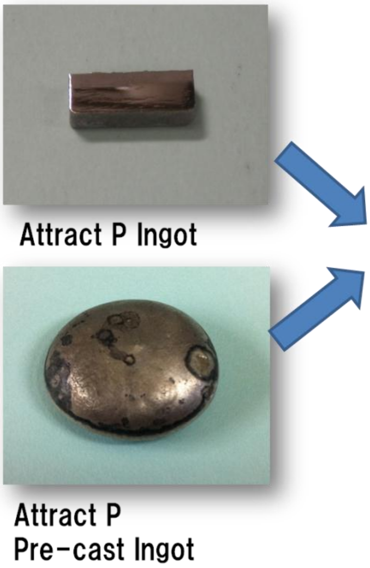
Color : silver
Melting point : 1148-1192℃
Castable temperture : 1300℃
Specific gravity : 10.5kg/cm^3
Strength : 197HV
Yeild Strength : 300MPa
Elongation : 13.5%

2. Experimental method

2.1 Sample fabrication method

Two metals were used for sample fabrication, Attract P ingot and hearth formed by casting the sample using Attract P ingot. The investment material and oxidized layers on the hearth surface was removed using a carborundum point, followed by sandblasting to reuse for casting.

Five different samples including a mixture of Attract P ingot and hearth at ratio of 1 : 3 (0) , 1 : 1 (25) , and 3 : 1 (50) , ingot alone (75), and hearth alone (100) were prepared. The number of each sample was 5 (Fig. 2). Figures 3 and 4 show completed samples and their size.



Cntent of pre-cast ingot by percentage		0%	25%	50%	75%	100%
Total weight (g)	Virgin metal	10	7.5	5	2.5	0
	Pre-cast ingot	0	2.5	5	7.5	10

Fig2. Sample preparation method

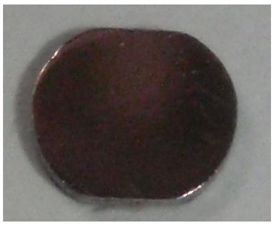


Fig3. Sample

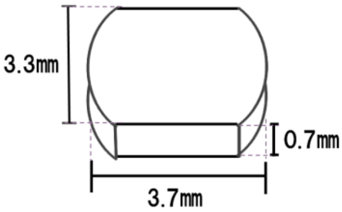


Fig4. Sample Size

2.2 Attractive force measurement

Magnetic assembly GIGAUSS C600 was used, and attractive force between the samples and magnetic assembly was measured using a compact table-top universal tester machine EZ test (SHIMAZU) 10 times for each sample at 5 mm / min crosshead speed. A custom-made jog devised by Tanaka et al. (1)(2) was attached to EZ test (Fig. 5). Samples were fixed to the mold using instant adhesive so that magnetic assembly and keeper adsorption face are tightly adhered.

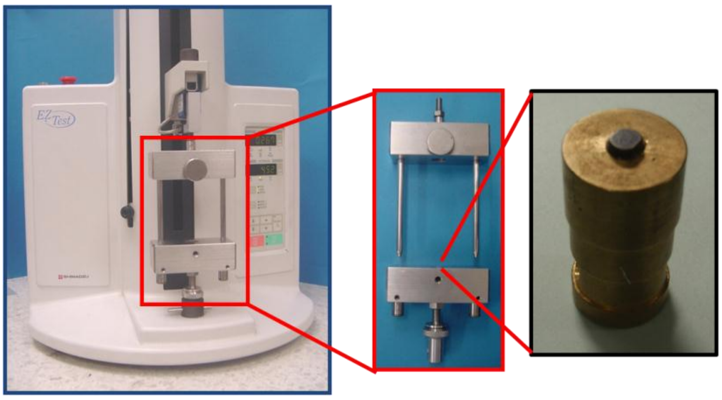


Fig5.   Compact Table-top universal tester Ez-test & special JIG

2.3 Constituent element analysis method

Constituent element analysis was performed using an electron probe micro analyzer JXA-8340F (JEOL). Constituent elements were identified by point analysis, followed by the surface analysis of 2 x 3 mm area using a probe with 9 μm diameter.

In addition to observation of the adsorption face of each sample, arbitrary face of the ingot surface was observed as a control.

2.4 Statistical analysis

Attractive force measurement and constituent element analysis were performed for each sample. Pearson's product-moment correlation analysis was performed for each result to investigate factors affecting the change of attractive force.

Results

Attractive force decreased with an increase of hearth content. Constituent element analysis revealed that Co content in samples decreased and segregation of samples is more likely to happen with an increase of hearth content.

Regarding Co content in samples, Co w% on the observation surface in sample was employed as an approximate value of Co content in samples.

Since the segregation phase is rich in Ag, the area with more than 45% Ag content in the Ag mapping image was regarded as the segregation phase. Segregation phase area ratio on the adsorption face in samples was calculated based on Ag content.

Statistical analysis result revealed a moderate correlation between attractive force and Co content, attractive force and area ratio of the segregation phase on adsorption face (segregation phase ratio), hearth and Co contents, and attractive force and Co at 1% significance level. There was a minor correlation between hearth content and segregation phase ratio (Table 2, Figures 6, 7, 8, 9 and 10).

Table2.   Attractive force, Co contents,   segregation phase ratio,   hearth content

Sample No	Attractive Force(gf)	Co Content (%)	Segregation Phase Ratio (%)	Hearth Content (%)
1	278	34.42	0.8	0
2	275	34.22	2	0
3	263.7	34.49	2.1	0
4	251.5	32.08	10.2	0
5	268.8	32.85	4.9	25
6	260.5	32.75	7.3	25
7	260.4	31.05	12.3	25
8	254.3	31.6	11.8	25
9	250.4	31.47	9.7	25
10	270.1	34.58	3.4	50
11	258.1	32.98	7	50
12	255.3	32.56	6.4	50
13	251.2	34.04	3.9	50
14	249.5	31.31	14.1	50
15	242.6	33.6	2.9	50
16	262.2	33.1	3.5	75
17	260.4	32.88	7.3	75
18	259.5	33.5	4.9	75
19	246.1	30.41	9.4	75
20	240.3	32.24	5.5	75
21	260.7	30.56	6.2	100
22	255.1	32.36	9	100
23	247.9	30.26	15.2	100
24	246.5	29.56	14.5	100
25	235.4	31.17	11	100

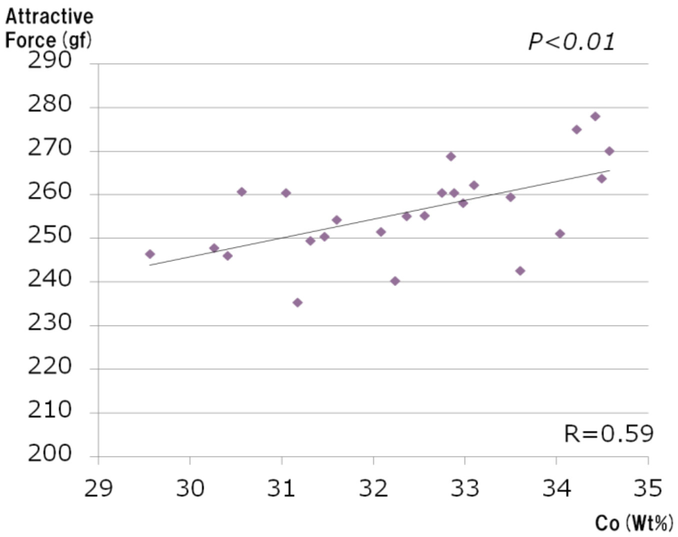


Fig6. Attractive force - Co contents

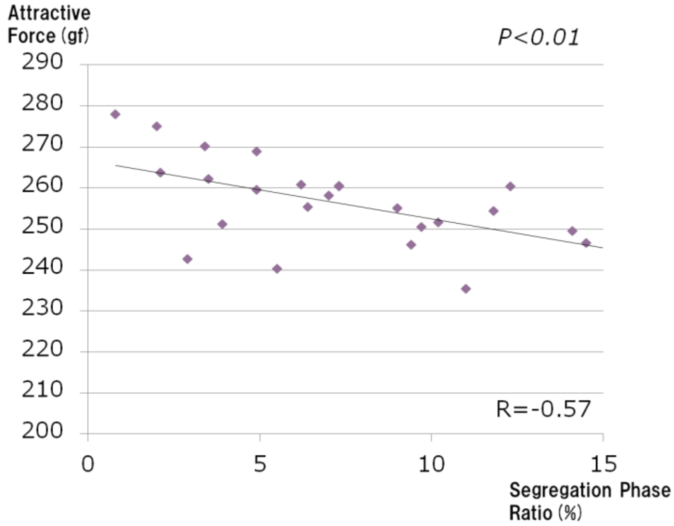


Fig7. Attractive force - hearth content

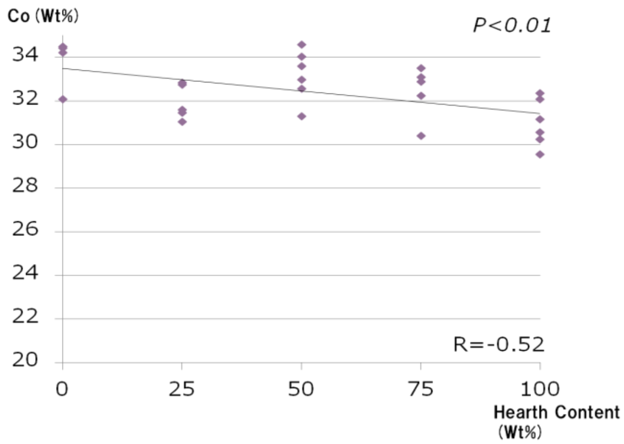


Fig8. hearth content - Co contents

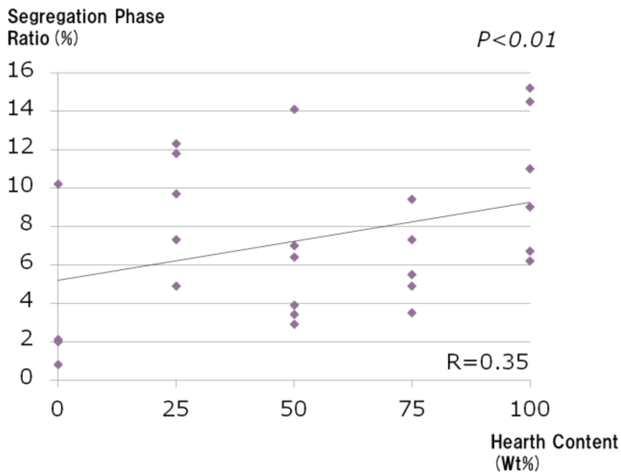


Fig9. segregation phase ratio - hearth content

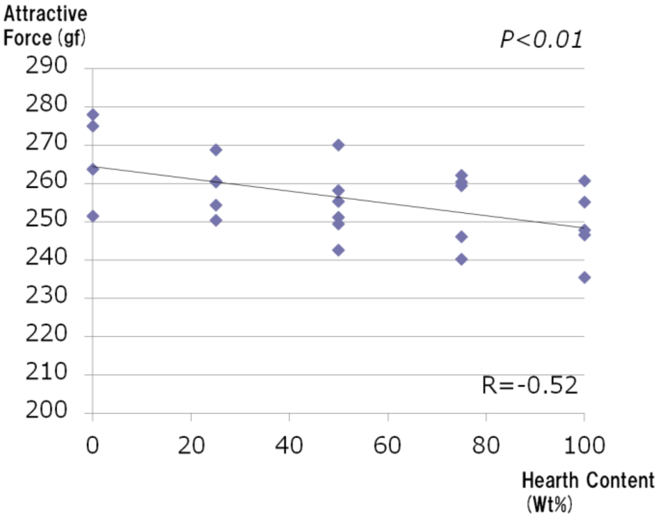


Fig10.　hearth content - Attractive force

Constituent element analysis of an ingot confirmed the area with multiple segregations (Fig. 11).

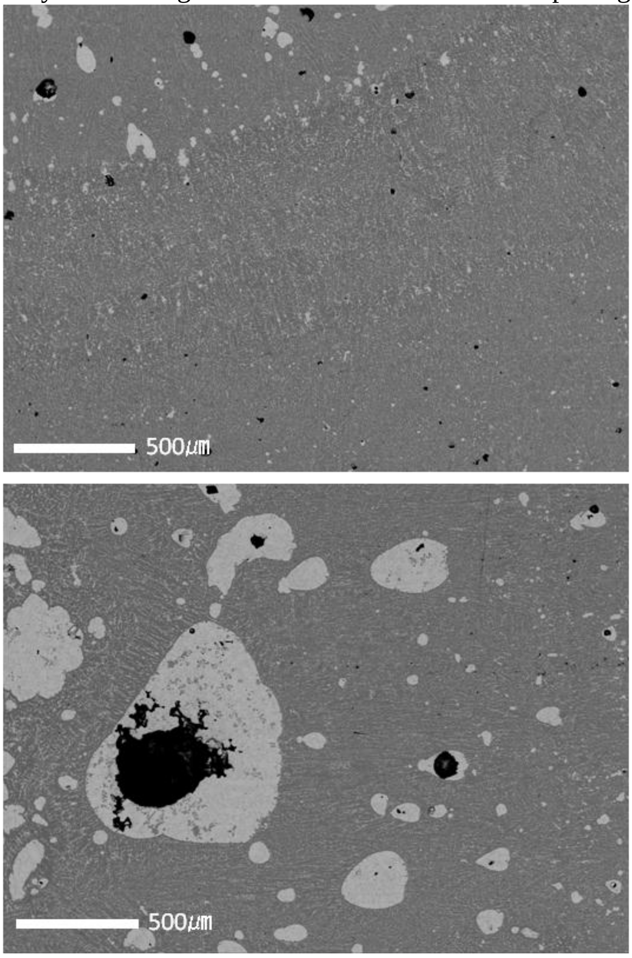


Fig11.　SEM of an Ingot

Point analysis of the segregation phase showed that the main component of the segregation phase was Ag-Pd, whereas that of base alloy was Co-Pd (Fig. 12).

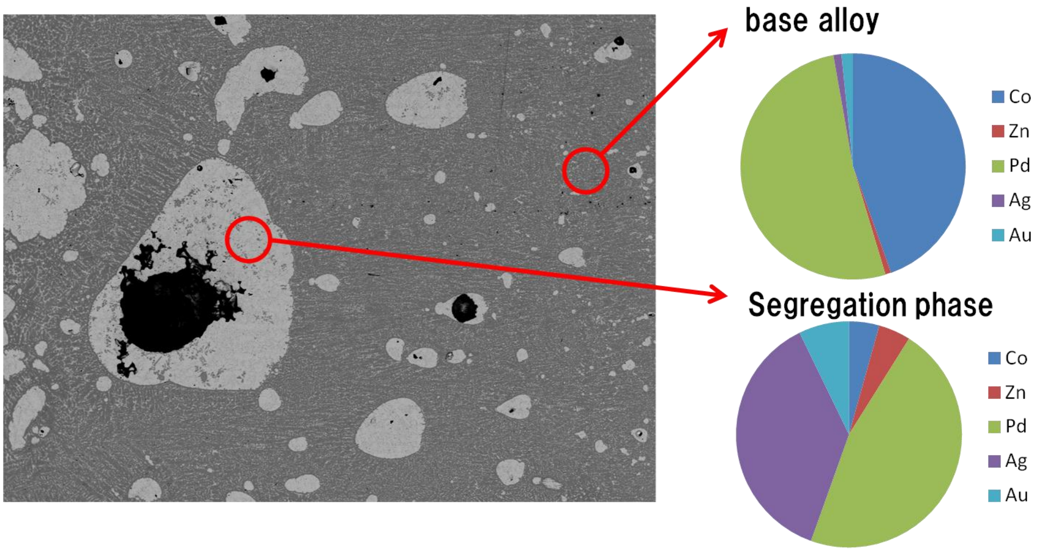


Fig12. Result of point analysis

Discussions

1. Hearth and Co contents

A moderate correlation between hearth and Co content is considered to be due to the lost Co contained in the removed oxidized layer. Oxidized layers are formed not only on the surface of the hearth but also on the contact surface with the investment material, and were observed on the surface of the cast. (Fig. 13) It is recommended to perform the process from melting to casting in argon atmosphere to prevent oxidization of the metal.

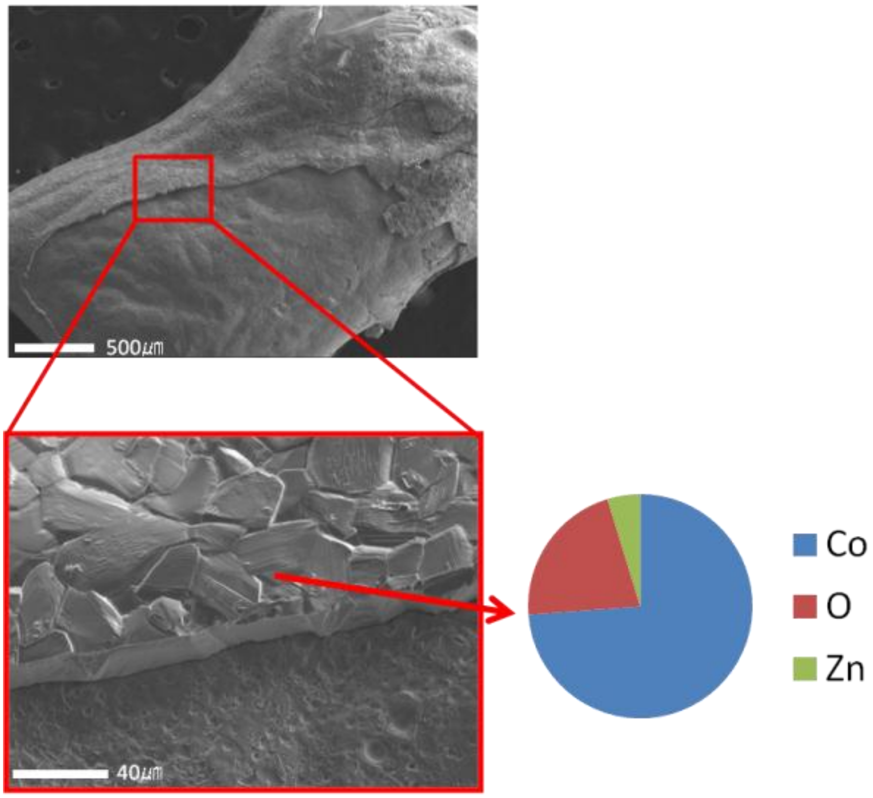


Fig13.　Oxidized layers

2.　Hearth content and segregation phase ratio

Segregation was observed on all the sample surfaces. The correlation between the size and amount of segregation and hearth content was weak. It is considered that composition of Attract P easily forms segregation regardless of the use of hearth.

Considering segregation phase was commonly observed in the ingot, the influence of biased segregation caused by coagulation condition of a cast is higher than hearth content.

3.　Attractive force and Co content

Co is a strong magnetic body, and is considered to be involved in magnetic property. Okamoto et al(3) reported that Au-Co alloy shows magnetic property in 8 ? 82 wt%, and Pd-Co alloy shows magnetic property in more than 5 wt%.

Considering there was a moderate correlation between Co content and attractive force, Co content is considered to affect attractive force.

The Co amount of the adsorption face in samples was analyzed and evaluated in the present study. The overall Co content may change if larger segregation exists in the deeper area. Melting samples and measuring accurate Co content may confirm stronger correlation.

4.　Attractive force and segregation phase ratio

The segregation phase was observed only on the adsorption face, and the size of segregation phase varied from 10 μ to 500 μm in diameter. Although the influence of segregation phase with a small diameter on attractive force may be small since the master alloy is situated just below the segregation phase, that with a large diameter may cause decrease in attractive force in a similar way as air gap.

A moderate correlation was observed between attractive phase and segregation phase ratio in the present study. Although the size of segregation phase was not considered, the influence on attractive force may be different between multiple segregation phases with a small diameter and a few segregation phases with a large diameter despite of the same area ratio.

The size of segregation phase affecting attractive force needs to be investigated. It is also necessary to confirm the relationship between segregation phase with a large diameter and attractive force.

Conclusions

Moderate correlation was observed between hearth and Co contents, attractive force and Co content, and hearth content and attractive force. The results suggested that Co content decreased after recasting using a hearth, resulting in a decrease in attractive force.

A hearth in the present study was formed after casting once from the virgin metal. However, a hearth is repeatedly used in clinical practice, and it is concerned that composition of the alloy significantly changes.

The composition of the base alloy after casting using a repeatedly-used hearth needs to be confirmed.

References

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