Studies on the Castability of Co-Cr Alloy for Cast Plates

Part 2: Effect of Form of Sprue Attachment to the Wax Pattern

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Abstract

Co-Cr alloy is used more frequently than Ni-Cr alloy as a non-precious alloy for cast plates in Japan. However, since the melting point of Co-Cr alloy is very high, about 1300°C, and since it oxidizes easily, a vacuum-pressure casting machine capable of melting this alloy in a reducing atmosphere has recently been developed.

Using this vacuum-pressure casting machine, the authors studied the effects on the castability of Co-Cr alloy due to the form of sprue attachment to the wax pattern.

The results clarified that in the vacuum-pressure casting method, the form of sprue attachment to the wax pattern has a significant effect ($p < 0.01$) on the castability of Co-Cr alloy.

Introduction

Because of its superior characteristics including hardness, elongation and tensile strength, Co-Cr alloy is frequently used as a denture base non-precious alloy^[1]. The melting point of this alloy, however, is extremely high, around 1300°C, so that the casting has to be done using a vacuum-pressure casting machine in which the alloy is melted in either a vacuum or an oxygenless (reducing) atmosphere^[2].

A large number of studies have been made on the castability of precious alloys with melting points below 1100°C, using the spring-propelled broken-arm method, but studies on the castability of Co-Cr alloy have been very limited.

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The aim of the present study was to clarify the castability of Co-Cr alloy for a denture base using a vacuum-pressure casting machine. The authors had earlier investigated an upper complete denture plate using an upper complete edentulous model to study the effects on castability of sprue attachment direction and investment direction in a refractory model. The results clearly showed that both factors significantly affected castability^[1].

This study investigated experimentally the effect of the form of sprue attachment to the wax pattern.

Materials and Methods

1. Materials

A refractory model was made using a phosphate-bonded casting investment (Hi-Vest D, SHOFU Inc.).

Two types of Co-Cr alloy were used for making the metal plates. One was a Co-Cr alloy containing 0.5%/wt titanium (SHOFU Inc., Summalloy Cobalt; referred to hereafter as “Co-Cr alloy”) and the other, a Co-Cr alloy containing 5% /wt titanium (SHOFU Inc., Summalloy Titanium; “Co-Cr-Ti alloy”) (Table 1).

Table 1 Materials

Alloys	Components (%)		Brand	Manufacturer	Batch No.
Co-Cr Alloy	Co	61.0	Summalloy cobalt	SHOFU	048521
	Cr	26.0			
	Ni	—			
	Mo	7.0			
	Mn	—			
	Ti	0.5			
	others	5.5			
Co-Cr-Ti Alloy	Co	40.0	Summalloy titanium	SHOFU	048631
	Cr	23.0			
	Ni	28.0			
	Mo	—			
	Mn	—			
	Ti	5.0			
	others	4.0			

2. Methods

1) Construction of the Refractory Model

The original model used for making the cast plate was an upper complete edentulous plastic model (Nissin Dental Products Inc., 402-U). The refractory model was made by taking an impression of the plastic model with silicone rubber impression material, using phosphate-bond investment. This model was then dried for 1 h in a drying oven at 110°C and immersed in a model-coating solution for 30 s.

2) Waxing

Identical original wax pattern forms were made using #28-gauge sheet wax, these wax patterns were then placed at prescribed locations on the refractory model.

3. Investment

1) Forms of sprue

Forms of sprue tip attached to wax patterns can be divided roughly into two categories: forms seen from the frontal plane (referred to hereafter as frontal form) and forms seen from the sagittal plane (referred to hereafter as sagittal form). The frontal form was further subdivided into three forms: one with a parallel tip (referred to hereafter as a parallel gate), one with a gradually widening tip (referred to hereafter as an open gate) and one with a tapered tip (referred to hereafter as a closed gate). The sagittal form was further subdivided into two types: one with a parallel tip (referred to hereafter as parallel type) and one with a tapered tip (referred to hereafter as closed type) (Fig. 1).

2) Combination of wax sprue forms

In this experiment, six combinations of sprue form were used for casting, as shown in Fig. 2. These were a combination of parallel gate and parallel type (referred to hereafter as P-P), open gate and parallel type (referred to hereafter as O-P), closed gate and parallel type (referred to hereafter as C-P), parallel gate and closed type (referred to hereafter as P-C), open gate and closed type (referred to

Fig. 1 Wax sprue form

Fig. 2 Combination of wax sprue form

hereafter as O-C), and closed gate and closed type (referred to hereafter as C-C).

3) Investment method

Based on the results obtained in Part I, the direction of attachment of the wax sprues was established as rear attachment, in which two wax sprues ($\phi 4 \times 30$ mm) were attached from the rear of a wax palatal plate^[1]. For the investment of a refractory model, we used horizontal investment in which the model is invested vertically to the long axis of the casting ring.

4) Casting and Polishing

For casting using the Co-Cr and Co-Cr-Ti alloys, we used a vacuum-pressure casting machine (SHOFU Inc., Argon caster-DX) capable of casting by melting the alloy under an atmosphere of argon gas.

The casts were polished by sandblasting with carborundum sand with a particle size of 300 μm (SHOFU Inc.).

A total of 60 plates were cast as sample casting plates: five plates for each of the six combinations of sprue forms, using both Co-Cr alloy and Co-Cr-Ti alloy.

5) Measurement of Cast Ratio

The cast ratios in this experiment were obtained by the following process. First, the surface area of the original wax-pattern form of the plate was measured, followed by the surface area of the upper metal plate, and finally, the cast ratio was obtained from the ratio of the surface area of the cast plate relative to that of the wax pattern^[1].

For these area measurements, the authors used an image-analysis system (Model LA-500, PIAS Co.). The surface area of the original wax-pattern form was found to be 2245 mm² using this system.

Results

1. Cast ratios for the six combinations of sprue forms using Co-Cr alloy

Table 2 and Fig. 3 show the cast ratio for each of the six combinations of

Code Alloys		P-P	O-P	C-P	P-C	O-C	C-C
Co-Cr alloy	Mean	84	100	75	77	59	51
	(S. D.)	(9)	(0)	(11)	(7)	(11)	(11)
Co-Cr-Ti alloy	Mean	99	100	97	94	98	81
	(S. D.)	(2)	(0)	(2)	(2)	(2)	(12)

unit: %

sprue forms. As the table clearly shows, the cast ratio for O-P was 100% and that for C-C, 51%, which was the lowest ratio of all the six combinations of sprue forms.

Casting defects in each of the six combinations are shown in Fig. 4.

In the cast using Co-Cr alloy, sprue form had a significant effect on the cast ratio ($P < 0.01$), for either the frontal or sagittal form, as clearly shown in the results of analysis of variance in Table 3.

2. Cast ratios for the six combinations of sprue forms using Co-Cr-Ti alloy

Fig. 3 Cast ratios of Co-Cr Alloy

The cast ratio for each of the six combinations of sprue forms is shown in Table 2 and Fig. 5. As the table clearly shows, the cast ratio for O-P was 100% and that for C-C, 81%, which was the lowest ratio of all the six combinations of sprue forms.

Examples of casting defects in each of the six combinations of sprue forms using Co-Cr-Ti alloy are shown in Fig. 6.

In the cast using Co-Cr-Ti alloy, sprue form had a significant effect on cast ratio ($P < 0.01$), in either the frontal or sagittal form, as clearly shown in the results of analysis of variance in Table 4.

3. Comparison of cast ratios between Co-Cr alloy and Co-Cr-Ti alloy

Table 5 and Fig. 7 show a comparison of the cast ratios between Co-Cr and Co-Cr-Ti alloy for the six combinations of sprue forms. As Table 5 clearly shows, there was no significant difference between the ratio for Co-Cr alloy and that for Co-Cr-Ti alloy in O-P, but with the other combinations there was a significant difference ($P < 0.01$).

Table 3 ANOVA table for Co-Cr alloy according to sprue form

	SS	df	V	F
A	4233.56	1	4233.56	50.43**
B	1971.9	2	985.948	11.75**
A×B	1479.1	2	739.551	8.88**
E	2014.69	24	83.9454	
T	9699.24	29		

A: sagittal form B: frontal form ** : $P < 0.01$

Table 4 ANOVA table for Co-Cr-Ti alloy according to sprue form

	SS	df	V	F
A	380.208	1	380.208	11.90**
B	586.562	2	293.281	9.18**
A×B	294.482	2	147.241	4.61**
E	766.868	24	31.9528	
T	2028.12	29		

A: sagittal form B: frontal form ** : $P < 0.01$

Fig. 4 Casting defects according to sprue form for Co-Cr alloy
upper: left to right (P-P, O-P, P-C)

Fig. 5 Cast ratios of Co-Cr-Ti alloy

Fig. 6 Casting defects according to sprue form for Co-Cr-Ti alloy
upper: left to right (P-P, O-P, P-C)
lower: left to right (P-C, O-C, C-C)

Fig. 7 Cast ratios of Co-Cr alloy and Co-Cr-Ti alloy

Table 5 ANOVA table for Co-Cr alloy and Co-Cr-Ti alloy

sprue form	P-P	O-P	C-P	P-C	O-C	C-C
	**	—	**	**	**	**

** : $P < 0.01$

Discussion

In the spring-propelled broken-arm casting method, the contact area between the sprue and the wax pattern is reported to affect the castability^[3], i. e. the larger the area, the higher the castability^[4]. In their report on the forms of sprue attached to wax patterns, NOMURA and MORI^[5] reported that the open gate in the frontal form and the tapered form in the sagittal form have a favorable effect on castability.

In the present study we investigated the effect of sprue form on the castability of both Co-Cr alloy and Co-Cr-Ti alloy, using a vacuum-pressure casting method. The results for both alloys showed that the combination of an open gate in the frontal form and of the parallel type in the sagittal form produced the highest castability. Comparison between the two alloys showed that castability was significantly higher with Co-Cr-Ti alloy than with Co-Cr alloy when the combination was P-P.

With the vacuum-pressure casting method, the highest castability was obtained with an O-P sprue form. This is because the sprue's cross-section in contact with the wax pattern is maximal, allowing the molten alloy to flow with least resistance. In other words, cross-sections of different sprue forms are believed to affect the castability of both alloys (Tables 3, 4).

In the vacuum-pressure casting method using both alloys, the molten alloy presumably flows from the rear part of the plate along the border of the plate, and finally fills the palatal part of the plate (Figs. 4, 6).

Comparison between Co-Cr-Ti alloy and Co-Cr alloy showed that the cast

ratio of Co-Cr-Ti alloy is higher than that of Co-Cr alloy probably because of the difference in the components of each (Table 1).

Conclusions

1. The highest cast ratio was obtained when the sprue form was a combination of the open gate of the frontal form and the parallel type of the sagittal form.
2. The frontal form and the sagittal form of sprue significantly ($P < 0.01$) affected the castability of both Co-Cr alloy and Co-Cr-Ti alloy.
3. When the castabilities of Co-Cr alloy and Co-Cr-Ti alloy were compared in each of the six types of sprue form, it was established that Co-Cr-Ti alloy had significantly higher ($P < 0.01$) castability than Co-Cr alloy in five types with the exception of the O-P type.

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