Effect of Casting Machine on Nickel-Chromium Alloy Castings for Fixed Prosthesis

Part 1. Change in Tensile Strength

Kiyoshi TAJIMA, Hiroshi KAKIGAWA, Yoshio KOZONO and Ichiro HAYASHI

Department of Materials Science, Kyushu Dental College, 2-6-1 Manazuru, Kokurakita, Kitakyushu 803, Japan

Received on March 31, 1986

The effect of the type of casting machine (Argoncaster, Acetron, Sure, Castmatic, Diner and Thermotrol) on the tensile strength of nine commercial Ni-Cr alloys for crown and bridge and for ceramo-metal restoration, and of two precious alloys for comparison was examined.

The tensile strength of both types of Ni-Cr alloys was greatly affected by the casting machine used, but not that of the precious alloys. There were significant differences in the effect of casting machine between the Ni-Cr alloys for crown and bridge and those for ceramo-metal. Argoncaster was relatively compatible with the Ni-Cr alloys for crown and bridge, while Diner and Castmatic showed better compatibility with the Ni-Cr alloys for ceramo-metal restoration.

Key words: Dental casting alloy, Dental casting machine, Tensile strength

INTRODUCTION

Many dental casting Ni-Cr alloys for fixed prosthesis are currently available. These Ni-Cr alloys are classified into two types, namely those for crown and bridge, and those for ceramo-metal restoration¹⁻⁴⁾.

For melting and casting the Ni-Cr alloys having high fusion temperatures, several high-energy heating sources such as arc, high frequency induction, and flame with oxygen-containing gas mixture are usually applied in combination with casting pressures such as centrifugal force, vacuum-pressure and suction-pressure. These various types of casting machines are commercially available⁵⁻⁷⁾.

Several reports⁸⁻¹¹⁾ have already been made on the representative melting methods for early nonprecious alloys intended for removable prosthesis. These evaluations, however, are not always applicable to current Ni-Cr alloys for fixed prosthesis. Although the surface roughness, castability, mechanical properties of a few current alloys have also been examined using several casting machines¹²⁻¹⁷⁾, which casting machine is preferable to produce consistently satisfactory Ni-Cr alloy casting has not been determined.

Several types of casting machines were compared in this study by examining the tensile strength of the casting for five commercially available Ni-Cr alloys for crown and bridge and four for ceramo-metal restoration.

MATERIALS AND METHODS

Table 1 shows the alloys used in this study along with their alloy composition as

Table 1 Alloys used

(%)

Alloy name	Code	Alloy composition published						Manufacturer			
		Ni	Cr	Si	Others						
Super Soft	SPS	93	6		1				Towa Giken Co., Osaka		
Summalloy Ni S.	SMS	84	9		7				Shofu Inc., Kyoto		
Suncolium U.S.	SCU	90	10						Sankin Industry Co., Osaka		
Taicrown	TCR	82	13		5				Taisei Industry Co., Osaka		
Nirostar	NST	72	19	6	3				Nippon Shiken Dental Co., Tokyo		
		Ni	Cr	Mo	Fe	Al	Others				
SB • Bondloy I	SBB	56.4	17.4	12.4	9.9		3.9	Towa Giken Co., Osaka			
Nichrome Bond	NCB	59	20	15			6	Sankin Industy Co., Osaka			
Negium	NGM	53	30	6.5		5	5.5	Towa Giken Co., Osaka			
Uni Metal*	UNM	77	14.9				8.1	Shofu Inc., Kyoto			
		Au	Ag	Pd	Cu	Others					
Casting Gold Type III M.C.	CGIII	75	7	3	15					G-C Dental Industry Corp., Tokyo	
Castwell M.C.	CWL	12	45	20	15	8					G-C Dental Industry Corp., Tokyo

* Beryllium is known to be present, but the amount is uncertain.

Table 2 Casting machines used

Casting machine	Heating source	Atomosphere	Pressure type	Manufacturer
Argoncaster-DX	High frequency induction	Argon gas in chamber	Vacuum-pressure	Shofu Inc., Kyoto
Acetron SA-200	High frequency induction	Air	Centrifugal force	Sankin Industry Co., Osaka
Sure CV-51	A gas mixture flame*	Air	Centrifugal force	Yamano Dental Supply Co., Tokyo
Castmatic CM-230	Arc	Argon gas in chamber	Suction-pressure	Iwatani & Co., Osaka
Diner OAC-200	Arc	Argon gas blow in air	Centrifugal force	Ohara Co., Osaka
Thermotrol 2500	Electrical resistance	Air	Centrifugal force	J.F. Jelenko & Co., N.Y., U.S.A.

Each casting was performed with no flux.

* Propane gas-oxygen flame was used for Ni-Cr alloys, and town gas-air flame for precious alloys.

Graphite crucible was used.

Table 3 Investments used

Alloy	Investment	Investment type	Manufacturer
Ni-Cr	Ceravest	Phosphate-bonded	Taisei Dental Co., Osaka
CGIII	Harbar Vest	Cristbalite	Nitto Gypsum Co., Nagoya
CWL	Pallavest	Quartz	G-C Dental Industry Corp., Tokyo

provided by the manufacturer. The top five Ni-Cr alloys are for crown and bridge use, and the middle four are for ceramo-metal restoration. The bottom two are a conventional type III casting gold alloy and a casting Ag-Pd-Au alloy chosen as the control.

Six available casting machines were used (Table 2). Five casting machines, Argoncas-

ter, Acetron, Sure, Castmatic and Diner, were adopted for the Ni-Cr alloys, and three casting machines, Argoncaster, Sure and Thermotrol, were used for the precious alloys. When Sure was used, a propane gas-oxygen flame* was employed to melt the Ni-Cr alloys and a town gas-air flame[#] for the precious alloys.

Original rod patterns ($2.1 \phi \times 45$ mm) were longitudinally invested in the ordinal casting ring, using the investments shown in Table 3. The mold temperature was 800°C for the Ni-Cr alloys and 700°C for the precious alloys.

In the case of Castmatic, the alloy was automatically cast through its systematized process¹⁴⁾, and in Thermotrol the casting temperature was preset at the temperature approximately 100°C higher than the melting temperature for each alloy. The most suitable instant for the alloy to be cast was determined visually from the appearance of the molten alloy, except for Castmatic and Thermotrol. All the casting procedures were performed by a specific operator to avoid any possible individual deviations among the operators.

Six casting specimens of each Ni-Cr alloy and three specimens of each precious alloy were made with each casting machine. All castings were checked for cast tearing by the naked eye, and only the apparently undefective castings were subjected to tensile testing with a universal test machine^{\$} at a crosshead speed of 5 mm/min to determine the ultimate tensile strength.

RESULTS

Figure 1 shows the average tensile strength of the castings for Ni-Cr alloys for crown and bridge, Fig. 2 that for the Ni-Cr alloys for ceramo-metal restoration and Fig. 3 that for the precious alloys when each casting machine was employed. Cast-torn specimens were visually noticed in some of the castings made of Ni-Cr alloys for crown and bridge, and the numerals in Fig. 1 denote their numbers. The tensile strength of both types of Ni-Cr alloys were greatly affected by the type of casting machine used, as compared with that of the precious alloys. Considerable differences in the effect on the tensile strength were also observed between the crown and bridge type and the ceramo-metal type, and the changes were more liable to occur in the former than in the latter.

The results were subjected to a two-way analysis of variance to test the statistical significance among the alloy brands and the casting machines in each of the three types of alloys. The cast-torn Ni-Cr casting specimens, which had been already broken at deinvesting before the tensile test, were also subjected to the analysis, in which their values of the tensile strength were estimated to be 0 kgf/mm². There were significant differences both among the alloy brands ($p < 0.01$) and among the casting machines ($p < 0.01$) in each of the two Ni-Cr alloy types. Interactions between the above two factors were also found ($p < 0.01$). In the precious alloys, on the other hand, there was a significant difference only between the two alloys ($p < 0.01$), and no significant difference among the casting machines ($p > 0.05$).

Then, the t-test was performed to determine the differences among the casting machines

* Torch New OP Type, Nippon Iryoki, Tokyo

Torch DN-OP Type, Nippon Iryoki, Tokyo

\$ TCM 5000-C, Shinkoh, Tokyo

Fig. 1 Effect of casting machine on tensile strength of the Ni-Cr alloys for crown and bridge. Numerals in figure indicate the number of the castings broken during casting.

Fig. 2 Effect of casting machine on tensile strength of the Ni-Cr alloys for ceramo-metal restoration.

Fig. 3 Effect of casting machine on tensile strength of the precious alloys.

Table 4 Significance of the differences in the tensile strength among casting machines for each of the two Ni-Cr alloy types

a) Ni-Cr alloys for crown and bridge

A:Induc/Ar (53.0) ^s	-				
B:Flame/Air (37.8)	**	-			CI = ±3.3
C:Arc/Ar (35.1)	**	n	-		
D:Induc/Ar (33.2)	**	*	n	-	
E:Arc/Ar (b) (24.0)	**	**	**	**	-
	A	B	C	D	E

b) Ni-Cr alloys for ceramo-metal restoration

A:Arc/Ar(b) (74.2)	-					CI = ± 2.5
B:Arc/Ar (72.8)	n	-				
C:Induc/Ar (70.4)	*	n	-			
D:Flame/Air (66.1)	**	**	*	-		
E:Induc/Air (65.9)	**	**	*	n	-	
	A	B	C	D	E	

\$: mean tensile strength of all of the castings made by each casting machine, kgf/mm²

* : significant at $\alpha=0.01$

** : significant at $\alpha=0.05$

n : not significant at $\alpha=0.05$

CI : 95% confidence interval

for each of the two Ni-Cr alloy types (Table 4). In the crown and bridge type of alloys, the castings made by Argoncaster had the greatest strength with a statistical significance ($p < 0.01$) and those made by Diner had the smallest ($p < 0.01$). In the case of the ceramo-metal type, the castings made by Diner or Castmatic had significantly greater tensile strength than those made by Acetron or Sure ($p < 0.01$).

DISCUSSION

Dental casting Ni-Cr alloys have been introduced as alternatives to precious alloys. As

generally known, however, their properties are considerably different from those of the gold based alloys¹⁸⁻²²). In addition, Ni-Cr alloys are much more sensitive to the casting procedure than precious alloys^{23,24}). This study also revealed that the tensile strength of these alloys varied extremely with the casting machine used when compared with that of the precious alloys.

The commercially available Ni-Cr alloys are different in mechanical properties because of their large variations in composition^{18,21,25}). The user must choose an alloy on the basis of the clinical need by consulting the manufacturers' informations. The properties of the casting alloys, however, may occasionally vary with the process of fabricating the restoration. This study was focused on the effects of the type of casting machine used on the tensile strength of two types of the Ni-Cr alloys for fixed prosthesis.

There was no comparison between Argoncaster and Diner concerning their compatibility with the Ni-Cr alloys for crown and bridge. Argoncaster showed the best compatibility with all of the alloys, while Diner dramatically lowered the tensile strength to the level below the value provided by the manufacturer. As previously reported²³), the use of Diner caused marked gas uptake in some Ni-Cr alloys (Super Soft and Summalloy Ni Soft). Such a gas uptake may partly account for the deterioration of the castings when Diner is employed. The melting in an inert gas atmosphere is generally considered desirable for alloys being easily oxidized such as the nonprecious dental alloys^{7,26}). In both Argoncaster and Diner the alloys are melted in an argon gas atmosphere. However, the use of argon gas seems not always to be as effective in every casting machine as generally expected, the reason of which is uncertain. The two casting machines use different argon gas supplying methods as well as different heating sources (Table 2), and further studies will be necessary to clarify the relationships between them.

As mentioned above, Argoncaster was the most suitable casting machine for any of the Ni-Cr alloys for crown and bridge tested. In the case of the alloys for ceramo-metal restoration, on the other hand, the compatibility of the casting machine differed with the alloy brands used (Fig. 2). The statistical analyses showed the general tendency that melting in the air (Sure and Acetron) resulted in the decrease of tensile strength and melting in an argon gas atmosphere (Diner, Castmatic and Argoncaster) resulted in an increase as expected. It must be noted that Argoncaster could not always give the best results with the ceramo-metal type alloys as it could with the crown and bridge type alloys. Especially with the alloy Uni Metal (UNM), the tensile strength was much lower than the manufacturer's announcement when it was cast by Argoncaster (Fig. 2), indicating that Argoncaster was incompatible with this alloy. Thus, it is more difficult to predict the adequate alloy-casting machine combination in the Ni-Cr alloys for ceramo-metal than those for crown and bridge.

The significant differences seen between the two Ni-Cr alloy types and even among the alloy brands must be attributed to their different alloy composition. The contents of the primary elements, nickel and chromium, are substantially different between the two types; the crown and bridge alloys include higher amount of nickel and lower chromium than the ceramo-metal alloys. The content of these elements also differs with the alloy brand in each type. Such differences in composition, however, were not reflected on the variations of the tensile strength. The sensitiveness to the casting machine appears to result from the

additional elements such as deoxidizer. Further in the case of the ceramo-metal type, the presence of the inherent additives for improving the bond with porcelain, thermal expansion and other properties of the alloys^{4,19,20)} might make the alloy-casting machine combination more selective.

The casting procedure includes many manipulative variables in the stage of investing, melting and casting. From the results in this study it was found that the selection of the casting machine was one of the greatest factors affecting the tensile strength of the Ni-Cr alloy castings. There was no single almighty casting machine for all the Ni-Cr alloys used so far as the tensile strength was concerned. Therefore, it is inevitable, for the present, to select the optimum casting machine for each alloy. Improvements of the alloys and/or the casting machines are awaited to minimize the deterioration of the alloy by the casting procedure.

CONCLUSIONS

The effect of the casting machine on the tensile strength of several commercially available Ni-Cr alloys for crown and bridge and for ceramo-metal restoration, and of two precious alloys as the control was examined.

The following results were obtained.

- (1) The tensile strength of both types of Ni-Cr alloys were greatly affected by the casting machine used, as compared with that of the precious alloys.
- (2) The effect on the Ni-Cr alloys for crown and bridge was also considerably different from that on the alloys for ceramo-metal restoration.
- (3) Larger variations were liable to appear with different casting machines in the crown and bridge type alloys than in the ceramo-metal type alloys.
- (4) Argoncaster was generally compatible with the alloys for crown and bridge, while Diner was incompatible.
- (5) Diner or Castmatic was relatively compatible with the Ni-Cr alloys for ceramo-metal restoration, while Sure or Acetron was relatively incompatible with them.

REFERENCES

- 1) Nakamura, K., Goto, S., Yamatoya, F., Fukuda, T., Onozato, Y., Hasegawa, T. and Nakai, A.: Properties of casting nickel-chromium alloys for crown and bridge, *Shigaku* **73** (4): 930-945, 1985. (in Japanese)
- 2) Noguchi, H.: Porcelain veneering alloy today, *Quintessence* extra issue: 23-30, 1983. (in Japanese)
- 3) Shinya, A.: Study of the alloy used in porcelain fused to metal restorations, *Quintessence* **2** (6): 63-77, 1983. (in Japanese)
- 4) Bertolotti, R. L.: Selection of alloys for today's crown and fixed partial denture restorations, *J Am Dent Assoc* **108** (6): 959-966, 1984.
- 5) Nomura, J., Okada, H. and Nakaya, K.: Theoretical views of fabricating cast plates and practical laboratory procedures (19), *J Dent Technol* **10** (6): 519-532, 1982. (in Japanese)
- 6) Nomura, J., Okada, H. and Nakaya, K.: Theoretical views of fabricating cast plates and practical laboratory procedures (20), *J Dent Technol* **11** (1): 87-99, 1983. (in Japanese)
- 7) Yamaga, R., Tsutsumi, S. and Ida, K.: Non-oxygen casting of high fusing-temperature alloys and alloys for fused porcelain, *J Osaka Univ Dent Sch* **15**: 47-62, 1975.

- 8) Harcourt, H. J. and Cotterill, W. F. : Induction melting of cobalt-chromium alloys — a comparison with flame melting, *Brit Dent J* **118** (8) : 323-329, 1965.
- 9) Strandman, E. : The influence of carbon content of the mechanical properties in a cast dental Co-Cr alloy, *Odont Revy* **27** (4) : 273-286, 1976.
- 10) Lewis, A. J. : A radiographic evaluation of microporosity in a nickel base casting alloy, *Aust Dent J* **20** (4) : 221-226, 1975.
- 11) Nasu, T., Hikichi, H. and Noguchi, H. : On defect of cobalt-chromium-nickel alloy for dental castings, *J Japan Soc Dent Appar Mat* **19** (45) : 39-47, 1977. (in Japanese)
- 12) Phillips, R. W. : Skinner's science of dental materials, 8th ed., *W. B. Saunders Co.*, 1982, pp. 555-560.
- 13) Hayashi, H. : Nickel-chromium alloy casting by using an argon-arc casting machine 1. Surface roughness, *J Stomatol Soc* **44** (4), 293-302, 1977. (in Japanese)
- 14) Ida, K., Togaya, T., Takahashi, J., Yamaga, T., Yamada, T. and Nokubi, T. : The measurement of fusing time of alloys with various heat sources in dental casting, *J Japan Res Soc Dent Mat Appl* **35** (3) : 234-244, 1978. (in Japanese)
- 15) Ida, K., Tsutsumi, S., Togaya, T. and Takeuchi, M. : Structure and properties of new dental casting machine "CASTMATIC", *Bull Stom Kyoto Univ* **19** (Bound volume) : 33-44, 1979. (in Japanese)
- 16) Asgar, K. and Arfaei, A. H. : Castability of crown and bridge alloys, *J Prosthet Dent* **54** (1) : 60-63, 1985.
- 17) Kito, M. Honda, Y., Kawamura, N., Iwai, K. and Hasegawa, J. : The casting rate of Ni-Cr casting alloys for crown and bridge — effect of casting method —, *J J Dent Mat* **3** (4) : 508-514, 1984. (in Japanese)
- 18) Moffa, J. P. : Physical and mechanical properties of gold and base metal alloys. In Valega, T. M. ed. : Alternatives to gold alloys in dentistry. *DHEW Pub. No. (NIH) 77-1227*, 1977, pp. 81-93.
- 19) Kelly, J. R. and Rose, T. C. : Nonprecious alloys for use in fixed prosthodontics : A literature review, *J Prosthet Dent* **49** (3) : 363-370, 1983.
- 20) Baran, G. R. : The metallurgy of Ni-Cr alloys for fixed prosthodontics, *J Prosthet Dent* **50** (5) : 639-650, 1983.
- 21) Hasegawa, J. : Properties of Ni-Cr alloys for castings, *J J Dent Mat* **3** (5) : 547-553, 1984. (in Japanese)
- 22) Inoue, M., Tabata, T., Haga, M. and Yokotsuka, S. : Clinical evaluation of nickel-chromium alloys for crown and bridge work, *J Japan Prosth Dent* **28** (7) : 25-41, 1984. (in Japanese)
- 23) Tajima, K., Kakigawa, H., Kozono, Y. and Hayashi, I. : Oxygen and nitrogen uptake in dental Ni-Cr alloy castings by several melting methods, *Dent Mater J* **3** (2) : 262-271, 1984.
- 24) Reisbick, M. H. ed. : Dental materials in clinical dentistry, 1st ed., *John Wright • PSG Inc*, 1982, pp. 198-203 and 241-245.
- 25) Johnson, L. N. : The physical properties of some alternative alloys, *Int Dent J* **33** (1) : 41-48, 1983.
- 26) Ida, K. : Dental casting technique — for preventing casting defects —, *Bull Stom Kyoto Univ* **18** (Bound volume) : 1-15, 1978.

ついて高い評価が得られ他の床用材料にはみられない特長が示された。

以上、いくつかの基礎実験と臨床観察との結果を考え

合わせると、今後さらに改良すべきいくつかの点を残しているとはいえ TRUTISSU は床用材料として有用な材料であることが理解できた。

コンポジット型接着性オペークレジンに関する研究

松村英雄*, バルガ・ユディト**, 増原英一*

*東京医科歯科大学医用器材研究所有機材料門

**東京医科歯科大学歯学部第二歯科補綴学教室

コンポジット型接着性オペークレジンの諸性質を検討した。このレジンで同種合金どうしを接着した場合、Sn 電析処理をした Type IV 金合金や金銀パラジウム合金、およびサンドブラスト処理したステンレス鋼などはすぐれた接着耐久性を示した。一方、このレジンで硬質レジ

ンと合金を接着する場合は、操作性に改善の余地が認められた。その他、光重合型歯冠用硬質レジンの物性に対し、熱と照射時間が影響を及ぼしていることが明らかとなった。

クラウン・ブリッジ用および陶材焼付用 Ni-Cr

合金 casting 体に及ぼす casting 機の影響 —— (第 1 報) 引張強さの変化 ——

田島清司, 柿川 宏, 小園凱夫, 林 一郎

九州歯科大学歯科理工学講座

市販のクラウン・ブリッジ用および陶材焼付用 Ni-Cr 合金 9 種類を、5 種類の歯科用 casting 機を用いて溶融・ casting し、 casting 機による casting 体の引張強さの差異を調べた。また貴金属系合金 2 種類を 3 種類の casting 機により溶融・ casting し、Ni-Cr 合金の場合と比較した。

Ni-Cr 合金の引張強さには貴金属系合金の場合に比べて、使用した casting 機が大きく影響を与えていた。この影響は Ni-Cr 合金のタイプ別、さらに同じタイプでも合金ごとに異なっており、特に、クラウン・ブリッジ用合金

では著しい引張強さの変化が認められた。本実験に用いた casting 機の中で、クラウン・ブリッジ用 Ni-Cr 合金にはアルゴンキャスター（アルゴンガス雰囲気溶融＋真空加圧 casting）が、一方陶材焼付用 Ni-Cr 合金にはダイナー（大気中アルゴンガス吹付けアーク溶融＋遠心 casting）あるいはキャストマチック（アルゴンガス雰囲気アーク溶融＋吸引加圧 casting）が、引張強さの高い casting 体を与える傾向にあった。

EVA-MMA-TBBO 接着性コンポジット材料の根管充填剤としての評価

陳 中和*, 藤沢盛一郎**, 張 伯寅***, 増原英一****

*高雄医学院, 牙医学系口腔外科

**東京医科歯科大学歯学部総合診断部門

***高雄医学院牙医学系材料部門

****東京医科歯科大学医用器材研究所有機材料部門

EVA-MMA, AH26, Super bond, 酸化亜鉛ユーージノールを用いて透過性テストを行ない、根管封鎖性を評価した。EVA-MMA, AH26, Super bond は酸化亜鉛ユーージノールより封鎖性が良かった。EVA コンポジットは根

管壁適合に対し最も良好な性質を示した。EVA-MMA, KP-MMA, ハイドロキシアパタイト (HAP) をサルの抜歯窩にインプラントする系と EVA-MMA, KP-MMA, PMMA をラットの皮下にインプラントする系