広大歯誌 26, 284-289, 1994.

A Study on Gold Alloys for Dental Casting

Kunio Wakasa and Masao Yamaki

(Received for publication, April 5, 1994)

ABSTRACT

Dental gold alloys were developed for crown and bridgework, changing the metal additives in gold alloys including Au, Pd and others, and also examining commercial dental reduced Au-containing alloys. First, newly-designed Au/Ag/Pd-based alloys (A series) contained In and Zn as the metal additives, showing that the increased Pd content exhibited the increased hardness number ranging approximately from 150 to 250 for interdendrites and dendrites as the cast structure, associated with the increased percentage of dendrites (71 to 84%). Second, for Au/Pd-based alloys (B series), the interdendrite and dendrite structures showed different magnitudes of hardness number. The metal additives in Au/Pd-based alloys affected the formation of interdendrite structures with below 100 and dendrite structures with about 220 for B2 gold alloy, and also about 150 (interdendrites) and above 220 (dendrites) for the others B1 and B3. The results demonstrated that metal elements in developed gold alloys modified the hardness number within a wide range and the dendrite matrix phase controlled the cast structures.

INTRODUCTION

Gold alloys for dental casting contained mainly as Au, Ag, Cu and Pd as the chemical compositions[1-5]. The precious gold alloys were improved by the metal additives for crown and bridge applications. The precious alloys were specified by their compositions, and the additives affected the parameters to change the structures and mechanical property in gold alloys and aluminum-copper alloys[6-10]. The addition of metal element showed a wide range of hardness number because of dendrite structure after casting. In general, the alloy structure was composed of a well-developed dendrite structure[1-10]. The effect of cast structure on hardness number was observed for dental gold cast alloys containing Au, Ag, Cu and [7,9]. Clinically, high Au alloys (70 to 90% Au), reduced Au alloys (20 to 60% Au) and Ag/Pd alloys (0 to 10% Au) were used[11], showing 470 MPa as a proportional stress (high Au), 425 MPa (reduced Au) and 462 MPa (Ag/Pd alloy). High Au and reduced Au alloys corresponded to Type III or Type IV, and low Au/Ag/Pd-based ones were similar to high Au alloys.

Consequently, to clarify the characteristics of the structures in dental gold alloys, Au/Ag/Pd-based alloys containing Au, Ag and Pd as a constituent metal and In and Zn as the additives were made experimentally, and also reduced Au/Pd-based alloy systems with 150 to 220 as the hardness number for crown and bridge applications were developed based on the corroded structures.

MATERIALS AND METHODS

Alloy systems tested were six types of experimental gold alloys and two commercial gold alloys (Table 1). For A1, A2 and A3 alloys, the low-fusing additives In and Zn were added to the matrix phase, whereas such metal additives were not added to B1, B2 and B3 gold alloys. The detail was not described for the patent of Au/Pd-basaed alloys in this study. The condition to measure hardness number on cast surface was used as reported previously[12,13]. The test samples (5 pieces) were cast by centrifugal casting with high frequency melting (Castron 8, Yoshida Co, Tokyo). The gypsum-bonded investment Cristobalite P (Shofu Inc, Kyoto) was used for all gold alloy samples tested. The casting procedures were carried out similar to the previous study[12].

Hiroshima University School of Dentistry, Department of Dental Materials (Chairman; Professor Masao Yamaki).

Correspondence to *Dr K. Wakasa*;

Hiroshima University School of Dentistry, Department of Dental Materials, Kasumi 1 chome, Minami-ku, Hiroshima City, 734 Japan.

Table 1 Gold alloys developed and tested. See text for key.

Materials	Code	Chemical composition (wt %) Au	Ag	Cu	Pd	Others
Alloys	A1	20	43	—	20	In (13), Zn (4)
	A2	25	28	—	30	In (13), Zn (4)
	A3	20	25	—	35	In (16), Zn (4)
	B1	15	*	*	17	*
	B2	20	*	*	16	*
	B3	25	*	*	15	*
Hojo White Gold	C1	29	29	—	18	Pt (3), R
GC Castwell MC	C2	12	47	18	20	R

*not described for the patent. R means the residual elements (unknown).

The properties measured were the microstructural features and Vickers hardness of gold alloys. The test samples after casting were polished using the same procedures as the previous studies[13-15]. The metallographic etch to observe photomicroscopically the crystalline grains of cast samples was performed using 10% Nital etchant (10 mL HNO_3/90 mL ethanol)[15]. The hardness values were measured when 200 gram load was applied to the specimen (15×20×2.5 mm). The reported values mean the range obtained for five test samples for each gold alloy.

RESULTS

Fig. 1 shows Vickers hardness number in gold alloys A1, A2 and A3, representing that the magnitude increased with increasing Pd content in Au/Ag/Pd-based gold alloys. And also the percentages of dendrites were 71 (7) for A1, 71 (4) for A2 and 84 (5) for A3. There was no difference of hardness between the interdendrite (not-etched) and dendrite (etched).

Fig. 2 shows the hardness number in gold alloys B1, B2 and B3, representing that the magnitude was different for the interdendrite (etched) and dendrite structures (not-etched) when Au addition increased from 15 to 25%. The hardness number ranged less 100 and around 150, whereas the values for the dendrites were about 220 (B2), or more than 220 (B1, B3).

The cast microstructures were shown in Fig. 3 (A1, A2 and A3 gold alloys) and Fig. 4 (B1, B2 and B3 gold alloys). The structures were composed of dendrite structure and also interdendrite structure between the dendrites. Typically the dendrite structure was corroded by the etchant for Au/Ag/Pd-based alloys A1, A2 and A3. On the contrary, the Au/Pd-based alloys exhibited interdendrite structures in gold alloys B1, B2 and B3. These microstructure characteristics affected a wide range of hardness number.

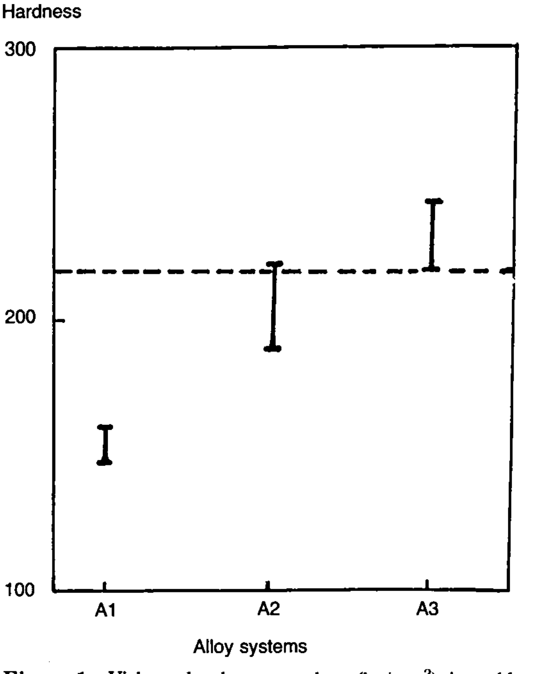

Figure 1 Vickers hardness number (kg/mm^2) in gold alloys A1, A2, A3. Dotted line shows hardness value for age-hardened gold alloys Type IV.

DISCUSSION

An analysis was performed for Vickers hardness values and crystalline grains. The cast structure by the metallographic etch is an important parameter with the hardness

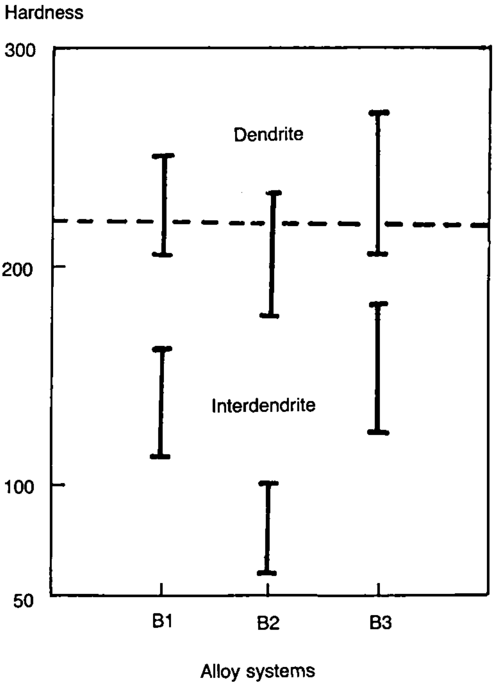

Figure 2 Vickers hardness number in gold alloys B1, B2, B3. See Table 1 for key.

number. For examples[16,17], dental Ni-based alloy systems tested were classified by two soft and hard systems, showing that hardness number was ranging from about 150 to 220 (extra soft and soft types) and more than 220 (hard and extra hard types), referring to the specification of casting gold alloys.

In this study, dental casting gold alloys were also specified as the Type I alloy (extra soft; Vickers number of less than 90, softened), Type II (soft; ranging from 90 to 120), Type III (hard; range between 120 to 150) and Type IV (extra hard; 150 or above after a softening treatment, and more than 220 for age-hardened condition)[17]. As a control alloy the hardness numbers of C1 and C2 were respectively 170 (5) and 125 (5), showing the specification of gold alloys Type III or Type IV. During casting, gypsum-bonded investment (Cristobalite P) was used to cast the gold alloys tested, and the layer between the investment and metal was removed using ultrasonic cleansing, because the adherent oxide layers or attached investment powders were not found.

As expected in Figs. 1 to 4, the improvement of the alloy structure was done by metal additives in case of gold alloys. Pd content in Au/Ag/Pd-based alloys controlled the magnitude of hardness number (Fig. 1), and the metal element Au in Au/Pd-based alloys affected the structure parameter (Fig. 2). The parameter to represent hardness number was either interdendrites or dendrites as a structure parameter (Fig. 2). Based on the results in Figs. 3 and 4, gold alloys is developed by the metal additivess. On the contrary (dental Ni-based alloys)[18−20], such additives as molybdenum, cobalt, silicon and manganese exhibited the increased values of hardness and tensile properties as compared with binary Ni-Cr-based alloys. Each metal additive was effective to change the cast microstructures in Au/Ag/Pd-based or Au/Pd-based alloy, exhibiting the increased hardness number with the metal additives.

The difference of corroded structures between interdendrites and dendrites was observed (Figs. 3, 4). The dendrite structure was heavily attacked by etchant in case of A1, A2, A3 gold alloys, but the dendrites in B1, B2, B3 gold alloys were not corroded. Considering the solidification of their gold alloys, the dendritre structures solidified initially and continuously the interdendrites between the dendrites formed after the solidification of dendrites. Thus, respective melting temperature as the additives was important to control the formation of cast dendrite structures in gold alloys. Compared gold alloys A1, A2, A3 and B1, B2, B3 (Table 1), metal additives with higher melting temperature were added to gold alloys B1, B2, B3 in this study. The low-fusing pure metals as In (156.4°C) and Zn (419°C) were contained in gold alloys A1, A2, A3. The metal additives were effective to control the hardness number in Ni-Cu-Mn-based alloys[12−15]. Thus, the additives were used effectively for the development of dental gold alloys.

SUMMARY

The hardness number was a parameter to represent structural characteristics of dental gold alloy matrix phase. Dental Au/Ag/Pd-based alloys exhibited the corrosion attack of dendrite structures, showing the different metallographic etch in interdendrite and dendrite structures. The metal additives In and Zn in Au/Ag/Pd-based alloys improved cast structures of dendrites and uncorroded interdendrites with the same hardness for each alloy. On the contrary, the metal additives in Au/Pd-based alloys were effective to improve corrosion-resistance of dendrites as shown in B1, B2, B3 gold alloys when the high-fusing additives are added to the matrix. In these Au/Pd-based alloys the hard structure was dendrite

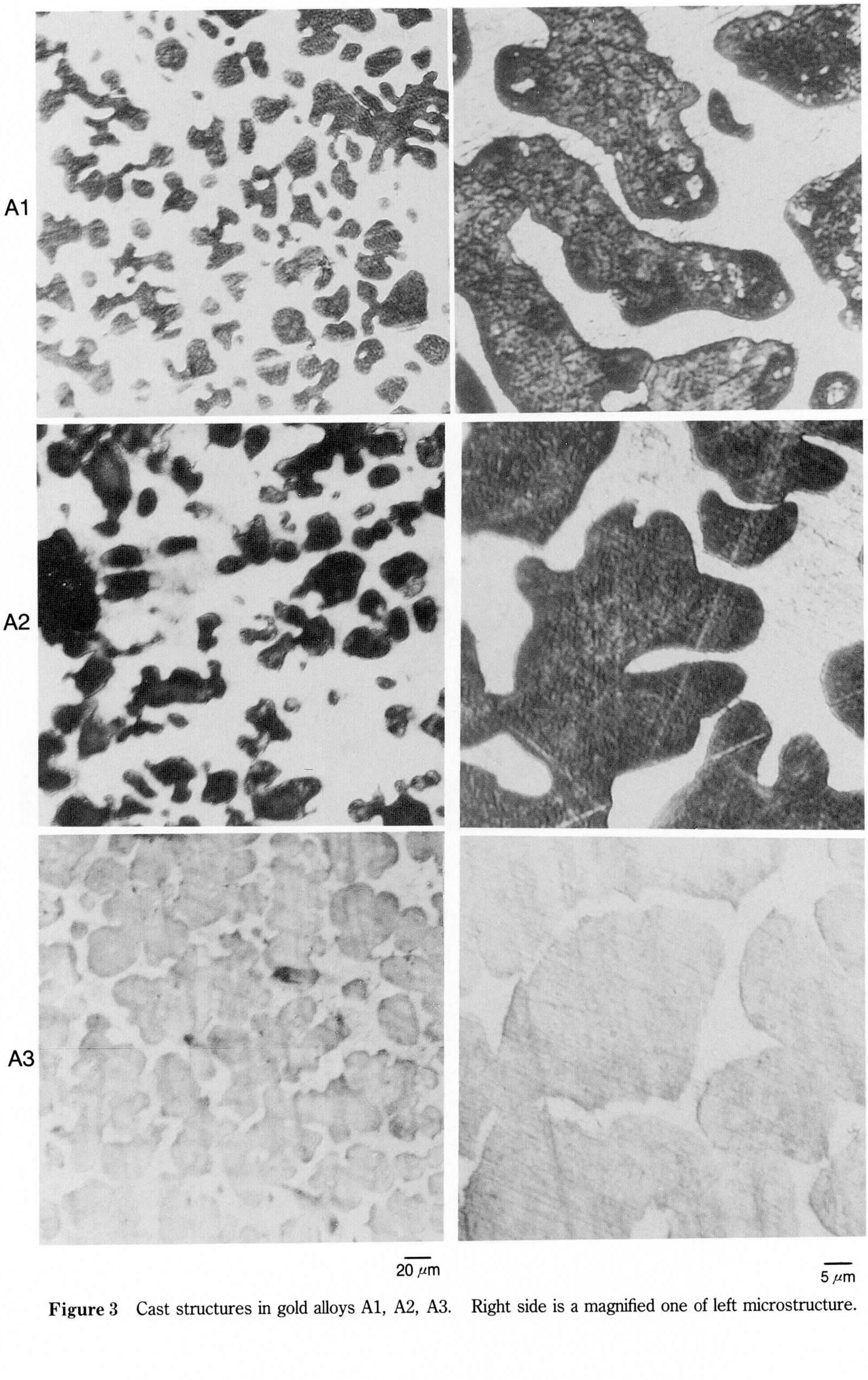

Figure 3 Cast structures in gold alloys A1, A2, A3. Right side is a magnified one of left microstructure.

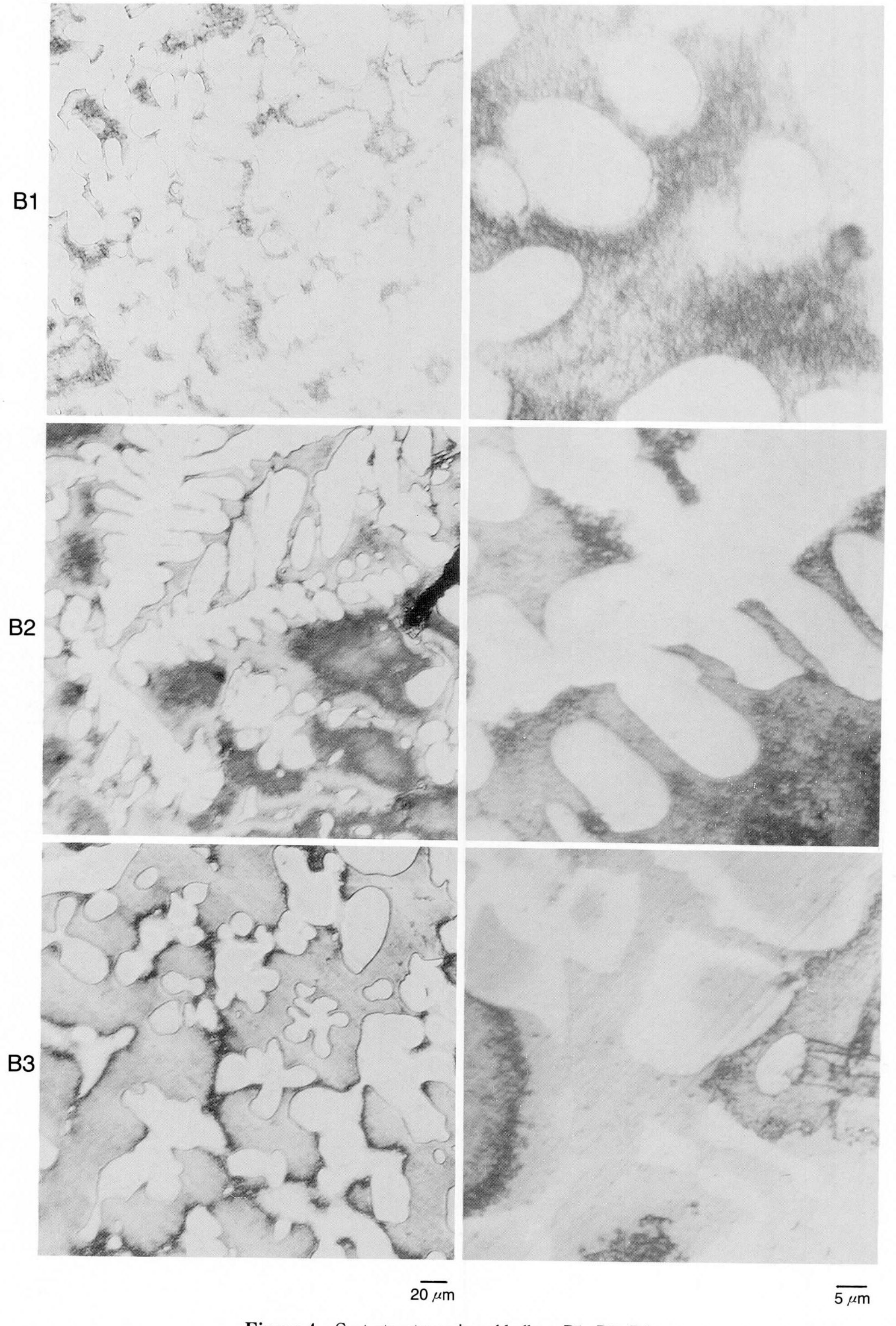

Figure 4 Cast structures in gold alloys B1, B2, B3.

with 180 to 280, and the soft structure was the interdendrites ranging from 60 to 180. Therefore, the surface microhardness of the gold alloys was modified according to the addition of metal elements.

REFERENCES

1) Kanetake, T.: Ag-Pd-Au alloys. *Shika Gakuhou* 54, 225–232, 1954.
2) Kaires, A. K. and Thompson, J. C.: The effect of heat treatment variables on the microstructure and hardness of a cast dental gold alloy. *J. Dent. Res.* 38, 888–900, 1959.
3) Nishimura, F.: Distortion of dental castings by finishing and heat treatment. *Kou Byou Shi* 33, 5–29, 1966.
4) Nakamura, K.: Pickling of Au-Ag-Pd alloys for dental casting. *Shika Gakuhou* 67, 379–386, 1967.
5) Onuki, S.: Studies on the finishing work of prosthetic appliances finishing work of dental metal. *Nihon Hotetsushikagakkai Zasshi* 12, 215–239, 1968.
6) Gillete, W. B., Cohen, G. and Abrahamson, B.: Cast aluminum dental prostheses. *J. Prosthet. Dent.* 21, 92–96, 1969.
7) Mori, T., Ohta, M. and Yamane, M.: A study on Ag-Pd alloys during dental casting. Part 1. *Shika Rikougaku Zasshi* 13, 117–126, 1972.
8) Thompson, D. H.: Use of industrially available aluminum-bronze alloys for cast restorations. I. Preliminary study. *Aust. Dent. J.* 28, 153–155, 1983.
9) Byrne, G., Goodacre, C. J., Dykema, R. W. and Moore, B. K.: Casting accuracy of high-palladium alloys. *J. Prosthet. Dent.* 55, 297–301, 1986.
10) Veronesi, G. S., Consani, S. and Ruhnke, L. A.: The influence of casting methods on the surface microhardness and crystalline formation of aluminum-copper alloys. *J. Prosthet. Dent.* 67, 26–29, 1992.
11) Brockhurst, P. J. and Cannon, R. W.: Alloys for crown and bridgework. *Aust. Dent. J.* 26, 287–291, 1981.
12) Wakasa, K., Yamaki, M., Nakatsuka, A. and Nishimura, T.: Tensile deformation behaviour and mechanical properties in dental Ni-based casting alloys. *Shika Rikougaku Zasshi* 22, 217–221, 1981.
13) Sosrosoedirdjo, B. I., Wakasa, K. and Yamaki, M.: A study on nonprecious cast alloys. Part 1 Tarnish evaluation of nickel-copper-manganese alloys. *J. Mater. Sci.* 24, 1243–1246, 1989.
14) Sosrosoedirdjo, B. I., Wakasa, K. and Yamaki, M.: A study on nonprecious cast alloys. Part 2 Nickel release from nickel-copper-manganese alloys. *J. Mater. Sci.* 24, 1247–1251, 1989.
15) Sosrosoedirdjo, B. I., Wakasa, K. and Yamaki.M.: A study on nonprecious cast alloys. Part 3 Tensile properties in ternary nickel-copper-manganese alloys: Influence of adding aluminum and indium. *J. Mater. Sci.* 24, 3667–3672, 1989.
16) Hasegawa, J.: Some properties of Ni-Cr alloys for crown and bridge applications. *Dental Engineering* 70, 17–27, 1984.
17) Phillips, R. W.: *Skinner's Science of Dental Materials*, W. B. SAUNDERS Co, Philladelphia, pp 381–397, 1973.
18) Lewis, A. J.: The metallography of a nickel base casting alloy. *Aust. Dent. J.* 23, 298–303, 1975.
19) Lewis, A. J.: Porosity in the base metal removable partial denture casting alloys relative to observable metallographic features. *J. Biomed. Mater. Res.* 11, 447–458, 1977.
20) Civjan, S., Huget, E. F., Gogfrey, G. D., Lichtenberger, H. and Frank, W. A.: Effect of heat treatment on mechanical properties of two nickel-chromium based alloys. *J. Dent. Res.* 51, 1537–1546, 1972.