NATIONAL BUREAU OF STANDARDS REPORT

9917

Progress Report

on

CHEMICAL COMPOSITION OF DENTAL GOLD CASTING ALLOY

AND DENTAL WROUGHT GOLD WIRE ALLOYS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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CHEMICAL COMPOSITION OF DENTAL GOLD CASTING ALLOY AND DENTAL WROUGHT GOLD WIRE ALLOYS

By

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Chemical Composition of Dental Gold Casting Alloy and Dental Wrought Gold Wire alloys

J. D. Eick, H. J. Caul, T. Hegdahl, and G. Dickson

The chemical composition of 136 dental casting gold alloys and 21 dental wrought gold wire alloys was determined by an x-ray emission method. The changes in composition from 1928 and 1932 to the present time are small. There has been a decrease in platinum content in both castings and wires. About 1% nickel is found in the present-day wire which was not present in 1928 and 1932.

Introduction

American Dental Association Specification No. 5 for Dental Casting Gold Alloy and No. 7 for Dental Wrought Gold Wire Alloy require that a minimum amount of gold and metals of the platinum group be present in each type of alloy (1). Therefore, a chemical analysis of at least the noble metal content is necessary when these alloys are tested for compliance with these specifications. Compositions of dental gold alloys were determined and published a number of years ago (2, 3). Since modern formulations are not available in

the literature, the total chemical composition was determined during recent surveys of these alloys. The chemical compositions of 136 dental casting gold alloys and 21 dental wrought gold wire alloys were determined using a modification of the x-ray emission method described previously by Eick, et al (4).

Methods and Materials

Two specimens of each alloy were cast into a flat disk approximately 1 mm thick and 32 mm in diameter. The "lost-wax casting technic" (5) was utilized with a gypsum bound investment. An electric resistance-heating furnace connected to a centrifugal casting machine, with a pyrometer attached which measured temperature to within ± 15°C, was employed to melt and cast the alloys into molds preheated for two hours at 650°C. The specimens in the mold were quenched in water immediately after casting, removed from the investment mold, and mounted in acrylic resin to facilitate surface preparation and x-ray analysis.

The surface was prepared by finishing with 600 grit wet silicon carbide paper. Each specimen was analyzed five times in a multi-channel x-ray emission unit* using a sequence designed to minimize the effects of instrumental drift (6). The x-ray intensity data for each element were automatically recorded on tape, then transferred to computer cards, and corrected for absorption and enhancement effects before using the the Lucas-Tooth and Price Equation (7). The corrections of silver and platinum intensities for an overlap resulting from palladium and copper were necessary because less resolution was achieved with the PXQ. In the previous paper (4) overlap was not a problem when the inverted sample three position spectrograph was used. The corrections were made as follows

$$I_{Ag} - mI_{Pd} = I_{Ag} \text{ corrected}$$

where $m = 0.084$

$$I_{Pt} - mI_{Cu} = I_{Pt} \text{ corrected}$$

where $m = 0.0975$

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*The PXQ manufactured by Applied Research Laboratories.

The values for m were found to be very nearly constant from run to run for the particular instrument that was employed for the analyses. The corrected intensity values for silver and platinum were then used in the computer program for the Lucas-Tooth and Price equation. This procedure enabled the chemical composition of each element to be determined to an accuracy of about 0.2% or less.

Results and Discussion

The chemical compositions of each casting gold alloy and wrought gold wire are listed in Table 1. Each type of casting gold and wrought gold wire alloy may be characterized by representative formulas. The formulas for the casting gold alloys are listed in Table 2. One class consists of those alloys containing little or no platinum or palladium, the second, those containing platinum but little or no palladium, and third, those containing palladium but little or no platinum. The last classification consists of alloys containing both platinum and palladium.

The average compositions of the four types of casting gold alloys are listed in Table 3. The gold content decreased while the copper and zinc content increased from type I to type IV. The silver content was about the same for types I, II, III, and IV, and both the platinum and palladium content increased from type I to type IV. It is well known that copper plays an important part in the hardening of gold alloys but these data suggest that palladium and platinum may also play a significant role in the hardening mechanism of dental gold casting alloys.

The representative formulas for the type I wrought gold wire alloys are listed in Table 4. These alloys could be classified as those containing little or no nickel, 1% nickel, and 2% nickel. In general, as the nickel content increased, copper increased, and platinum decreased. The palladium and platinum content in these alloys is much higher than in any of the casting gold alloys. The three formulas for the type II wrought gold wire alloys are listed in the same table. In general, these alloys contained more nickel than the type I wires, while the palladium and platinum content was significantly less. The amount of other constituents was comparable to those of the type I alloys.

The average compositions for the wrought gold wire alloys are listed in Table 5. The type I alloys contained less nickel, gold, silver and copper and significantly more palladium and platinum than the type II alloys.

Table 6 compares the composition of casting golds and wrought wires in 1928 and 1932 with those of 1968. The modern casting gold contains less platinum and more gold while the changes in the wrought gold wires are the presence of about 1% nickel, an increase in copper content and a decrease in platinum.

Summary and Conclusions

It was possible to represent each type of alloy by two or three typical chemical compositions. The gold content of the dental casting gold alloys decreased from type I to type IV, whereas the copper and zinc content increased. The silver content remained about the same for types I, II, III, and IV. The platinum and palladium content generally increased, with a large majority of the type IV alloys containing approximately 3% of both platinum and palladium. Many of the type I wrought gold wire alloys contained little or no nickel and large amounts of platinum and palladium. The type II alloys generally contained approximately 2% nickel, little or no

palladium and platinum, and a larger amount of gold than the type I wrought gold wire alloys.

The changes in composition for casting gold alloys and wrought gold wires from 1928 and 1932 to the present time are small. There has been a decrease in platinum content in both wires and castings. About 1% nickel is found in the present-day wire which was not present in 1928 and 1932.

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TABLE 1

CHEMICAL COMPOSITION OF TYPE I - CASTING GOLD ALLOYS

Alloy No.	Gold %	Silver %	Copper %	Palladium %	Platinum %	Zinc %	Total %
1	80.2	11.8	4.6	2.8	0.0	0.0	99.4
2	80.2	11.8	4.6	2.8	0.0	0.0	99.4
3	80.6	11.8	4.6	1.9	0.1	1.2	100.2
4	81.2	12.0	3.3	3.6	0.0	0.3	100.4
5	81.2	11.8	4.4	1.9	0.4	1.0	100.7
6	81.2	10.2	6.0	0.9	0.0	0.2	99.5
7	82.5	10.6	6.2	0.0	0.1	0.0	99.4
8	82.8	10.6	6.0	0.0	0.0	0.0	99.4
9	82.8	11.2	4.6	1.0	0.0	0.0	99.6
10	83.0	10.8	5.6	0.0	0.1	0.0	99.5
11	83.0	11.6	4.6	0.0	0.1	0.4	99.7
12	83.2	8.2	7.3	0.6	0.2	0.2	99.7
13	83.2	11.5	4.6	0.0	0.1	0.4	99.8
14	83.6	11.0	5.0	0.0	0.0	0.0	99.6
15	83.6	10.8	5.0	0.0	0.1	0.0	99.5
16	84.4	10.0	5.0	0.0	0.1	0.0	99.5
17	86.2	5.6	3.7	3.7	0.0	0.6	99.8
18	86.6	6.6	4.2	0.0	1.8	0.0	99.2
19	86.8	8.8	4.0	0.0	0.0	0.0	99.6
20	88.8	4.4	5.2	0.0	1.0	0.4	99.8
21	89.4	8.0	2.1	0.1	0.0	0.0	99.6
22	89.8	6.7	3.2	0.0	0.0	0.0	99.7
23	90.8	4.0	4.8	0.0	0.1	0.0	99.7
24	91.3	5.4	2.9	0.0	0.1	0.2	99.9
25	91.5	5.3	2.8	0.0	0.0	0.0	99.6
26	91.9	5.4	2.2	0.0	0.2	0.6	100.3
27	92.6	4.3	2.7	0.4	0.0	0.0	100.0
28	92.8	3.7	2.2	0.0	1.0	0.2	99.9
29	95.8	2.4	1.6	0.0	0.1	0.0	99.9

TABLE 1
(continued)

CHEMICAL COMPOSITION OF TYPE II - CASTING GOLD ALLOYS

Alloy No.	Gold %	Silver %	Copper %	Palladium %	Platinum %	Zinc %	Total %
1	73.0	14.6	6.0	5.6	0.0	0.0	99.2
2	74.7	14.4	7.0	2.8	0.0	1.1	100.0
3	75.2	14.2	6.9	2.8	0.0	0.7	99.8
4	76.6	13.6	8.2	1.0	0.0	0.0	99.4
5	76.7	13.5	8.2	1.0	0.0	0.0	99.4
6	76.8	10.3	10.5	1.4	0.0	0.6	99.6
7	76.8	12.6	8.0	1.9	0.0	0.1	99.4
8	76.8	13.4	8.0	0.9	0.0	0.0	99.1
9	77.0	11.2	10.2	0.9	0.0	0.1	99.4
10	77.0	11.2	7.2	1.9	1.8	0.0	99.1
11	77.0	13.8	7.0	1.2	0.0	0.5	99.5
12	77.2	13.0	8.0	0.9	0.1	0.7	99.9
13	77.3	11.6	9.2	1.0	0.0	0.6	99.7
14	77.4	13.3	6.6	0.0	1.9	0.0	99.2
15	77.4	12.4	7.4	1.9	0.0	0.6	99.7
16	77.5	12.8	7.2	0.0	1.5	0.2	99.2
17	77.6	13.0	7.2	0.0	1.5	0.0	99.3
18	77.7	12.3	8.0	1.0	0.1	1.0	100.1
19	77.7	12.0	7.4	1.9	0.0	0.6	99.6
20	77.8	13.2	7.0	0.0	1.8	0.1	99.9
21	78.0	10.4	9.2	0.0	1.7	0.0	99.3
22	78.2	11.5	6.7	0.0	2.6	0.0	99.0
23	78.4	11.4	8.6	0.0	0.9	0.0	99.3
24	78.6	9.5	6.4	0.0	4.3	0.0	98.8
25	79.0	9.6	6.8	0.9	2.7	0.4	99.4
26	79.1	10.6	6.4	2.9	0.0	0.7	99.7
27	79.9	9.4	7.6	0.0	1.9	1.4	100.2
28	80.0	9.1	6.3	0.0	3.4	0.2	99.0
29	80.0	9.4	7.5	0.0	1.9	1.1	99.9
30	80.1	10.4	9.0	0.0	0.0	0.0	99.5
31	82.0	6.9	6.6	0.0	3.5	0.0	99.0
32	83.0	7.5	5.8	0.2	2.5	0.2	99.2
33	83.7	7.8	7.9	0.0	0.1	0.4	99.9
34	83.9	7.6	3.9	3.8	0.0	0.5	99.7

TABLE 1
(continued)

CHEMICAL COMPOSITION OF TYPE III - CASTING GOLD ALLOYS

Alloy No.	Gold %	Silver %	Copper %	Palladium %	Platinum %	Zinc %	Total %
1	71.0	13.1	7.4	0.0	7.5	0.0	99.0
2	72.0	9.8	10.6	6.5	0.0	0.2	99.1
3	72.2	10.9	9.4	0.0	6.4	0.0	98.9
4	73.5	9.6	11.6	4.3	0.0	0.6	99.6
5	73.8	9.9	10.9	3.8	0.0	1.7	100.1
6	73.9	9.3	11.1	2.8	1.7	0.4	99.8
7	74.1	11.2	9.5	3.9	0.0	1.0	99.7
8	74.2	11.0	10.4	3.3	0.0	0.4	99.3
9	74.3	9.8	11.3	3.6	0.0	0.8	99.8
10	74.3	10.4	10.2	3.8	0.0	1.2	99.9
11	74.4	9.8	11.0	0.0	3.6	1.0	99.8
12	74.4	10.8	10.5	3.3	0.0	0.4	99.4
13	74.4	11.3	9.0	3.9	0.0	1.4	100.0
14	74.4	11.4	9.0	3.6	0.2	0.7	99.3
15	74.5	9.8	11.0	3.6	0.0	0.9	99.8
16	74.5	9.5	11.0	3.8	0.0	0.5	99.3
17	74.6	9.8	11.0	3.6	0.0	0.8	99.8
18	74.6	11.1	9.9	3.5	0.0	0.1	99.2
19	74.7	8.6	12.6	1.0	2.2	0.4	99.5
20	74.7	9.4	9.2	0.0	5.6	0.0	98.9
21	74.8	7.9	11.6	0.6	3.8	0.6	99.3
22	75.0	9.2	10.0	0.0	4.6	0.4	99.2
23	75.0	13.1	8.2	0.0	2.7	0.1	99.1
24	75.0	9.6	10.2	0.0	3.8	1.2	99.8
25	75.0	11.6	8.4	2.0	1.8	0.9	99.7
26	75.0	9.8	11.1	2.8	0.1	1.1	99.9
27	75.3	12.3	8.6	0.0	2.8	0.0	99.0
28	75.3	13.4	7.6	2.8	0.0	0.9	100.0
29	76.0	10.5	8.9	2.2	1.1	1.8	100.5
30	76.0	10.8	8.5	2.2	1.4	1.6	100.5
31	76.2	9.4	7.8	1.0	4.2	0.3	98.9
32	76.3	11.0	9.1	0.0	2.6	0.0	99.0
33	76.3	9.7	9.2	3.8	0.0	0.5	99.5
34	76.4	7.6	12.2	0.0	2.8	0.0	99.0
35	76.8	7.4	12.0	0.0	2.8	0.5	99.5
36	77.3	8.6	10.2	0.0	3.0	0.0	99.1
37	77.7	10.4	9.4	0.0	1.7	0.0	99.2
38	78.3	7.7	7.4	2.4	2.8	0.0	99.5
39	78.8	7.5	7.8	0.0	4.4	0.6	99.1
40	78.9	7.9	7.4	0.0	4.4	0.4	99.0
41	79.0	6.5	11.2	0.0	2.6	0.0	99.3
42	79.2	6.0	7.7	2.8	2.6	2.0	100.3
43	79.2	8.8	10.1	0.0	1.0	0.6	99.7
44	79.2	8.1	7.1	0.0	5.2	0.2	99.8
45	79.8	5.2	8.3	0.0	5.2	0.6	99.1

TABLE 1
(continued)

CHEMICAL COMPOSITION OF TYPE IV - CASTING GOLD ALLOYS

Alloy No.	Gold %	Silver %	Copper %	Palladium %	Platinum %	Zinc %	Total %
1	62.4	9.0	12.6	10.1	4.8	1.1	100.0
2	64.5	17.4	11.2	2.1	4.1	0.5	99.8
3	67.8	15.2	8.6	0.0	8.2	0.0	99.8
4	68.2	12.2	11.2	4.0	2.4	2.7	100.7
5	68.8	12.0	12.0	3.2	3.0	0.0	99.0
6	68.8	11.9	12.1	3.2	3.0	0.0	99.0
7	68.8	12.2	10.9	3.9	2.6	2.6	101.0
8	69.0	13.2	10.4	3.4	2.8	0.3	99.1
9	69.0	12.2	11.5	3.4	2.8	0.8	99.7
10	69.0	11.9	10.8	4.4	2.1	1.6	99.8
11	69.0	11.1	11.6	4.2	2.4	1.4	99.7
12	69.1	9.8	13.4	0.0	5.4	1.1	98.8
13	69.1	11.2	11.3	5.0	1.6	1.8	100.0
14	69.1	11.9	11.0	4.0	2.4	2.1	100.5
15	69.2	10.3	13.3	3.9	2.0	0.5	99.2
16	69.4	11.1	11.0	4.0	2.6	2.5	100.6
17	69.6	8.1	13.2	3.0	4.9	0.4	99.2
18	69.6	11.4	12.3	3.4	2.0	0.3	99.0
19	69.6	10.6	13.4	2.0	3.0	0.9	99.5
20	69.7	8.8	14.0	0.0	5.6	2.0	100.1
21	69.8	8.0	15.4	3.8	1.2	1.0	99.2
22	69.8	10.2	12.5	2.5	3.1	2.0	100.1
23	69.9	11.2	12.6	3.0	2.0	0.9	99.6
24	70.2	10.2	12.8	3.9	1.1	1.4	99.6
25	70.2	10.2	13.3	0.1	5.0	0.6	99.4
26	70.3	9.4	13.0	1.0	5.2	0.3	99.2
27	71.2	8.8	14.2	4.0	0.2	0.4	98.8
28	71.9	9.6	13.8	2.0	1.2	0.2	98.7

TABLE 1
(continued)

CHEMICAL COMPOSITION OF TYPE I - WROUGHT GOLD WIRES

Alloy No.	Gold %	Silver %	Copper %	Palladium %	Platinum %	Zinc %	Nickel %	Total %
1	53.6	8.5	15.2	8.1	14.8	0.0	0.9	101.1
2	55.2	9.4	13.8	6.8	15.0	0.0	0.9	101.1
3	55.7	9.9	13.8	6.7	14.0	0.0	0.9	101.0
4	56.1	9.7	12.9	7.4	14.1	0.1	1.0	101.3
5	56.4	6.6	13.2	7.8	17.4	0.2	0.1	101.7
6	57.0	7.6	11.4	8.2	17.6	0.4	0.0	102.2
7	58.4	12.2	10.2	4.1	15.7	0.6	0.0	101.2
8	60.6	9.4	15.0	6.6	7.9	0.0	0.2	99.7
9	61.4	11.7	10.8	0.0	16.4	0.0	0.0	100.3
10	62.2	12.4	10.2	0.1	15.3	0.1	0.0	100.3
11	62.6	8.6	14.6	5.2	6.8	0.0	1.8	99.6
12	62.8	8.6	14.6	5.0	6.8	.0	1.9	99.7
13	63.2	8.6	14.1	5.2	7.0	.0	1.8	99.9

CHEMICAL COMPOSITION OF TYPE II - WROUGHT GOLD WIRES

Alloy No.	Gold %	Silver %	Copper %	Palladium %	Platinum %	Zinc %	Nickel %	Total %
1	60.2	10.0	14.0	10.4	4.1	0.1	1.8	100.8
2	62.3	17.5	13.8	4.2	1.6	0.0	0.0	99.4
3	64.2	10.4	19.6	0.0	1.8	0.4	2.0	98.4
4	64.2	8.4	18.6	0.0	1.3	0.8	6.2	99.5
5	66.6	21.4	10.2	0.5	0.0	0.0	1.8	100.5
6	66.7	14.0	13.2	0.0	3.7	0.0	1.9	99.5
7	67.0	11.4	14.1	5.0	0.8	1.7	0.0	100.0
8	67.1	12.4	11.8	0.1	6.5	0.4	1.4	99.7

TABLE 2

REPRESENTATIVE COMPOSITIONS* OF CASTING GOLD ALLOYS

Type	Number of Alloys	Au %	Ag %	Cu %	Pd %	Pt %	Zn %
I	16	87.3	8.4	4.1	0.0	0.1	0.1
	3	89.7	4.9	3.9	0.0	1.3	0.2
	9	83.4	9.7	4.6	2.0	0.0	0.3
	1	80.6	11.7	4.4	1.9	0.4	1.0
II	2	82.2	9.2	8.4	0.0	0.0	0.2
	13	79.7	10.7	7.1	0.0	2.3	0.2
	17	77.4	12.5	7.7	1.9	0.0	0.5
	2	78.6	10.5	7.1	1.4	2.2	0.2
III	19	77.0	9.4	9.5	0.0	3.8	0.3
	17	74.6	10.6	10.2	3.8	0.0	0.8
	9	76.2	9.1	9.4	1.9	2.4	1.0
IV	4	69.6	11.1	12.4	0.0	6.0	0.9
	24	69.3	11.1	12.4	3.6	2.6	1.0

*Adjusted to total 100.0%

TABLE 3
COMPOSITIONS* OF CASTING GOLD ALLOYS BY TYPE

Type	Number of Alloys	Au %	Ag %	Cu %	Pd %	Pt %	Zn %
I	29	86.1	8.6	4.2	0.7	0.2	0.2
II	34	78.5	11.5	7.5	1.1	1.0	0.4
III	45	76.0	9.8	9.7	1.8	2.1	0.6
IV	28	69.3	11.1	12.4	3.1	3.1	1.0

*Adjusted to total 100.0%

TABLE 4

COMPOSITION* OF WROUGHT GOLD WIRE

Type	Number of Alloys	Au %	Ag %	Cu %	Pd %	Pt %	Zn %	Ni %
I	6	58.8	9.9	11.7	4.5	14.9	0.2	0.0
	4	54.6	9.3	13.7	7.2	14.3	0.0	0.9
	3	63.1	8.6	14.5	5.1	6.9	0.0	1.8
II	2	64.9	14.3	14.0	4.6	1.2	0.8	0.0
	5	65.2	13.6	13.8	2.2	3.2	0.2	1.8
	1	64.5	8.5	18.7	0.0	1.3	0.8	6.2

*Adjusted to total 100.0%

TABLE 5

COMPOSITION* OF WROUGHT GOLD WIRES BY TYPE

Type	Number of Alloys	Au %	Ag %	Cu %	Pd %	Pt %	Zn %	Ni %
I	13	58.4	9.4	13.0	5.5	12.9	0.1	0.7
II	8	65.0	13.2	14.5	2.5	2.5	0.4	1.9

*Adjusted to total 100.0%

TABLE 6

COMPARISON OF AVERAGE COMPOSITIONS OF

CASTING GOLDS AND WROUGHT GOLD WIRES

Type	Year	Number	Au %	Ag %	Cu %	Pd %	Pt %	Zn %	Ni %	Total
Casting Gold	1928[1]	30	72.2	9.8	9.4	1.9	5.8	0.5	0.3	99.9
	1968[3]	136	77.1	10.2	8.5	1.7	1.6	0.5	0.0	99.6
Wrought Gold Wire	1928[2] and 1932	33	64.6	8.5	9.7	3.6	13.1	0.2	0.0	99.7
	1968[3]	21	61.1	10.9	13.6	4.4	9.0	0.2	1.2	100.4

[1] These averages were calculated from Table 10 of Coleman (2) omitting the compositions of the gold solders.

[2] These averages were calculated from Table 1 of Coleman (2) omitting alloys "B" and "P" and from Table 1 of Paffenbarger et al (3) omitting alloy "O".

[3] These averages were calculated from Table 1 of this paper.


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