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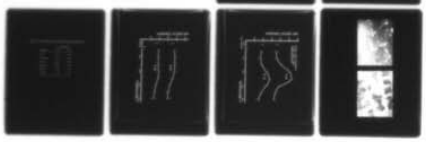

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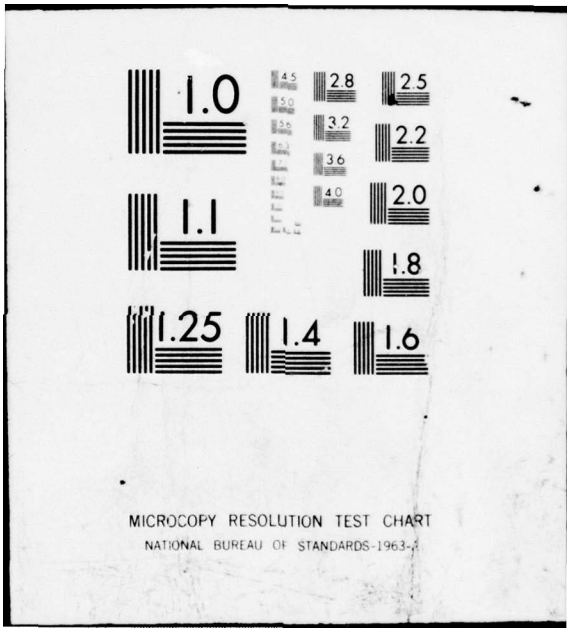
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Mechanical properties, compositions, microstructures and heat-treatment characteristics of two white ceramic-metal alloys (P-G and P-D) were studied. It was determined that P-D was a gold-palladium based material. Major components of P-G were gold, palladium and silver. Microstructures of the alloys differed markedly. P-D exhibited superior strength properties, whereas, P-G had greater ductility. Hardening and strengthening of the alloys could be related to the formation of base metal (gallium or nickel) containing precipitates.

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Studies on white crown-and-bridge alloys

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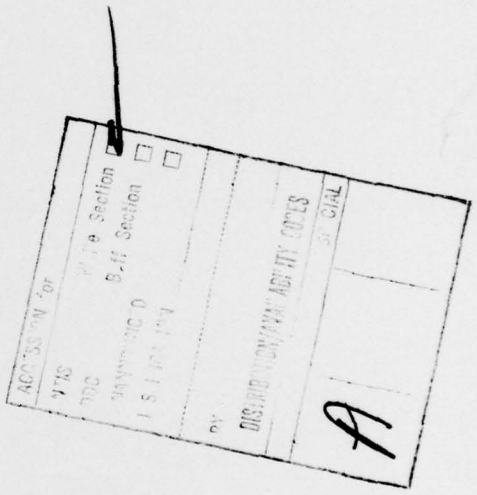

Commercial materials and equipment are identified in this report to specify the experimental procedure. Such identification does not imply official recommendation or endorsement or that the materials and equipment are necessarily the best available for the purpose.

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Since the middle 1950's, the use of porcelain-metal combinations for the restoration of damaged and missing teeth has increased markedly. Accordingly, a variety of precious, semiprecious and base metal alloys intended primarily for use in the ceramic-metal technique have appeared on the commercial market. The paucity of information relevant to many of these products has obviated the need for their characterization.

This report is based upon data on two veneerable white crown-and-bridge alloys: P-G* and P-D.*

MATERIALS AND METHODS

Preparation of cast specimens. Tensile bars conforming to the tolerances of ADA Specification No. 14 for dental chromium-cobalt casting alloy[1] as well as discs (13 mm. X 3 mm.) were fabricated by conventional lost wax laboratory procedures. All specimens were made in phosphate bonded molds+ that were subjected to a 45-minute burnout at 1,350° F. The test alloys were melted by induction heating and cast with the use of an automatic machine.#

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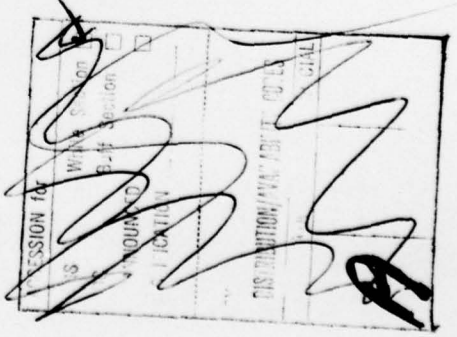
* American Gold Co., Los Angeles, CA 90004.

\+ Ceramigold Investment, Whip-Mix Corp., Louisville, KY 40208.

\# Electromatic Casting Machine, Howmet Corp., Chicago, IL 60632.



Respective casting temperatures for P-G and P-D were 2,370° F. and 2,400° F. The cast molds were bench-cooled to room temperature before retrieval and further handling of the specimens.

The test surfaces of metallographic and hardness specimens (13 mm. X 3 mm.-discs) were finished sequentially with abrasive papers (240-600 grit), diamond paste (6 μm.) and fine alumina (.05 μm.). Discs for determination of microstructure were etched by immersion in a solution of 55.2 percent (conc.) HCl, 3 percent (conc.) H_2SO_4, 1.8 percent (conc.) HNO_3 and 40 percent water, by volume. Immersion time for specimens of both alloys ranged between 5 and 15 minutes. Unetched mounted specimens were used for hardness measurement.

Determination of mechanical properties. Tensile tests were performed on a constant strain rate testing machine.[§] Crosshead speed of the machine was 0.02 inch per minute. Elongation was measured over a 1-inch gauge length with a breakaway extensometer.[¶] Reported values for tensile properties are based on a minimum of six observations for each test alloy. Vickers hardness (D.P.H.) was

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§ Instron Universal Testing Machine, Instron Engineering Corp., Canton, MA 02021.

¶ Strain Gauge Extensometer, model LG-51-12, Instron Engineering Corp., Canton, MA 02021.

measured on a testing machine[Ω] equipped with a 136° square base diamond pyramid indenter. Reported hardness values are averages of eight measurements on each of duplicate (two) specimens.

Determination of response to heat treatment. Heat treatment of tensile and hardness specimens was accomplished by a simulated porcelain firing cycle.[Π] Tensile properties and hardness (D.P.H.) were determined upon completion of the cycle's fourth step.

Ω Kentrall Hardness Tester, model MC-1, Riehle Testing Machine, East Moline, IL 61244.

Π (1) Degassing: Specimens were heated from 1,200 to 1,950° F., held at 1,950° F. for 5 minutes, removed from the furnace and cooled in open air. (2) Simulated application of opaque porcelain: Specimens were heated from 1,200 to 1,825° F., removed from the furnace immediately on reaching 1,825° F., removed from the furnace immediately on reaching 1,825° F., and cooled to room temperature in open air. (3) Simulated application of body porcelain: Specimens were subjected to two successive firings from 1,200 to 1,775° F. Specimens were cooled to room temperature in open air after each firing. (4) Simulated application of glaze. Specimens were heated from 1,200 to 1,800° F., removed from the furnace immediately on reaching 1,800° F., and cooled to room temperature in open air.

Additional experiments were conducted to determine the softening and hardening temperature ranges of the test materials. Cast discs were subjected to repetitive 15-minute heat treatments at 200-degree intervals from 400 to 1,800° F. All heat treatments were terminated by water quenching. Hardness (D.P.H.) was measured for each treatment temperature. Members of a second series of discs were water quenched after an initial 15-minute heat treatment at 1,800° F. These specimens were reheat treated at 200-degree intervals from 400 to 1,800° F. All discs were water quenched and retested after a 15-minute treatment at each temperature.

Chemical analysis and evaluation of microstructure. Constituents of the "as-received" materials were determined by wet analytical techniques.

The surfaces of etched specimens (13 mm. X 3 mm.-discs) were observed with an optical microscope[Φ] at a magnification of 400 X.

RESULTS

Mechanical properties of the alloys are presented in Table I. Strengths and hardness values of P-D were significantly higher than those of P-G. The elongation (ductility) of P-G, however, exceeded the elongation of P-D. Differences in rigidity (Young's modulus) were not detected. Heat treatment of P-D by the porcelain firing cycle elicited increases in strength, hardness and elongation. The properties of P-G were not altered appreciably by the four-step heat-treatment procedure.

Φ Unitron, model BN-11, Unitron Instrument Co., Newton Highlands, MA 02161.

Data depicting the responses of the alloys to softening and hardening heat treatments are shown in Figures 1 and 2 respectively. Alterations in hardness which accompanied heat treatment of the as-cast materials were not profound (Fig. 1). However, both P-G and P-D tended to soften at treatment temperatures between 1,200 and 1,800° F. Maximum hardening of both materials was attained on reheat treatment of annealed specimens at 1,200° F. (Fig. 2).

Quantitative analysis of the test materials revealed significant compositional differences (Table II). The binary gold-palladium base of P-D was modified by a minor addition of a single base-metal constituent (gallium). P-G was based on a gold-palladium-silver ternary system. Minor constituents of P-G included nickel, gallium and platinum.

As-cast microstructures of the "white" golds are shown in Figure 3. The microstructure of P-D was characterized by isolated colonies of a discontinuous lamellar phase. Major grain boundary areas of this alloy were devoid of precipitates to the extent that grain boundaries were difficult to detect. Grain boundaries of P-G, however, were delineated clearly by a complex precipitate. Heat treatment of P-D and P-G by the simulated porcelain firing cycle did not elicit detectable microstructural changes.

DISCUSSION

The alloys considered in the present study offer a broad choice of contrasting properties. P-D appears to be particularly suited for the fabrication of high strength fixed prostheses. On the other hand, the greater ductility and lower yield strength and hardness of P-G would probably facilitate the adaptation and finishing of small dental castings.

Hardness data obtained on the reheat treatment of castings quenched from 1,800° F. indicate that P-D and P-G are age hardenable. It is likely that the aging process involves the formation of base metal containing precipitates.

Hardening and strengthening of P-D upon its heat treatment by the porcelain firing cycle appear to be manifestations of aging. Failure of the treatment procedure to elicit discernible changes in the microstructure of P-D suggests that a relatively large portion of the aging phase (presumably an intermetallic compound of gallium) remains coherent with a solid solution matrix of gold and palladium.

SUMMARY

Mechanical properties, compositions, microstructures and heat-treatment characteristics of two white ceramic-metal alloys (P-G and P-D) were studied. It was determined that P-D was a gold-palladium based material. Major components of P-G were gold, palladium and silver. Microstructures of the alloys differed markedly. P-D exhibited superior strength properties, whereas,

P-G had greater ductility. Hardening and strengthening of the alloys could be related to the formation of base metal (gallium or nickel) containing precipitates.

REFERENCE

1. American Dental Association: Guide to Dental Materials and Devices, ed 6, Chicago, 1972, American Dental Association, pp. 207-209.

LEGENDS FOR FIGURES

Figure 1: Effect of heat-treatment temperature on hardness of two white crown-and-bridge alloys.

Figure 2: Effect of reheat-treatment temperature on hardness of two white crown-and-bridge alloys.

Figure 3: As-cast microstructures of two white crown-and-bridge alloys: (A) P-D and (B) P-G.

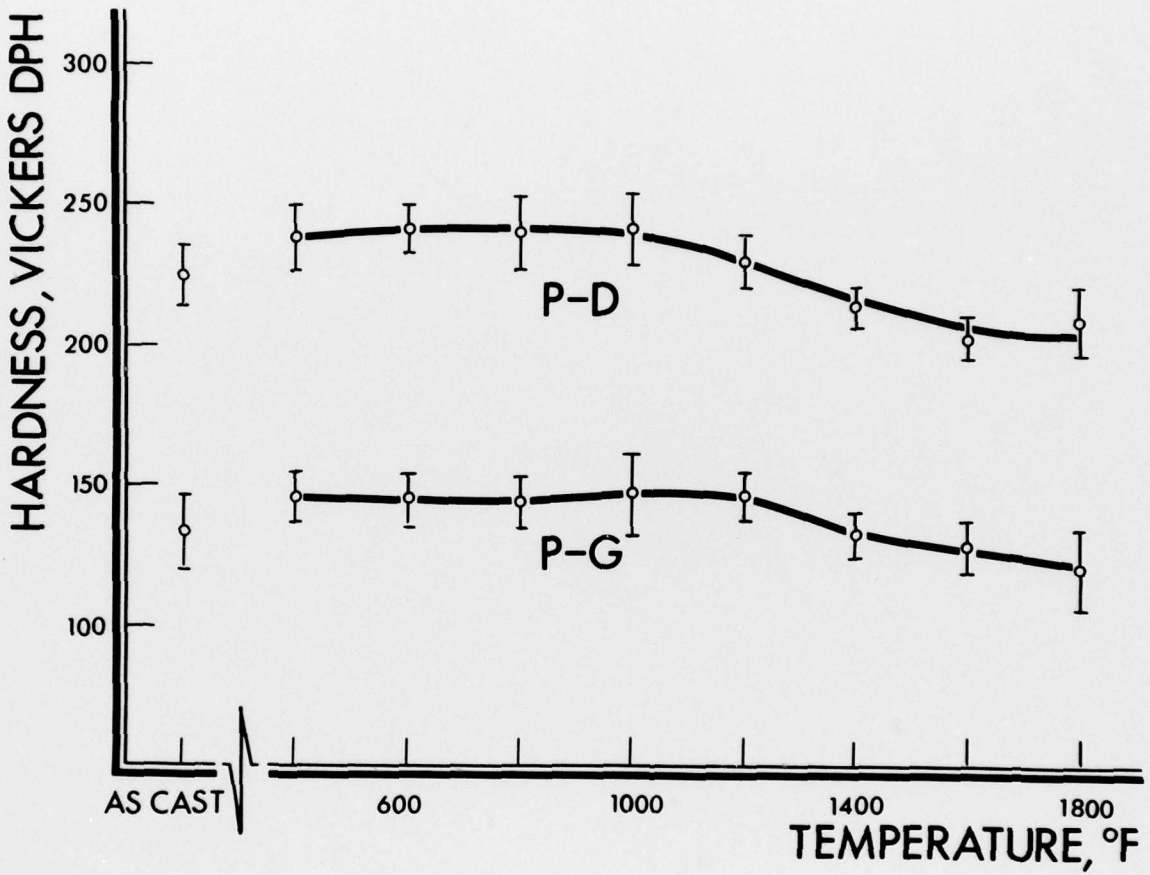
Table I. Mechanical properties of two white crown-and-bridge alloys

Alloy	Properties											
	Tensile strength X 10^3 psi		Yield strength 0.2% offset X 10^3 psi		Elastic limit X 10^3 psi		Young's modulus X 10^6 psi		Elongation %		Hardness D.P.H.	
	AV	SD	AV	SD	AV	SD	AV	SD	AV	SD	AV	SD
P-G												
as-cast	70	2	49	2	41	2	17	1	19	1	133	13
heat-treated*	70	2	47	0	38	2	16	2	22	2	144	9
P-D												
as-cast	96	4	73	1	57	2	17	2	4	2	226	11
heat-treated*	114	3	91	3	72	3	18	2	10	1	271	20

* Simulated porcelain firing cycle

Table II. Compositions of two white crown-and-bridge alloys

Element	Percentages	
	P-D	P-G
Gold	59.43	19.89
Palladium	36.44	39.05
Silver	Trace	35.85
Platinum	Trace	0.92
Nickel	0.00	2.95
Gallium	4.02	1.24


HARDNESS, VICKERS DPH
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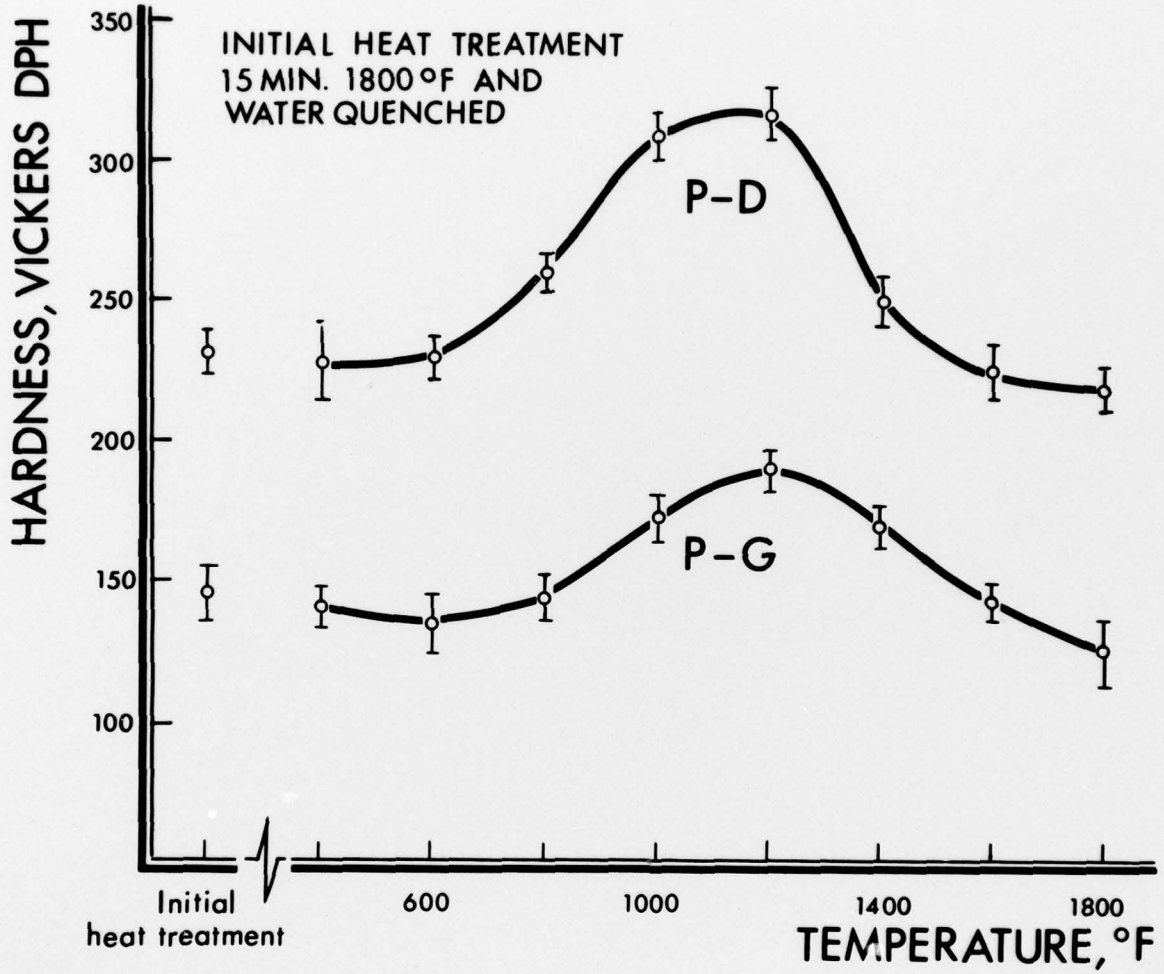
250
200
150
100
P-D
P-G
AS CAST
600
1000
1400
1800
TEMPERATURE, °F


INITIAL HEAT TREATMENT
15 MIN. 1800°F AND
WATER QUENCHED
P-D
P-G
HARDNESS, VICKERS DPH
350
300
250
200
150
100
Initial
heat treatment
600
1000
1400
1800
TEMPERATURE, °F