Porosities in a dental silver–palladium casting alloy

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Twelve single crowns were cast in a silver–palladium alloy by six different casting techniques. Polished sections of the crowns were inspected and photographically recorded by light microscopy. The area of the inspected section of the casting and the number and area of pores were recorded on the photographs by means of a digitizing table connected to a microcomputer. A great number of defects were observed unevenly distributed in all castings. Only small variations were observed between the various casting techniques. □ *Casting technique; crowns; dental materials; investing technique*

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Silver–palladium-based alloys for dental use have been available for many years. Such alloys can have certain mechanical properties similar to those of the traditional gold-based casting alloys. However, the present casting techniques involve a considerable risk of creating internal defects due to oxidation or gas absorption during melting (1, 2). These factors, in addition to problems related to the tarnish and corrosion, have limited the use of such alloys.

The increased demand for casting alloys with a low content of noble metals has been followed by increased interest in silver–palladium-based alloys and their quality. It was the purpose of the present study to evaluate the influence of certain variations in the common investing and casting procedure on the amount and distribution of defects in castings of a silver–palladium alloy.

Materials and methods

The casting alloy used in this study was Hvitstøp (K. A. Rasmussen, Hamar, Norway) with a content of 56% Ag, 25% Pd, 14% Cu, and 5% Au by weight (2).

Twelve single complete crowns were made on a stone die without any precautions to standardize the waxing procedure except for

Table 1. Casting methods and materials

Code	Investment type	Melting procedure	Other variations
A	Gypsum-bonded*	Electric†	—
B	Gypsum-bonded*	Electric†	Flux‡
C	Gypsum-bonded*	Electric†	Air vent§
D	Gypsum-bonded*	Methane/air	Flux‡
E	Phosphate-bonded¶	Electric†	—
F	Phosphate-bonded‖	Electric†	—

* Kerr Cristobalite Inlay Investment, Sybron/Kerr, Kerr Europe, Scafati, Italy.
† Degussa Tigelschleuder TS-1, Degussa, Frankfurt, FRG.
‡ Veriflux®, Degussa, Frankfurt, FRG.
§ See Fig. 1.
¶ Aurovest® soft, BEGO, Bremer Goldschlägerei Wilh. Herbst, Bremen, FRG.
‖ Aurovest® B, BEGO, Bremer Goldschlägerei Wilh. Herbst, Bremen, FRG.

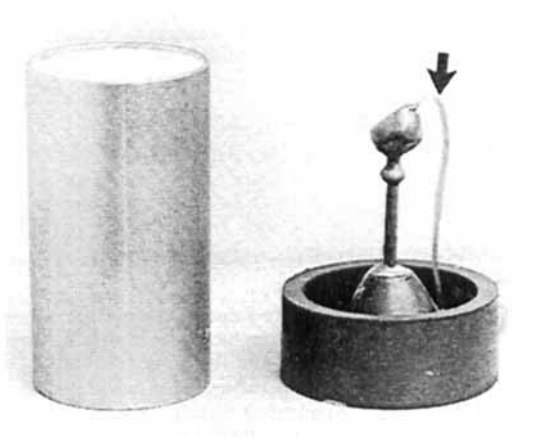

Fig. 1. Investing ring with fiberglass lining and wax model with air vent (arrow) mounted for investing.

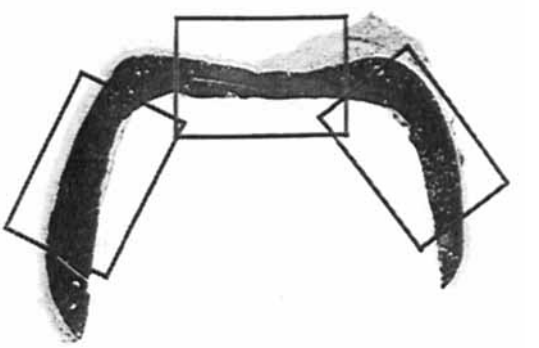

Fig. 2. The location of the three photomicrographs of one section of a crown.

visual inspection. Two wax patterns were invested and cast by each of the six procedures outlined in Table 1.

All wax patterns were placed in an iron ring with one layer of a glass fiber liner, as shown in Fig. 1. All the casting molds were subjected to the same preheating and final heating procedures: 30 min at 400°C, followed by 30 min at 700°C.

After being cast, devested, and cleaned, crowns were mounted in an epoxy resin (Epofix, Struers, Copenhagen, Denmark) and sectioned twice with a diamond cutter, both times parallel to the long axis of the tooth.

The two cut surfaces, with a minimum of 1 mm from each other, were polished, finally with 1-μm diamond paste, for inspection and photography in an optical microscope (Leitz, Orthoplan, Wetzlar, FRG). Three photographs were taken of each polished section as shown in Fig. 2.

The positive black and white prints (magnification, ×60) were mounted on a digitizing table (Graphic Tablet, Apple Computer Inc., Calif., USA) connected to a microcomputer (Apple II). The table's working area (27.9 × 19.1 cm) was resolved into 53760 coordinate points. The circumference of the area of the casting section shown on the magnified picture and the circumference of each defect were recorded with a special sensing pen (tip, approximately 0.3 mm in diameter). Defects smaller than the resolving power of the table were assigned a unified unscaled value of 0.34 mm^2, which at ×60 magnification gives a true size of 95 μm^2. By means of locally developed software, the area of the casting section shown on the photograph was calculated, as were the number, total pore area, mean pore size, and the ratio (in percentage) between the total pore area and the inspected area.

Table 2. Precision of the recording procedure. Pilot study

Print	Area of castings, mm^2	No. of pores	Area of pores, mm^2
1	2.380/0.37*	50.6/4.05	0.0064/1.56
2	1.884/0.46	93.3/1.34	0.013/0.77
3	2.953/0.96	156.7/7.03	0.0473/6.55
4	6.885/0.21	871.3/7.44	0.4057/2.39

* Mean/coefficient of variation.

Table 3. Density, mean size and relative area of porosities

Code	Inspected area of castings, mm^2	Pore density, pores/mm^2	Pore size, μm^2		Pore area, %
			Mean	S.D.	
A	33.55	55.4	159.1	345.7	0.9
B	31.46	39.2	123.3	346.4	0.5
C	22.63	34.2	141.1	263.5	0.5
D	31.38	60.9	141.4	214.8	0.9
E	22.32	36.5	162.9	298.5	0.6
F	23.99	28.3	162.7	243.4	0.5

Results

An initial study of the precision of the recording procedure was done on four randomly selected photographs. All photographs were recorded three times, and the variations in the area of casting and the number and area of defects are given in Table 2. The coefficient of variation was always less than 10% of the mean value and relatively small compared with the variations observed in different pictures from the same casting and between different castings of the same type (Fig. 2).

The total inspected surface, the number and individual size of the pores, and the total area of pores were recorded from 12 photographs—that is, 3 from each of 4 sections from 2 castings made under similar conditions. The total inspected area, the part of it (in percentage) comprising pores, the pore density, and the mean pore size for each casting condition are given in Table 3.

Most defects were identified as pinhole porosities (Figs. 3 and 4). Other defects seemed to be micro-porosities (Fig. 5) caused by shrinkage during solidification of the alloy (5). A concentration of pores could be observed in random parts of all types of castings.

Discussion

The problem of defects in dental castings has been studied by visual inspection of the castings, microscopical inspection, radiological

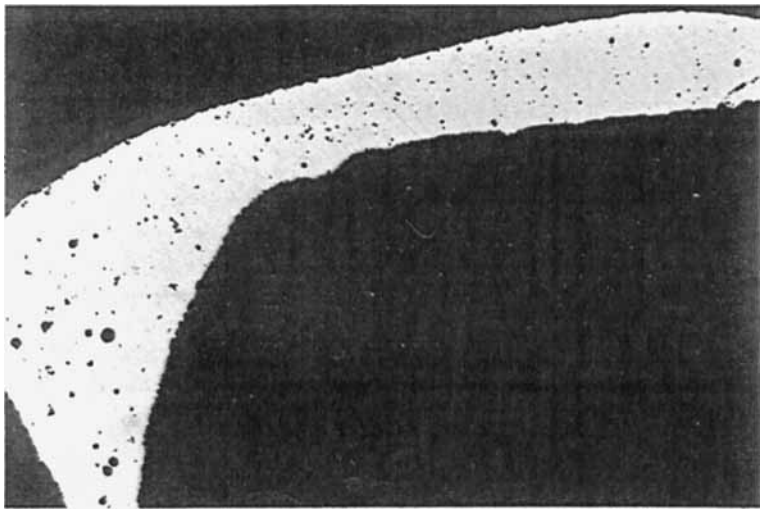

Fig. 3. Micrograph from crown cast with method A.

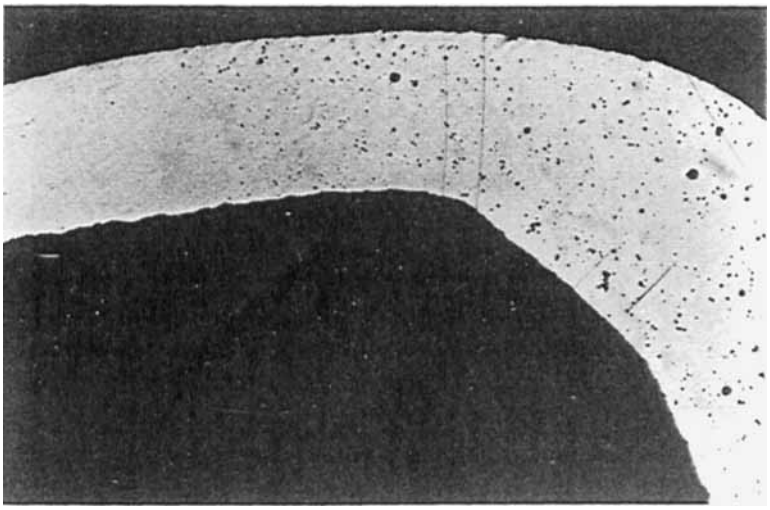

Fig. 4. Micrograph from crown cast with method D.

control, and density measurements (3–8). Microscopy has given qualitative information about type and localization of defects (4, 5). The density measurements have provided quantitative information (6, 8), and semi-quantitative and qualitative information has been achieved by radiological inspection (7).

It was thought that the present method could give both quantitative and qualitative information about defects. The method comprised human and technical possibilities for errors, connected with both the recording and the limitations of the pen and the digital table used. However, the initial study showed the method to be applicable and of sufficient precision, especially when the variations within the same casting are taken into account.

In spite of the simple geometry of the cast, a sprue, a reservoir, and a position in the muffel which should reduce shrinkage and back pressure porosities (3–5, 8), a relatively large number of defects could be found in all types of castings. The mean percentage of the inspected area occupied by defects

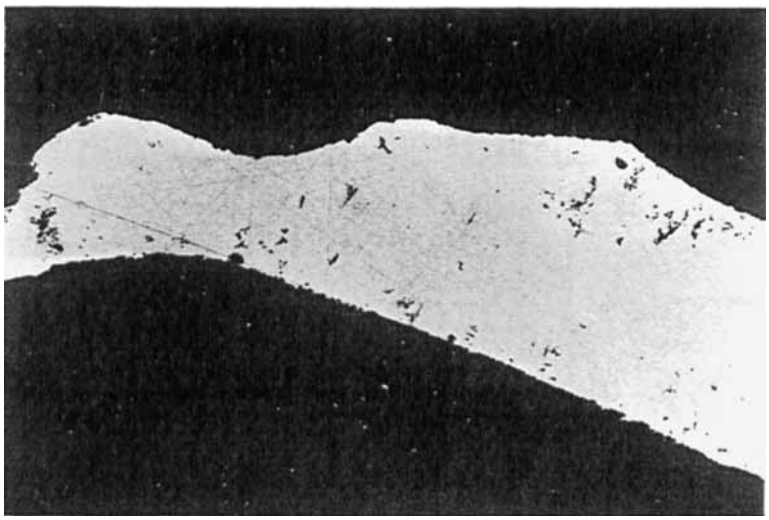

Fig. 5. Micrograph from crown cast with method A.

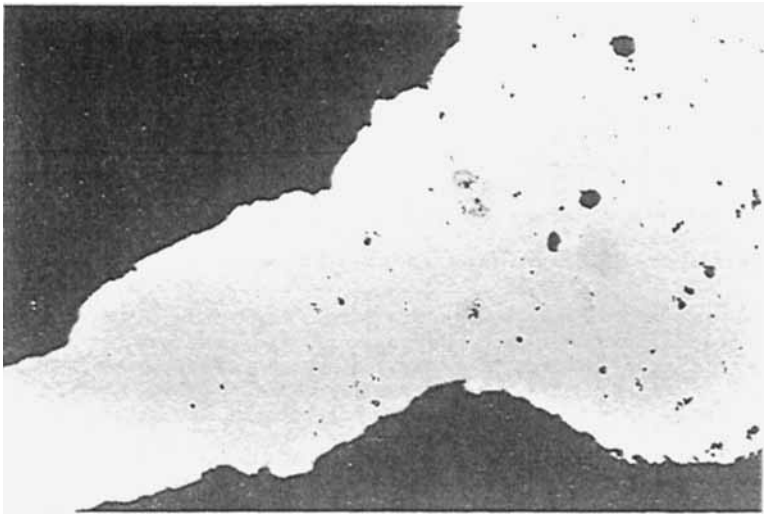

Fig. 6. Micrograph from crown cast with method F.

and the variations in this respect between the various types of castings seemed to be limited. However, the concentration of pores that occurred in random parts of all types of castings could be a more severe problem for the mechanical strength of the crown. No cause and effect relationship could be found for this phenomenon.

Some of the smaller defects were probably inclusions of copper oxides. The material contains approximately 14% copper, and copper oxides were identified in similar defects in a previous study with the same alloy (2).

Electric melting with a flux as protection (method B) seemed to reduce the number and size (Table 3) of pores as compared with melting without flux (method A). An air vent (method C) seemed to have a similar effect, and one might speculate that the gas absorption and/or inclusion was reduced in both types of castings. The flux could obviously not protect the alloy to the same extent by gas melting (method D, Fig. 4), possibly because of the special gas/air combination used (Table 1). It is also conceivable that the powdered flux was blown away by the torch.

Phosphate-bonded investments seemed to reduce the number of pores but increase the mean pore size (Table 3, Fig. 6). This observation could indicate an influence from back pressure which would increase gas absorption and probably the size of pinhole porosities (5).

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