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A COATING AGENT FOR PROMOTION OF METAL-TO-PORCELAIN BONDING, (U)
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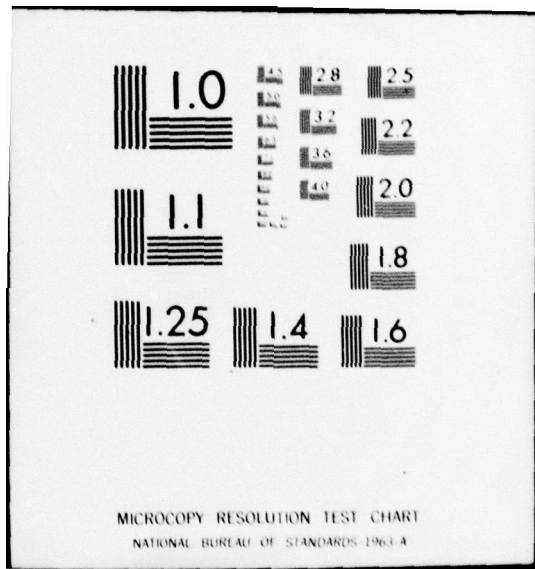
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6 A COATING AGENT FOR PROMOTION OF METAL-TO-PORCELAIN BONDING

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The fusion of porcelains to metals is an ancient art. Although its specific origin cannot be substantiated, it is known that metal ceramic decorative and functional devices were fabricated in many early civilizations, particularly those of the Egyptians, Greeks and Persians.

Since the early 1950's, esthetic porcelain-fused-to-metal dental treatment devices have enjoyed wide clinical use. The following problems, however, initially encumbered the production of porcelain-metal dental restorations: (1) Fused porcelain displayed cracks after firing because of the mismatch of thermal expansion between the porcelain and the metal substructure; (2) the color of fused porcelain was altered adversely by color forming oxides and by technique; (3) relatively soft gold-based casting alloys lacked sufficient strength and rigidity to withstand rigorous functional service.

Over the past decade, the foregoing difficulties have been reduced in frequency of occurrence and in severity (1,2). Today, the degree of bonding of fused porcelains to improved gold-containing (precious) alloys appears to be adequate. However, the mechanisms by which bonding occurs are not understood completely. Several explanations of the so-called porcelain-to-metal bond have been advanced. Van der Waal's forces (3,4), and the beneficial effects of compression forces resulting from small differences in thermal expansion of two dissimilar phases may contribute to bond formation.

In recent years, costs incurred in the laboratory fabrication of porcelain-fused-to-metal fixed prosthetic devices (crowns and bridges) have increased markedly. Increased production costs have been, for the most part, reflections of the advancing international

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market values of gold and other precious metals. Searches for less expensive venerable metallic substrates from which functional as well as esthetic restorations might be fabricated have led to interest in the use of materials alloyed from base metals rather than from precious constituents. Nickel (-60 to 80 percent) and chromium (-12 to 20 percent) are major components of the majority of available substitutes for high-fusing gold-based dental casting alloys. Although the physical and mechanical properties of the nickel-chromium alloys are sufficient for functional intraoral usage, difficulties have been experienced in obtaining reliable porcelain-to-metal bonding (6).

It would appear, from laboratory and clinical observations, that a relatively thick scale which accrues at the substrate surface during the application of the esthetic ceramic veneer is not conducive to the formation of color-stable and strong porcelain-to-metal bonds. Pretreatment of metallic substructures by the application of colloidal gold or by metal-ceramic mixtures prior to the application of porcelain presents an intriguingly expedient means for achieving improved bonding of fused dental porcelain to nonprecious (nickel-chromium) casting alloys. However, the excessive expense of colloidal gold preparations and the highly critical parameters of technique demanded for the effective use of proprietary metal-ceramic mixtures have limited the scope of acceptance of adhesion-promoting coating agents for base metals.

Tasks directed toward the development of inexpensive coating agents and the refinement of techniques for the promotion of nonprecious metal-to-porcelain bonding are being conducted at the United States Army Institute of Dental Research. This report provides an up-to-date summary of our progress.

MATERIALS AND METHODS

A simple test for rapid measurement of the apparent bond strength of metal-porcelain couples was developed within this laboratory. The metallic components of the test pieces were 1/4 X 1/16-inch discs. The discs were cast from six proprietary base metal alloys* in accordance with the laboratory procedures recommended by the respective manufacturers of the materials. Two series of castings for each of the alloys were used in specimen preparation. Test surfaces of the member castings of one series were handground on 240-grit metallographic papers. Then the discs were subjected to a 5-minute

* Nevdium, J. M. Ney Co., Hartford, CN 06101; Gemini II, Kerr Sybron Corp., Romulus, MI 48174; NP-2, Howmedica, Inc., Dental Division, Chicago, IL 60632; Omega-VK, Pro-Met, Inc., Oak Brook, IL 60521; Ticon, Ticonium Co., Inc., Albany, NY 12207; Ceramalloy, Johnson & Johnson Dental Products Division, East Windsor, NJ 08520.

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heat treatment at 1,950° F., cooled to room temperature in open air and again ground lightly on 240-grit abrasive paper. Castings included in a subsequent series were also surface-finished with 240-grit papers. Test surfaces of these discs were covered with a thin coating produced from a slurry of ethyl alcohol and a metal-ceramic powder. Composition of the powder component of the coating material was fine aluminum (1 part by weight) and opaque dental porcelain (5 parts by weight). The coated discs were heated to 1,900° F. and cooled to room temperature. Sintered remnants of the metal-ceramic coating were scraped from the discs to create relatively flat surfaces on which porcelain could be condensed.

Segments of 1/8-inch inside diameter polyethylene tubing approximately 3/16 of an inch in length were attached to the castings with the use of rubber cement. This arrangement provided adequate matrices into which aqueous slurries of the opaque powder component of a dental porcelain⁺ could be placed. After thorough condensation of the porcelain, the specimens were set aside and allowed to dry in room air for 20 minutes. Then the assemblies were placed in an open muffle for ignition and thermal destruction of the tubing.

The specimens were placed inside the muffle after temperature stabilization at 1,200° F. was achieved. The furnace temperature was increased at a rate of 80° F. per minute until the porcelain-fusion temperature of 1,825° F. was reached. The muffle vacuum was broken and the specimens were held at 1,825° F. for two minutes. The fused components were removed from the muffle and cooled to room temperature in open air. The fused alloy-porcelain pieces were placed in 9/16-inch cubic silicone rubber molds. Cylindrical receptacles at the bases of the molds insured the desired orientation of the alloy-ceramic specimens. The mold cavities were filled with a commercial dental tray acrylic.[#] A schematic representation of the fused and mounted specimen-components is shown in Figure 1.

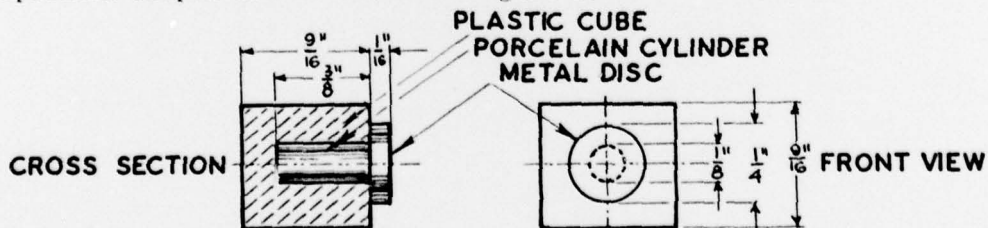


Figure 1. Specimen Design

+ B. F. Vacuum Porcelain (Paint-O-Pake), Ceramco, Inc., New York, NY 11101.

Fastray, Harry J. Bosworth Co., Chicago, IL 60605.

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Each cube was fastened in a small vise for added support. The assembly was oriented on a testing machine[§] to allow loading of the cast disc in a diametral direction. Crosshead speed of the testing machine was 0.02 inch per minute. Bond strength was calculated on the basis of ultimate load at shear failure per unit area of apparent porcelain-to-metal contact.

RESULTS

Load tracings (Figure 2) obtained on fracture separation of the metal-porcelain couples did not show deformation prior to bond failure.

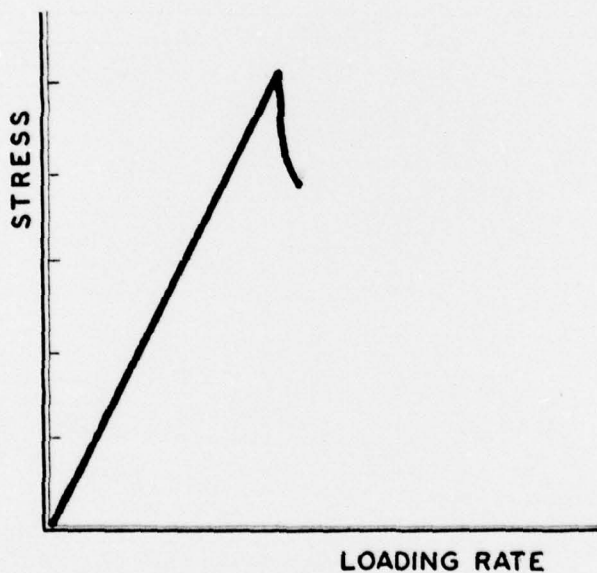


Figure 2. Typical load tracing.

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

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A prominent feature of the pattern of breakage displayed by specimens made from noncoated discs is shown in Figure 3. A black scale remained attached to the contact surface of the porcelain cylinder. It appeared that breakage occurred between the metal substrate and an oxide layer on its surface. All specimens produced from noncoated discs of the six test alloys failed in this manner when subjected to shear loading.

Failure of specimens made from aluminum-ceramic coated castings occurred in the vicinity of the coating-porcelain phase boundary (Figure 4). Remnants of porcelain of varying thickness remained attached to the coated surfaces of the metal discs.

Bond strength data for specimens fabricated from noncoated and coated cast discs are presented in Tables I and II, respectively. All reported values are based on a minimum of 30 observations.

Specimens made with the use of noncoated castings exhibited relatively poor porcelain-to-metal bonding. The six nickel-chromium based alloys gave bond strengths that ranged from 2,700 to 6,500 psi. Precision of the bond strength measurements was low. Coefficients of variation ranged from 29 to 42 percent.

A marked increase in measurement precision was obtained upon coating of the castings prior to the application of porcelain. Coefficients of variation declined to a narrow range of 11 to 17 percent. Also, specimens fabricated from coated castings gave significantly higher bond strength values than specimens made from noncoated castings. Increases in the apparent strengths of the metal-porcelain systems studied ranged from 10 percent to 66 percent for Gemini II-porcelain and Neodymium-porcelain combinations, respectively.

DISCUSSION

The application of porcelain to base metal alloys is technique sensitive. Failure of the porcelain-metal bond often occurs during the fabrication of a dental restoration. Such a failure is depicted in Figure 5. Separation of the porcelain from the underlying cast substructure is evidenced by the crevice at the occlusal juncture of the metal and the ceramic veneer. The crevice developed while the restoration was being cooled to room temperature following fusion of the porcelain.

Porcelain-fused-to-metal restorations made with the use of the aluminum-ceramic coating seldom exhibit separation defects (Figure 6).

The coating has been employed successfully in the fusion of porcelain to a wide variety of base metal dental treatment devices.

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Aqueous slurries of dental porcelain powders can be applied to coated castings with the use of common condensation techniques. Fusion of opaque, body, incisal and gingival porcelains as well as the final glaze can be accomplished without deviation from the time-temperature sequence prescribed by the manufacturer of the selected ceramic materials.

Improved porcelain-to-metal bonding that can be attained through the use of an aluminum-ceramic coating broadens the range of application of inexpensive nickel-chromium alloys in military dental practice.

SUMMARY AND CONCLUSIONS

A coating for enhancement of alloy-porcelain bond strength has been developed and its feasibility demonstrated. The development provides a composition of matter comprising substantially one part by weight fine powdered aluminum, substantially 5 parts by weight opaque dental porcelain, and sufficient water to form a useable aqueous slurry. The composition may include ethyl alcohol and any other liquid which will promote wetting of the substrate surface by the aluminum-ceramic admixture.

Improved base metal to porcelain bonding that can be attained through the use of the aluminum-ceramic coating material broadens the range of application of inexpensive nickel-chromium alloys in military dental practice. The advantages of this coating composition over prior art products are its low cost, ease of preparation and manipulation, and effectiveness in promotion of metal-porcelain bonding.

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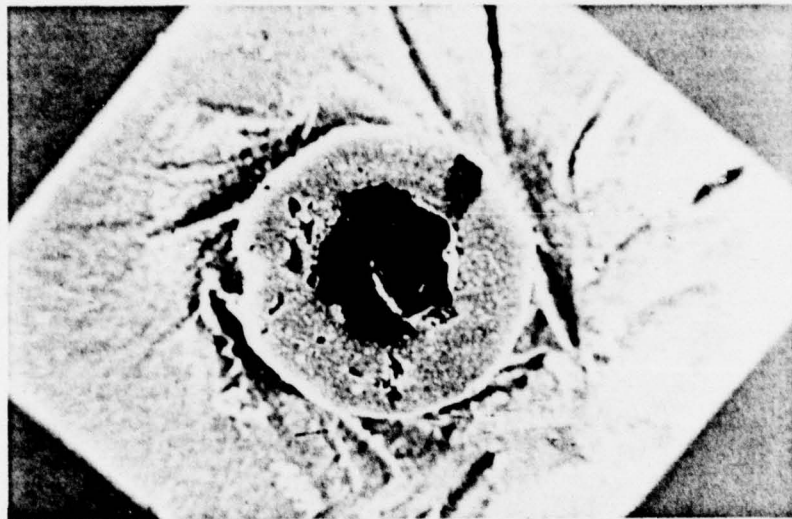


Figure 3. Breakage pattern of specimens
(noncoated discs).

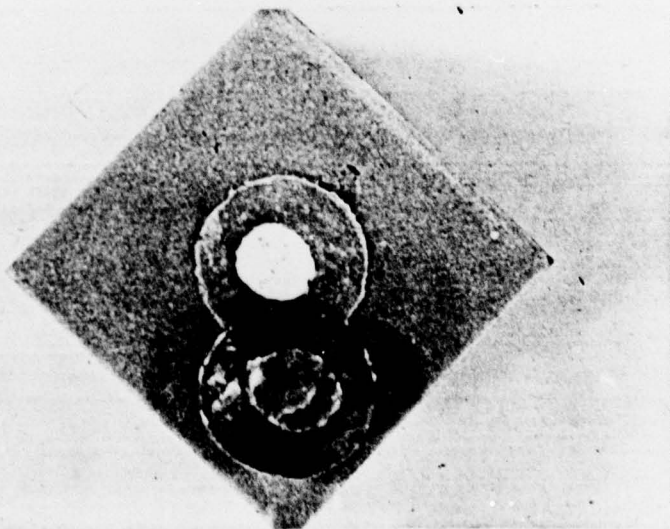


Figure 4. Breakage pattern of specimens
(coated discs).

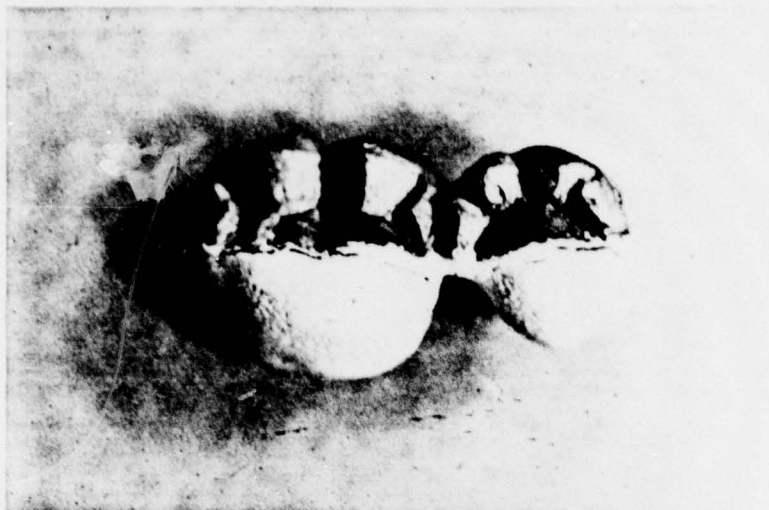


Figure 5. Metal-porcelain bond failure.

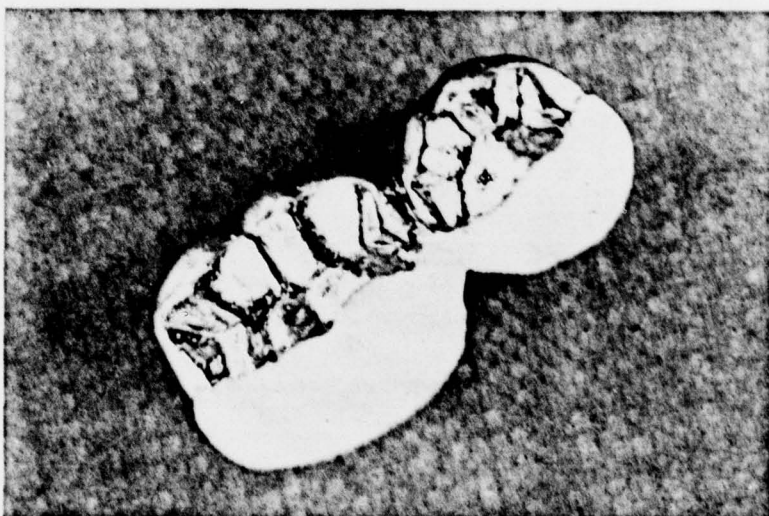


Figure 6. Esthetic fixed prosthetic device. Base metal sub-structure coated with aluminum-ceramic mixture prior to application of porcelain veneer.

TABLE I
APPARENT ALLOY-PORCELAIN BOND STRENGTH
NONCOATED CASTINGS

<u>Alloy</u>	<u>Mean Bond Strength (PSI)</u>	<u>C.V. %</u>
Neydium	2,700	34
Gemini II	6,500	29
NP-2	5,600	22
Omega-VK	5,500	33
Ticon	3,200	42
Ceramalloy	4,800	30

TABLE II
APPARENT ALLOY-PORCELAIN BOND STRENGTH
COATED CASTINGS

<u>Alloy</u>	<u>Mean Bond Strength (PSI)</u>	<u>C.V. %</u>
Neydium	7,800	12
Gemini II	7,200	17
NP-2	7,700	14
Omega-VK	7,100	11
Ticon	7,700	16
Ceramalloy	8,400	11