

Electroforming technology for ceramometal restorations

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Increased quality and reduced costs have made electroforming systems more appealing, even for use in smaller laboratories. What makes this new, easy-to-use system unique is that it eliminates the necessity of having a specialized technician.

Electroforming utilizes the electrochemical reaction to achieve electrodeposition. It was first introduced in 1838 by Jacobi in Russia. Electroforming was first employed in dentistry in 1856 by Newell. Its applications have been broadened by O.W. Rogers since 1970.¹ These innovations, along with the development of nontoxic plating solutions with high penetration power (the capacity to create an electrodeposition with a uniform thickness), make it possible to use this system to attain superior precision for porcelain-fused-to-highly precious-gold restorations (Fig 1).²

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■ Technique

The electricity passes through a microprocessor, an anode, an electrolytic solution, and a cathode. Closing the circuit generates the ion flow and results in deposition of the molecule onto the cathode (Fig 2). The copings to be plated are always positioned at the cathode. The gold is constrained to an ionic form in the electrolytic solution based on ammonium sulfite.

■ Laboratory Procedures

The master cast is prepared with the traditional techniques. To prevent chemical interaction with the duplicating material, a special die spacer is applied (Fig 3). The dies are duplicated with a silicon material in a casting muffle or special duplicating fixture (Fig 4). The duplicate die is poured with a stone material that has 0.1% to 0.2% expansion rate.³

The following steps are necessary to achieve electrical contact to the die surface. A hole is drilled directly beneath the preparation line of the duplicate die (Fig 5). The conductive silver lacquer is applied to the surface to be plated (Fig 6), and up to 20 units are placed

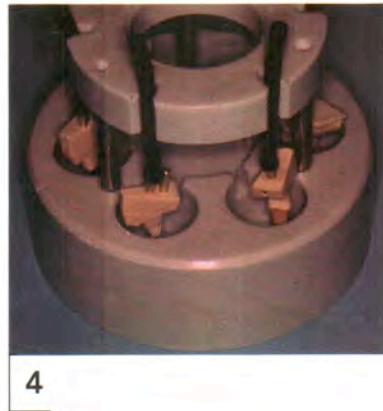
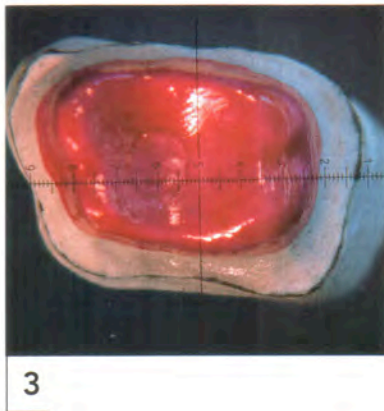
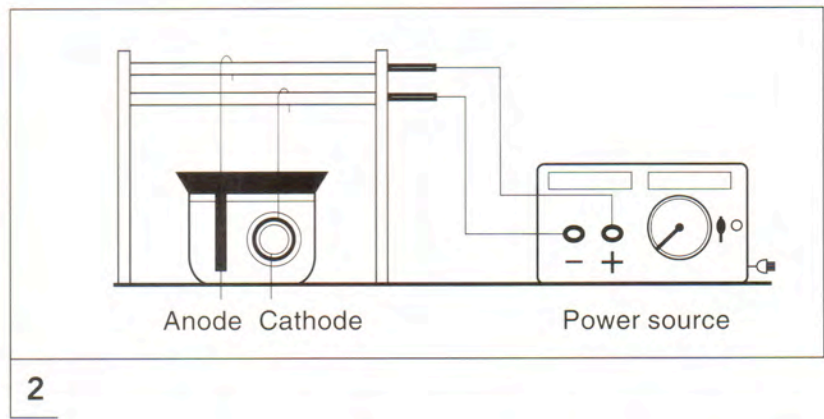


Fig 1 Scanning electron microscopic view of a sandblasted metal disk (dark area), on which a coat of electroformed gold is showing (light area). The image clearly shows the high-grade precision of this system. (Original magnification $\times 500$.)

Fig 2 Schematic illustration of an electroforming system.

Fig 3 Prepared die or fragment with space lacquer.

Fig 4 Fixture for the duplication of dies (Gramm).

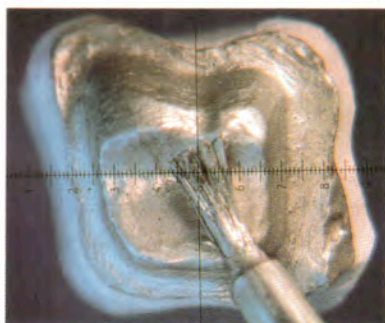
Fig 5 A hole is drilled underneath the preparation line of the duplicate stone die to allow attachment of a copper wire for electrical contact to the die surface.

onto the plating head (Fig 7). The program is started. The equipment (Fig 8) will automatically check the temperature and the intensity of current flow. In 3 to 11 hours depending on the desired wall thickness and the gold remaining in the solution, the electroplating process will be completed (Figs 9 and 10).

To remove the stone from the plated copings, the plating head is placed into a glass vessel with plaster stripper or manually

ground out and sandblasted. The stone and silver residue inside the copings (Fig 11) is removed by immersion in 30% nitric acid solution or sandblasting. An electrical peak is created at the marginal area; the excess gold should be refined with a silicon wheel (Figs 12 and 13).

The precision can now be confirmed on the master cast and compared to the fit of a traditional cast (Figs 14 to 18). Eliminating



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Fig 6 Application of conductive lacquer must be accurate; all areas should be covered. The precision at the preparation line is not as critical as might be believed (see Figs 16 and 17).

Fig 7 Electroforming head with the dies already mounted.

Fig 8 Electroforming equipment.



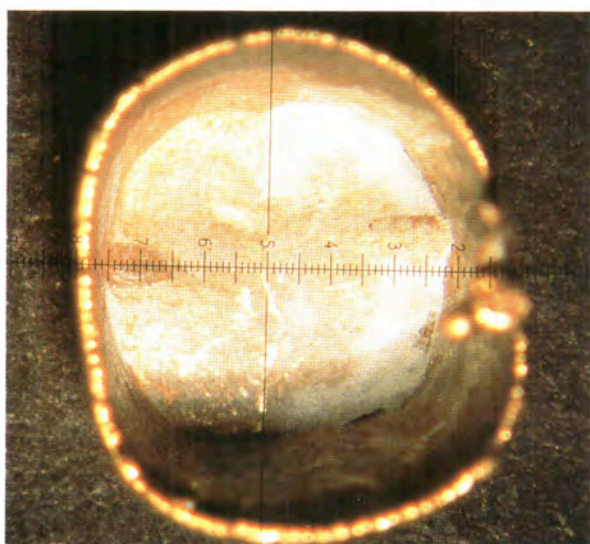
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Figs 9 and 10 Copings at the end of the plating process with a 0.2-mm wall thickness.

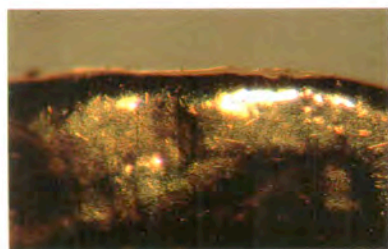
Fig 11 Inside of an electroformed coping immediately after the elimination of the gypsum, before sandblasting. Silver lacquer is evident.



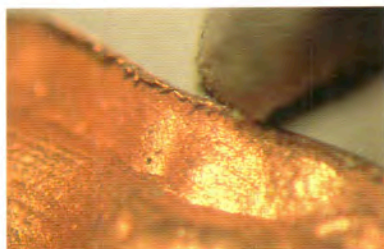
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porosities, stress, and oxides with the electroforming process ensures maximum biocompatibility⁴⁻¹⁰ and prevents uncontrolled deformation during firing, which frequently happens to cast structures.¹¹⁻¹⁴

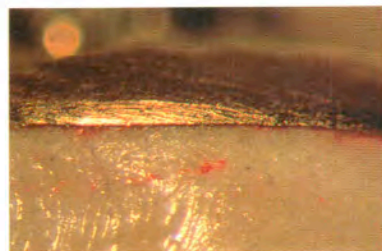
The copings are sandblasted with 110- μ m aluminum oxide at 2.5 bar (30 psi pressure) (Fig 19) and then cleaned in distilled water. A bonding agent must be applied in a thin and uniform layer that is fired at 900°C for 1 minute (Fig 20). The baking of the bonding agent is completed with the wash bake. It is advisable to bake conventional porcelain materials in thinner layers to minimize the negative effects of contraction that occur during sintering.¹⁵



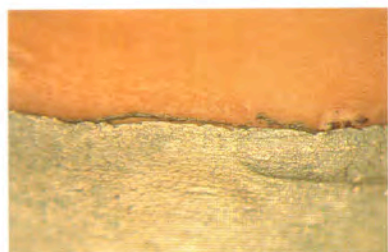
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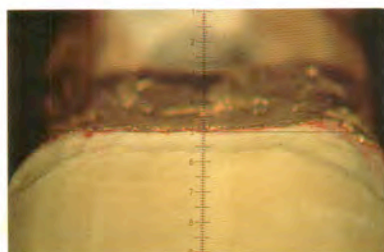
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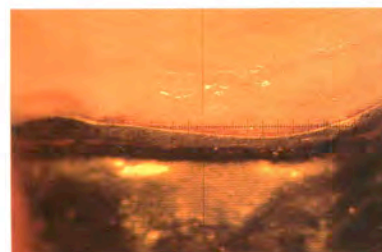
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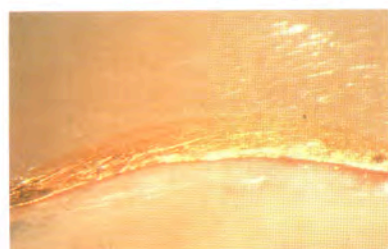
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Fig 12 Microscopic view at the electroformed margins before the finishing touches. (Original magnification $\times 62.5$.)

Fig 13 Microscopic view of the same coping during the finishing of the edge with a silicon wheel. (Original magnification $\times 62.5$.)

Fig 14 Microscopic view of superior regularity at the margin of an electroformed coping. (Original magnification $\times 62.5$.)

Fig 15 Microscopic view of uneven margin of a coping painted with silver lacquer. Compare to Fig 14. (Original magnification $\times 62.5$.)

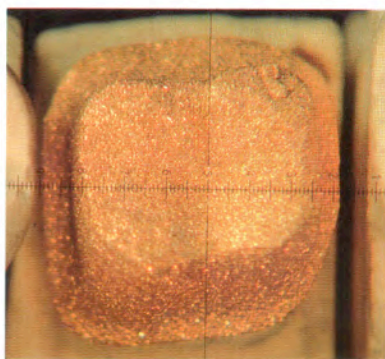
Figs 16 and 17 Microscopic views of the marginal closure of the electroformed coping (Fig 16; measurement from notch to notch is $24.6 \mu\text{m}$; original magnification $\times 40.6$) and of a coping cast in pure gold (Fig 17; measurement from notch to notch is $66.6 \mu\text{m}$; original magnification $\times 5$). The difference in the regularity of the margin is more appreciable.

Fig 18 Microscopic view of the marginal closure of an electroformed coping after the application of ceramic; the initial precision is unchanged.

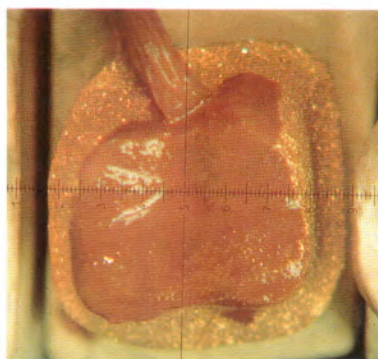
From an esthetic point of view, the electroformed crowns are the ideal substructure, because the gold tone of the copings frequently can be used without an opaquer; in this way it is possible to realize a greater space for stratification more closely resembling the natural tooth (Figs 21 to 28).

Application of the electroforming technique is not limited to the realization of single crowns and inlays. In recent years, methods

have been developed with a partial integration of the casting system, or new materials (eg, Carbo Galva Crown, Gramm Technik, Germany) allowing the realization of electroformed fixed partial dentures. These methods cannot be described in detail until more scientific data are available, although clinical results have been excellent. A research program on these new techniques is in progress.



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Fig 19 Electroformed coping after treatment with sandblasting and cleaning.

Fig 20 Coping during application of Gramm bonder.

Figs 21 to 27 Clinical cases resolved with electroformed porcelain-fused-to-gold restorations.



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Fig 21 Reconstruction of the maxillary left central and lateral incisors.

Fig 22 Reconstruction of the maxillary right central incisors.

Fig 23 Reconstruction of the maxillary right lateral incisor and canine.

Fig 24 Reconstruction of the mandibular left first and second molars.



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Fig 25 Reconstruction of maxillary central and lateral incisors.

Figs 26 Reconstruction of the maxillary right central and lateral, and left central incisors.

Fig 27 Reconstruction of the maxillary central incisors and left lateral.



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■ Analysis of Gold-Ceramic Bond Quality

The success of the bond between electroformed gold and ceramic materials is achieved by treatment of the metal copings. The compression bond is unmodifiable, because other metals cannot be added. Instead, the mechanical bond can be increased through the enlargement of the surface by sandblasting or application of a bonding agent, utilizing a process of diffusion. The bonder is a paste composed of gold and ceramic particles.

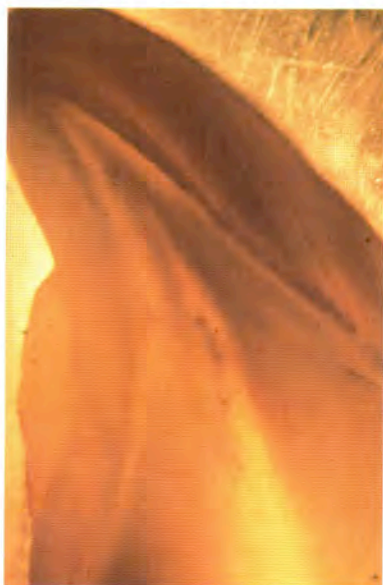
The results of current research have outlined a method to standardize the bond of electroformed gold to ceramic.

■ Methods and Materials

Following manufacturer's recommendations, six copings were fabricated with GAMMAT Dent 32 equipment (Gramm Technik) and Gramm's plating solution (Ecolyth). The copings were sandblasted with 100- μ m aluminum oxide at 2.5 bar (30 psi), placed in the ultrasonic cleaner with acetone for 10 minutes, and vaporized. The copings were then prepared as follows:

Group A. Two copings were coated with bonder (Gramm) and baked at 500°C for 1 minute (Flagship VPF, Jelenko, Armonk, NY), without vacuum.

Group B. Two copings were coated with a thin layer of bonder, baked for 1 minute at 900°C; the starting temperature was 500°C, increasing 60°C per minute with vacuum.



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Fig 28 Section of a natural tooth. The space available for prosthetic reconstruction is limited to the thickness of the enamel; the yellow-orange base tone (gold substructure) fosters the success of the esthetics of the reconstruction.

Figs 29 and 30 Scanning electron microscopic images of the bonder surface fired at 500°C (group A). (Original magnification $\times 500$.)

Fig 31 One of the preceding images of group A at higher magnification. (Original magnification $\times 1,500$.)

Figs 32 and 33 Scanning electron microscopic view of bonder baked at 900°C (group B). (Original magnification $\times 500$ [Fig 32] and $\times 700$ [Fig 33].)



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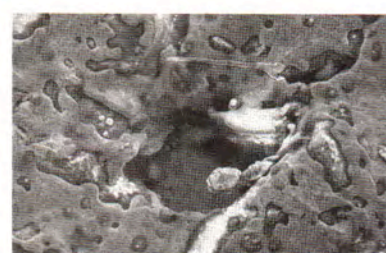
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Group C. No bonder was applied to the remaining two copings.

One coping in each group was coated with IPS opaquer (Ivoclar, Schaan, Liechtenstein), baked at 970°C for 1 minute; starting temperature was 400°C, increasing 80°C per minute with vacuum.

All units were analyzed with a scanning electron microscope with an acceleration of 1,000/1,500 V. The examination not only supplied an analysis of quality, but also provided a useful standard for everyday production, therefore allowing a quantitative analysis.

■ Results

Group A. Simple firing of the bonder at low temperature (500°C) did not guarantee an adequate exposure of the ceramic crystals

to the opaquer. They remained completely submerged in the gold matrix (Figs 29 to 31).

Group B. Because the chemical bond is determined by the fusion of ceramic particles to the opaquer, less exposure of the crystals means less bond. Consequently, the layer of the bonder must be thin and uniform, as in Group B (Figs 32 to 34). The images of the concave zones, where the bonder was present in larger quantities (Figs 35 to 37), showed empty spots where the ceramic grains were completely submerged in the gold matrix.

Group C. Detailed images showed that the adhesion of opaquer alone to a sandblasted gold surface lacked diffusion, indicating a weak bond (Figs 38 and 39).



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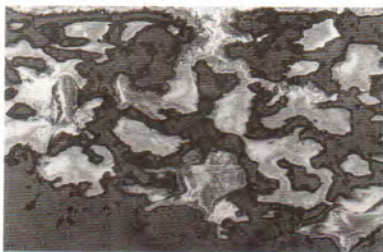
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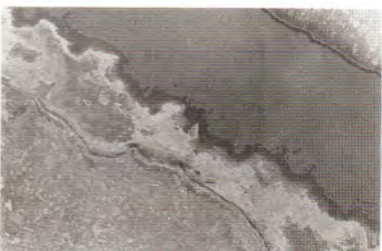
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Fig 34 One of the preceding images of group B at higher magnification. (Original magnification $\times 1,000$.)

Fig 35a Microscopic view of a longitudinal section of a galvanic coping with bonder applied. (Original magnification $\times 62.5$.)

Fig 35b Microscopic view of a longitudinal section of an electroformed coping with a thick layer of bonder. (Original magnification $\times 400$.)

Fig 36 Scanning electron microscopic view of the same section at the concave area of the margin. The coping is visible as a compact dark layer; the bonder is too thick and appears as an irregular layer with empty spots (ceramic submerged in the gold matrix). (Original magnification $\times 110$.)

Fig 37 Increased magnification of Fig 36. There are ceramic crystals isolated in the gold matrix. (Original magnification $\times 430$.)

Figs 38 and 39 Scanning electron microscopic views of sandblasted and opaqued surface, fired without application of bonder (group C). (Original magnification $\times 250$ [Fig 38] and $\times 330$ [Fig 39].)

■ Conclusion

The results of the study indicated the best treatment for electroformed copings:

1. Bonder should always be used and applied in a thin and uniform layer. Special attention must be paid to the concave areas.
2. The baking temperature must be high enough to provide adequate exposure of the ceramic crystals present in the bonder, but not so high to prevent complete exposure of the crystals.
3. The bonder should be baked with a starting temperature of 500°C , increasing 60°C per minute, under vacuum to 900° for 1 minute.

■ References

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