THE EFFECT OF GOLD ELECTROFORMING PROCEDURE ON GOLD-SILVER-PALLADIUM ALLOY

Bo-Yeon Hwang, D.D.S., M.S.D., Chang-Whe Kim, D.D.S., M.S.D., Ph.D., Young-Jun Lim, D.D.S., M.S.D., Ph.D., Myung-Joo Kim, B.Sc., D.D.S., M.S., Ph.D.
Department of Prosthodontics, College of Dentistry, Seoul National University

Statement of problem. The effect of gold electroforming on gold alloy was not studied.

Purpose. This in vitro study investigate the effect of gold electroforming on gold-silver-palladium alloy.

Material and methods. Three pieces of gold strips had undergone the electroforming procedures on one side and then half of the side again electroformed.

The set mode for this study was program 1 (200 μm). And the processing time was 15min (1/20 time to form 200μm coping).

The confocal laser scanning microscope (PASCAL 5, Carl Zeiss, Bernried, Germany) was used to measure the thickness of the pure gold layer electroformed on the gold strips. Half of the gold strip was coated two times with electroformed gold, and the other half one time. The data from the cone focal laser system was processed to get the vertical profile of the strips and the difference of the vertical height between the double coated and single coated layer was regarded as the thickness of the gold coating. The layer thickness value to built 3D image of the cone-focal laser was set 0.5 μm.

Next to the measurement of the thickness of the coating, the Vicker's hardness test was done. It was performed on the double coated surface, single coated surface and non-coated surface (back side) three times each.

Results. The mean thickness value gained from gold electroforming technique was measured to be 22 μm for sample 1, 23 μm for sample 2, 21 μm for sample 3. In the same condition of time, power and the amount of electrolyte, the data showed no difference between samples.

According to the results of variance analysis, the differences among the variations in number of coating were statistically insignificant ($p>0.05$), meaning that the two times of gold electroforming coating did not change the hardness of gold-silver-palladium alloy.

Conclusion. The test of thickness of gold coating proved the coherency of the gold electroforming procedure, in other words, when the power, the exposed surface area, processing time and the amount of electrolytes were set same, the same thickness of gold would be coated on.

The hardness test showed that the electroformed gold coating did not change the hardness of the gold-silver-palladium alloy when it is coated not more than 45 μm.

Key Words
Gold electroforming procedure, Gold-silver-palladium alloy, Confocal laser scanning microscope, Vicker's hardness test

The use of electroformed gold copings as the core of fixed oral prostheses was first introduced by Rogers in 1961.[1] The process recommended by Rogers has significant drawbacks. The process uses a highly toxic electrolyte that contains potassium cyanide, posing a potential health hazard.[2-5] In the late 1970s Wismann developed an electrolytic system that uses a cyanide-free electrolyte, but large, expensive equipment is required and the process is rather difficult to perform. Both factors make this system impractical for the average laboratory.[6]

In the late 1980s a new, much smaller system was developed by Gramm Technik[7], an industrial plating company in Germany. The GES Gold Electroforming System was first introduced to the dental industry in 1990.[1] In addition to being smaller; the equipment was less expensive than other systems, bringing electroforming closer to the range of affordability and practicality for dental laboratories of any size. The use of a cyanide-free electroplating solution eliminates the introduction of that hazard into the work environment.[8]

The GES system uses 24 karat gold to form copings for use in the production of very precisely fitting crowns, inlays, onlays, telescopic cases and bridges.[9,10] The system produces copings with an even wall thickness of 0.2mm and an average marginal gap of 19 μm.[8]

Gold electroforming technique was originally used for gold coating on any metal surfaces and it can change the corrosive characteristic and surface texture.

The thickness of coating is dependant on the power between the cathode and anode, the amount of electrolytes, exposed time.

In this study, whether coating pure gold on gold alloy (gold-silver-palladium) had changed the surface hardness was tested.

MATERIAL AND METHODS

The electroforming process was done using AGC Micro System(Wieland dental, Pforzheim, Germany). Three pieces of gold strips had undergone the electroforming procedures on one side and then half of the side again electroformed. To insulate the surfaces that should not be electroformed on were painted with a nail lacquer that contains no conductive material(Fig. 1). Each gold strip was attached to the copper rod by laser welding machine (combilabor, heraeus Kulzer, Hanau, Germany). The set mode for this study was program 1 (200 μm). And the processing time was 15min (1/20 time to form 200 μm coping).

After the electroforming, the welded copper rods were removed from each gold strip, which were immersed in acetone to remove the lacquer painted on the surfaces for 24 hours and attached on slide glasses using double stick tapes.

The Confocal laser scanning microscope (PASCAL 5, Carl Zeiss, Bernried, Germany) was used to measure the thickness of the pure gold layer electroformed on the gold strips. Half of the gold strip was coated two times with electroformed gold, and

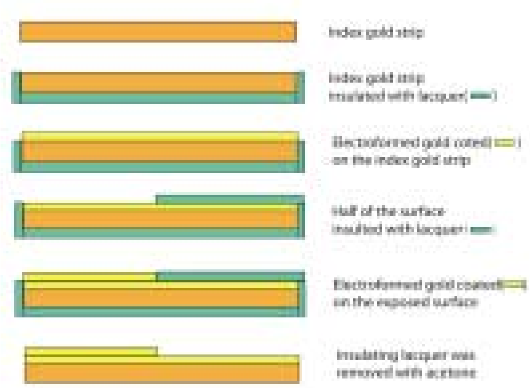

Fig. 1. Preparation of the index gold strip.

the other half one time. The data from the confocal laser scanning microscope was processed to get the vertical profile of the strips and the difference of the vertical height between the double coated and single coated layer was regarded as the thickness of the gold coating. The layer thickness value of the cone-focal laser was set 0.5 μm.

After the measurement of the thickness of the coating, the Vicker's hardness test(HMV, Shimadzu, Japan) was done. It was performed on the double coated surface, single coated surface and non-coated surface (back side) three times each.

RESULTS

The mean thickness value gained from gold electroforming technique was measured to be 22 μm for sample 1 (Fig. 2), 23 μm for sample 2 (Fig. 3), 21 μm for sample 3 (Fig. 4). In the same condition of time, power and the amount of electrolyte, the data showed no difference between samples.

Mean Vicker's hardness values and standard deviations of non coated, single coated and double coated surface are printed in Table I and Fig. 5.

The Vicker's hardness test values were statistically analyzed by a two-way ANOVA for electroforming Treatment and samples. According to the results of variance analysis, the differences among the variations in number of coating were statistically insignificant ($p>0.05$), meaning that the two times of gold electroforming coating did not change the hardness of gold-silver-palladium alloy. The mean value and the standard deviation were shown in Fig. 5.

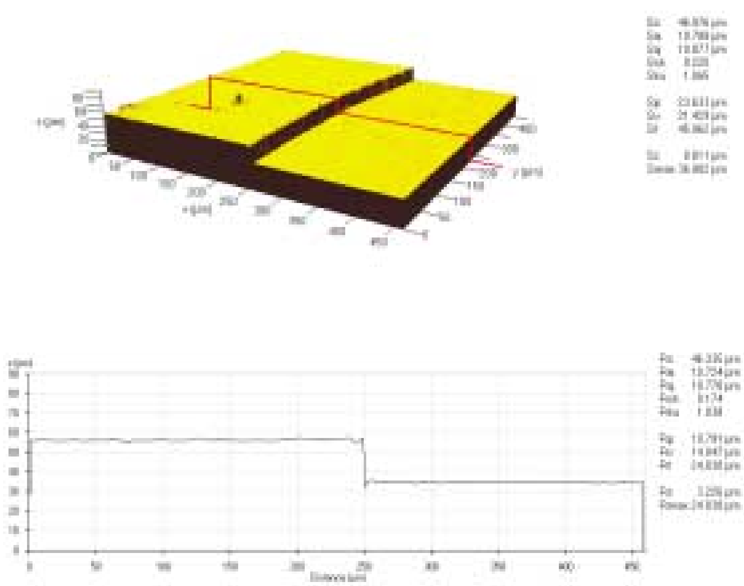

Fig. 2. Confocal laser scanning microscope data of sample 1.

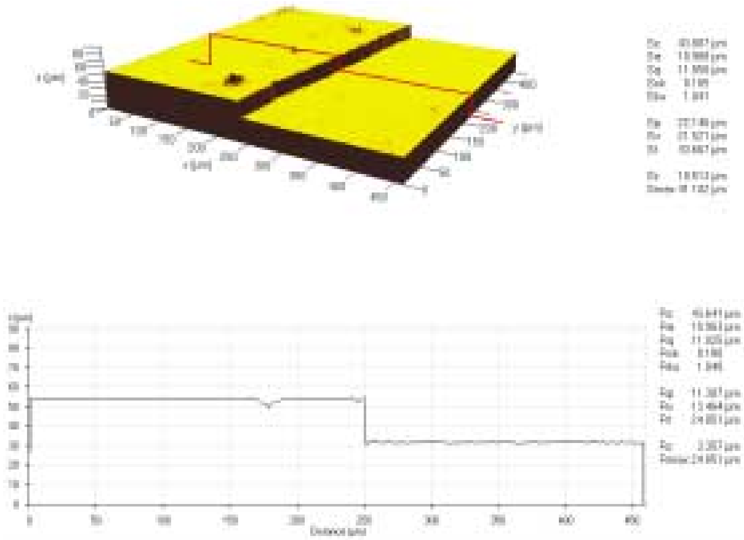

Fig. 3. Confocal laser scanning microscope data of sample 2.

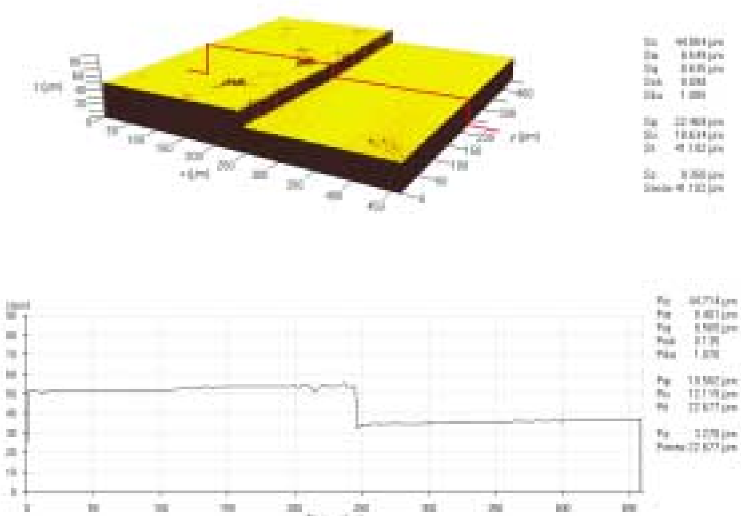

Fig. 4. Confocal laser scanning microscope data of sample3.

Table I. Mean Vicker's hardness values and Standard deviations

coating	Sample	Mean	Std. Deviation	N
raw	sample1	290.33	9.238	3
	sample2	268.67	4.041	3
	sample3	284.67	7.572	3
	Total	281.22	11.595	9
coating1	sample1	285.67	19.655	3
	sample2	279.67	2.887	3
	sample3	291.33	6.110	3
	Total	285.56	11.555	9
coating2	sample1	304.00	6.083	3
	sample2	244.67	12.220	3
	sample3	279.00	3.606	3
	Total	275.89	26.746	9
Total	sample1	293.33	13.973	9
	sample2	264.33	16.845	9
	sample3	285.00	7.450	9
	Total	280.89	17.855	27

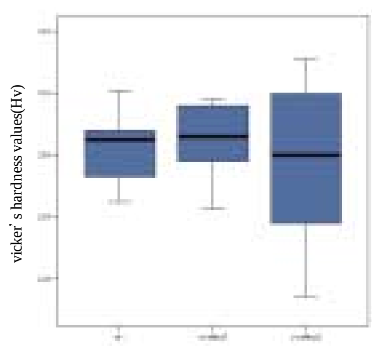

Fig. 5. Mean vicker's hardness values and standard deviations Data of each were obtained from the single electroformed surface (Single GEP), the double electroformed layer(double GEP), and the back side of the index gold strip specimen(control).

DISSCUSSION

The thickness of electroformed gold has the linear proportional relationship with electrical power and time factor.

$m \sim l \cdot t$ (Equation 1)

m = deposited mass

l = power

t = time

If the scale of power was constant throughout the entire electroforming procedure, the amount of deposited mass could be linearly controlled with the change of the time factor. Prior to performing this experiment, we had contacted the manufacturer of the gold electroforming machine to know the change of the programmed electrical power value through an electroforming procedure, but the information was not available because it's one of the secrets of the company. Some pilot study was needed then to know the time value for the formation of gold layer of about 10-20μm. In this experiment 15 minute was applied, and that time value was 1/20 of recommended value to make a gold coping of 200μm thickness. As a result, mean 21μm thickness was acquired through the electroforming procedure with the 1/20 time value, and it was hard to assume that the power value was constant through the electroforming procedure.

The test of thickness of gold coating proved the coherency of the gold electroforming procedure, in other words, when the power, the exposed surface area, processing time and the amount of electrolytes were set same, the same thickness of gold would be coated on.

The hardness test showed that the electroformed gold coating did not change the hardness of the gold-silver-palladium alloy when it is coated not more than 45 μm .

The electroformed gold has the advantage of greater metal density than cast metal and a lack of internal stress and porosity. Comparing the schematics of the molecular configuration of the two forms of metal, it can be seen that electroforming metal and cast metal have slightly different formations.[11] These characteristics enhance the potential for long-term durability of electroformed restorations.[12,13,10]

This study proved that the gold electroforming procedure on gold-silver-palladium alloy specimen increased the thickness of it without the change of surface hardness value. These results are expected to be applied for the use of this technique to increase the retentive force between the inner and the outer conus telescopic crowns.

The conus telescopic crown proposed by Körber[14] made telescopic RPDs popular; however, special technical skills and experience are required to fabricate a conus telescopic crown with suitable retentive forces. In a review of telescopic retainers, Langer[15] stated that the application of the double crowns requires considerable clinical skill and experience. Conus telescopic crowns required precise frictional retention between the coping and telescopic crown. The "conus friction force" was the main source of the retentive force in the conus telescopic crown system. It can be difficult to control the retentive forces of the conus telescopic crown within an appropriate range. Telescopic system has been used in various clinical situations, and these days even in implant prostheses. Several types of these retainers have been reported[16-18], but simply these can be categorized as cylindrical and conus type. The difference between the conus and the cylindrical crowns is the certain taper on the vertical surface of the conus crowns. The cylindrical telescopic crown (with parallel axial walls) has not been used recently because its retention is obtained by a tight contact[19]. Therefore, the conus crowned dentures are currently preferred instead of the cylindrical telescopic crown. The well designed tapered conus crowns can be easily removed without overfriction enabling the surrounding tissues to be treated gently.[18,20,21] In tec hnically perfect and smooth surfaced conus crowns, the retentive force is determined by the angle of the conus crown.[22,23]

A number of in vitro studies have been reported about the retention loss of telescopic crown after insertion / separation cycles. Ohkawa et al[18] demonstrated retentive forces of various types of conus telescopic crowns. They also reported a decrease in retentive forces after 10,000 insertion / separations cycles and the correlation between the conus angle and retention loss. Besimo et al[24], have researched the retention losses in 5.5° and 6.5° angled primary and secondary crowns made of pure titanium, gold and cobalt-chromium alloys. No significant difference or any changes in retention values between the titanium and golden secondary crowns were observed. Becker[25] reported that the change in the surface characteristics of frictional surfaces of the telescopic crowns would cause differences in retentive forces and that saliva also affect the retention.

Various clinical long term studies showed the retention change of Conus Crown Retained Denture and patient satisfactions. Margareta et al[26] reported 50% examiner-determined limited retention with a mean wearing time of 30.1 month, but none of the patients complained about the loss of retention. Johan Hulten[27] et al, have shown that 86% of patients satisfied with the retention of Conus Crown Retained Denture in a mean wearing time of 45 month. Yoshimasa Igarashi[28] et al reported that the retentive force of Conus Crown Retained Denture was significantly deficient in 58% of the few remaining group, and fairly deficient in 24% of the class I group.

The potential applicable field for the Gold Electroforming technique is unlimited and the advantages gained are evident, but the only drawback is its expensiveness.

CONCLUSION

1. The mean thickness value of the electroformed gold was 21μm.
2. The test of thickness of gold coating showed the coherency of the gold electroforming procedure.
3. The hardness test showed that the electroformed gold coating did not change the hardness of the gold-silver-palladium alloy (P>0.05).

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Reprint request to:

Chang-Whe Kim, D.D.S., M.S.D., Ph.D.
Department of Prosthodontics, College of Dentistry,
Seoul National University
28, Yonkon-Dong, Chongro-Gu, Seoul, 110-749, Korea
k43c46w@snu.ac.kr