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APPLICATIONS OF WIRE EXPLOSION IN THE FIELD OF PROSTHETIC DENTISTRY (I)

Metallic denture bases

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The research outlined in this paper concerns with applications of press forming and metallic spraying by means of electric wire explosion, in the field of prosthetic dentistry, and also the new apparatus developed in the course of the study. Results obtained are summarized as follow.

1. With a view to establishing the method of manufacturing metallic denture bases through underwater wire explosion press forming, a large number of tests were carried out under various forming condition characterized with energy of electric discharge, dimensions and arrangement of the wire, and so on. Eventually, it was found that a metallic denture base could be successfully formed with the aid of an ordinary dental stone die. Through this newly developed method, both the technique and apparatus of manufacturing a denture base have been remarkably simplified, and yet the accuracy of forming is as good as the case of a cast one [1,2,3,4].

2. In order to keep the adhesive force sufficiently large between a metallic denture base and resin, the contact surface of metal was made rough by means of explosion spraying of wire of the same metal as the base. In spite of the fact that this procedure is extremely simple, the adhesive strength between the resin and the base is found to be enhanced up to the order of the tensile strength of the resin itself.

3. Number of the dentures manufactured through this method amounts to 25. Case study of them reveals that clinically very good results have been yielded without exception.

4. On the bases of the study mentioned above, a new set of equipments of wire explosion press forming and spraying for prosthetic dentistry was developed. This apparatus may be applied to manufacturing other prosthetic appliances also.

1. Introduction

Most of the denture bases are made of acrylic resin or metal. The

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metallic base has the following characteristics when compared with the one of acrylic resin: larger strength, higher ductility allowing smaller thickness, better adaptation, better conductivity of heat, better sanitary condition, but, at the same time, higher price, and so on.

What are classified as metallic denture bases consist of cast bases, swaged metallic bases, and those manufactured through explosion press forming (high speed foming) [6,7]. Cast bases have larger adaptability. They are, however, more expensive, because of complicated process of manufacture. Besides, more processes are needed in polishing, because the surface of the ingot is roughened owing above all to moulding plaster remaining on the surface. On the other hand, swaged metallic bases can be produced having uniform and small thickness. Polishing is easy and readjustment is possible. However, they have less adaptability and higher skill, and more processes of manufacture are needed in forming. Generally speaking, they are being replaced by cast denture bases.

On the other hand, denture bases produced through high speed forming by means of explosion of gun powder have the defects which follow: danger encountered in treating gun powder, huge scale of equipment of production, and less adaptability; very little of them are put to practical use in these days.

The chief purposes of this research lie in automation and simplification of manufacturing process and equipment, reduction of cost, improvement in adaptability, and so on, for the production of metallic bases. Results of our study may be summarized as follow.

(1) The purposes above-mentioned were achieved through underwater wire explosion press forming. In the course of this research, because the appropriate magnitude of energy of electric discharge in the press forming could be determined experimentally, it became possible to form the base simply by using an ordinary dental stone die. Besides, the overall accuracy of manufacturing is found to be greater than in cast bases.

(2) Fine grains of metal are sprayed over the pertinent part of a base through wire explosion in order to prepare the roughened surface for adhesion between a base and resin. By this means, adhesive strength of the resin was found to increase almost up to the tensile strength of the resin itself. This resulted in facility of formings of posterior border sealings and also in simplification of the structure of resin holders.

(3) On the basis of the experiments stated above, a new wire explosion spray equipment for prosthetic dentistry was developed by designing specially the parts responsible for explosion press forming and metal spraying.

2. Equipment for underwater wire explosion press forming and metal spraying

Whole of the equipment constructed for prosthetic dentistry is shown in Fig. 1. As shown by Fig. 2, it consists of a circuit of electric discharge (an energy source and a controller), and apparatus for press forming by

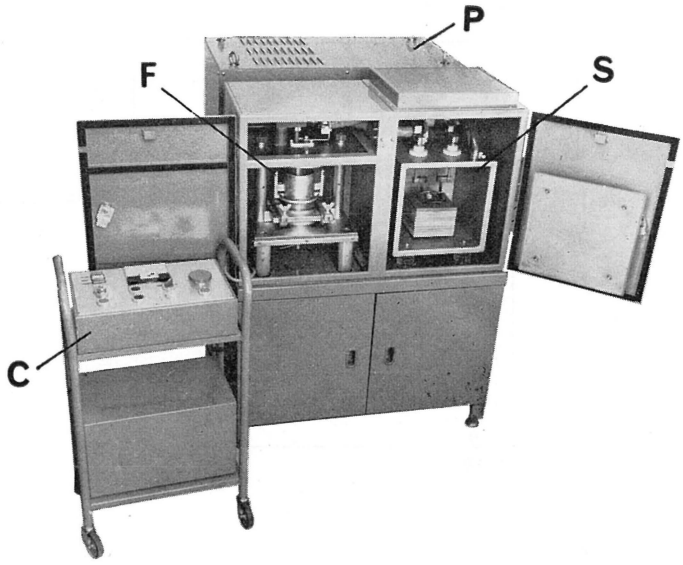


Fig. 1 Press forming and spraying equipment of wire explosion, specially designed for prosthetic dentistry
C: controller, P: condenser bank, F: forming apparatus, and S: spraying apparatus.

underwater wire explosion and for spraying of metal.

(a) The capacity of a capacitor contained in the electric source is 50 μF, the maximum charging voltage being 10 kV, the ringing frequency 20 kHz. Automatic and manual operations are both possible. However, simultaneous use of the press forming and the spraying parts is not admissible. The dimensions of the equipment is given as 900 mm (width) $\times$ 500 mm (depth) $\times$ 1200 mm (height).

(b) In the press forming part, the blank, placed upon a forming die made of dental stone, constitutes the bottom of a water tank, in which the tips of electrodes are bridged with a wire. The dimensions of this part are given as 900/2 mm (width) $\times$ 400 mm (depth) $\times$ 1200 mm (height).

(c) In the metal spraying part, a metallic base upon a stand is masked appropriately, and in its neighborhood are placed the tips of electrodes bridged with a wire of the same metal as the base. This part of the apparatus is shielded with a case doubly for the purpose of absorption of sound of explosion, and in addition is provided with an air cleaner. So that no smoke nor metal corpuscules are allowed to escape outside.

Incidentally, this equipment may be put to use also in forming a metallic dental crown.

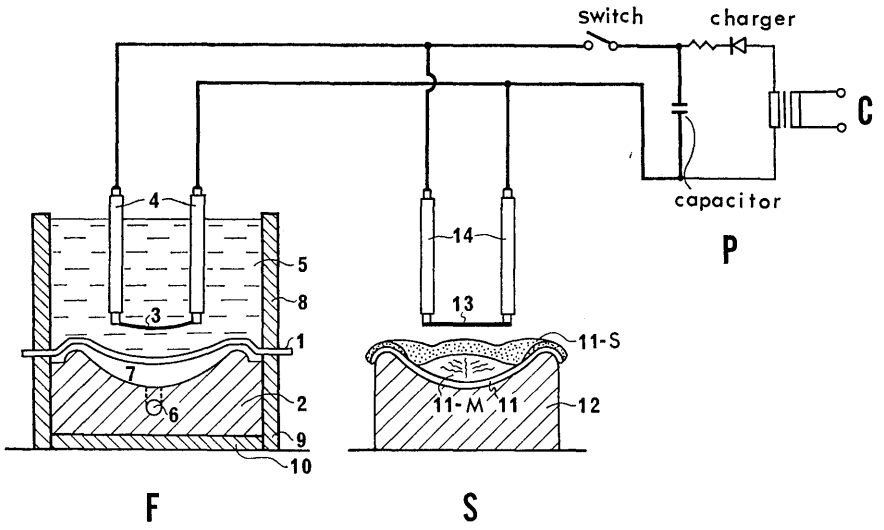


Fig. 2 Details of the equipment
C: controller, P: condenser bank, F: forming apparatus, and S: metal spraying apparatus.
1: blank, 2: dental stone die, 3: exploding wire, 4: electrodes, 5: water, 6: air vent, 7: gap between 1 and 2, 8: water tank, 9, 10: frame of die, 11: denture, 11-M: mask, 11-S: sprayed region, 12: holder, 13: wire of spray material, and 14: electrodes.

3. Forming of a metallic denture

3.1 Forming procedure [1]

Explanations about physical mechanism of the press forming in the prevailing underwater wire explosion are omitted here. The point of our forming procedure for prosthetic dentistry is to place a blank pre-formed immediately above a base die. By this means break of the die due to the impact against the metal plate can be prevented, since the mechanical energy necessary for the deformation of the plate to take place may be kept small. Accordingly forming can be done with the aid of an ordinary dental stone die. Because only a small quantity of air is allowed to remain between the blank and the die, by providing the gap with a simple air vent, air contained in it can be discharged without difficulty in the course of forming. It is not necessary, therefore, to evacuate the space intermediate.

As a blank, a plate of stainless steel 0.3~0.5 mm thick, 18-carat gold, or silver-palladium alloy is used.

The dependence of the optimum forming condition upon the wire is given by the formulas [5]

$$s=k_1CVf^{2/3}, \tag{1}$$

and

$$l=k_2CVf^{-2/3}, \tag{2}$$

where s and l denote respectively the optimum cross sectional area and the optimum length of the wire, k_1 and k_2 the numerical constants depending on the material of the wire, C the capacitance of the capacitor, V the charging

(a) (b) (c)

Fig. 3 Forming die of dental stone, and denture base of stainless steel
(a): die, (b): full denture base, and (c): partial denture base.

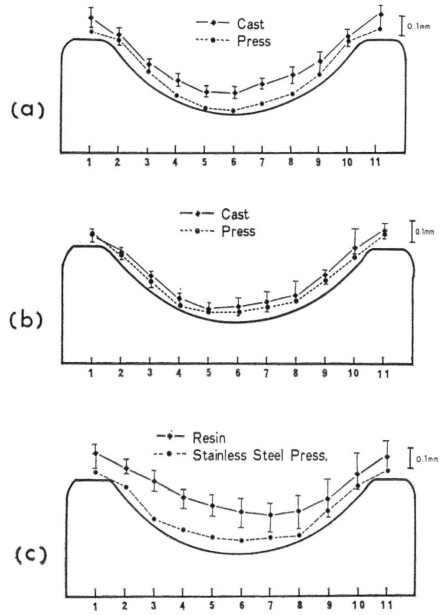


Fig. 4 Relative fitness of denture bases (transverse section)
(a): 18-carat gold, (b): silver-palladium alloy, and
(c): 18-8 stainless steel and heat cured acrylic resin.

voltage, and f the ringing frequency of the circuit. In practice, underwater wire explosion is given birth to using the apparatus shown in Part F of Fig. 2. In this case, the capacity of Part P is 50 μF, the charging voltage 5~8 kV, and the aluminum wire 0.3 mm in diameter and 30 mm in length is used. The water in the tank is about 300 cc in volume. The appropriate speed of protrusion of the blank during press forming was found to be 120~130 m/s.

3.2 Precision of dimensions [1,2,3]

A dental stone die and a product from it are shown in Figs. 3 (a) and 3 (b), respectively. Precision of dimensions were measured with respect to a standard model of an upper jaw and a test piece formed according to it; the results are given in Figs. 4 (a) and 4 (b). It is observed that the error of dimensions is less than 5/100 mm. This is less than that encountered in cast bases, 10/100 mm, and far less than that observed in acrylic resin bases, 30/100 mm, as shown in Fig. 4 (c). Besides, the base is workhardened by the amount 20~30 % through press forming procedure compared with the raw material.

4. Press formation of resin holder

4.1 Method of metallic spraying [1,5]

Generally the resin on a metallic denture base can be preserved through lattice work or frame work of the base itself. However, these structures are complicated and the formations are quite difficult. Besides, a finishing line for fairing is needed in these cases.

In our method, as shown in part S of Fig. 2, it is necessary only to spray a wire of the same metal as the base in the form of coarse grains against the holder of resin by means of explosion and thus to roughen the base surface to the extent of roughness more than 20 μ. The condition of spraying depending upon the material of a wire can be obtained by taking the value of k_1 ten times as large as in the equation (1), and that of k_2 two times as large as in the equation (2), valid for the press forming process. The distance d between the wire and the base has to be chosen within the range

$$20r \leqq d \leqq 30r, \tag{3}$$

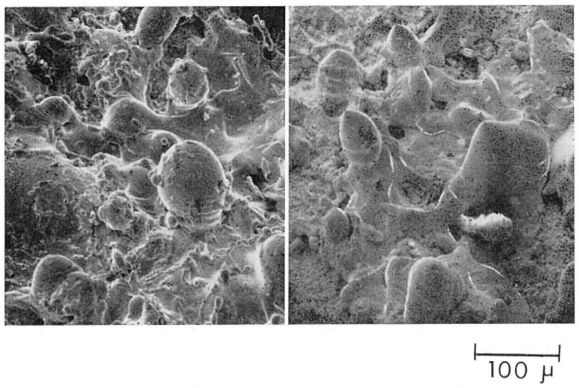
where r denotes the radius of the wire, while α, the angle of impact of the sprayed corpuscules against the base surface is to be taken within the range

$$45° \leqq \alpha \leqq 135°. \tag{4}$$

The part of the base, not to be sprayed upon, should be masked with cellophane tape or lacquer.

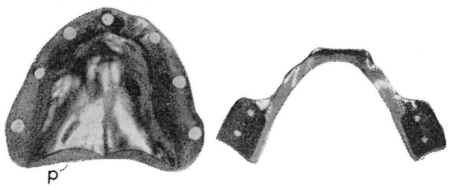
4.2 Adhesion strength of resin

The surface of a base, upon which metal was sprayed in order to adhere resin, is shown in Fig. 5. The roughness of this sprayed surface exceeds 20 μ, and self curing resin applied on this surface shows the tensile strength of separation about 4 kg/mm^2, which is approximately equal to the tensile strength of the resin itself, and the surface might be concluded to have the sufficient adhesion strength. This spraying technique can be applied also to the adjustment of position of a base for the posterior border sealing and the crest of a ridge. The base sprayed in this way is shown as Fig. 6.



(a) (b)

Fig. 5 Image of secondary electrons of EPM of the base surface, after sprayed through wire explosion (in the direction 45°) (a) sprayed surface of stainless steel, and (b) sprayed surface of tungsten.



(a) (b)

Fig. 6 Denture base sprayed
(a) for upper jaw, p: for posterior border sealing, and
(b) for lower jaw (partial denture base) bartype.

5. Results of clinical applications [3,4]

Twenty-five patients were furnished with the denture bases manufactured according to the procedure explained in this report. The result gains public favor. General comments are as follow.

(a) (b)

Fig. 7 Completed partial plate denture
(a) for upper jaw, and (b) for lower jaw.

1) Good adaptation and high adhesion.
2) No weight sensation.
3) Good affinity because of small thickness of the base.
4) Natural vocalization.

In Fig. 7 is shown a completed denture of upper and lower jaws.

6. Summary

Experiments were conducted through which the metallic denture base with thickness 0.3~0.5 mm through wire explosion technique. The result may be summarized as below.

(1) By pre-forming the blank, we can press form it with an ordinary dental stone die.

(2) The forming technique is quite simple.

(3) The accuracy of forming is good; re-pressing is also possible.

(4) Polishing after forming is hardly necessary.

(5) Construction of a resin holder is simplified, because the adhesion strength can be sufficiently maintained simply by roughening the surface with coarse grains of sprayed metal. No support is necessary.

(6) The posterior border sealing can be also formed without difficulty.

(7) Clinical tests were given public favor.

(8) On the basis of these experimental results, the new equipment for wire explosion spraying to be put to use in the field of prosthetic dentistry was developed.

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