An Appraisal of Ultrasonic Compaction of Gold Foil

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IN SPITE OF INTENSIVE SEARCHING for new materials, the most lasting restorative material in dentistry, to date, is gold foil. The public and the dental profession, alike, owe much to the men who saw the potential of gold foil as a filling material and were willing to discipline themselves to the extent necessary to render the best dental care for their patients. There is no need to say here that gold foil at its best is the quintessence of preventive dentistry. Recognition of that fact was the basis for the formation of the American Academy of Gold Foil Operators.

The Academy, moreover, is aware of the need to promote use of the technic in the profession by developing new forms of gold or new technics of compaction to make the method more easily accepted for general practice and, thus, more widely used. It is in this vein that we have experimented with several forms of gold under old and new technics. Among the pure golds, we have used Williams* mat gold and Morgan Hastings** gold foil and Goldent. Hardness and microstructure were studied under hand and pneumatic compaction.[1,2]

A thesis study by a graduate student in our Department of Operative Dentistry, showed better density and compaction with ultrasonic vibration.[3,4] However, there were problems with

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**Morgan, Hastings & Co., Philadelphia, Pa.

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heating and vibration which raised grave doubts about clinical use of the method.

To continue the research, we obtained temperature measurements during compaction and experimented with changes in cavity and condenser design. The armamentarium for the experiments included the ultrasonic dental unit,† the pneumatic condenser,* spot welder,** recording potentionmeter, *** an alcohol lamp and small bench vise. Chromel and Alumal wires of 0.003 inch diameter were twisted and spot welded to form the thermocouple connections. Acrylic blocks were prepared with small round cavities into which the gold was compacted over the thermocouple. The cold junction was taped to the bench top near the work in progress to provide ambient temperature for reference. Number 4 gold foil †† was used in one-sixty-fourth and one-thirty-second hand-rolled pellets. The condenser nib was a tapered cylinder with a flat face of 1 mm diameter (the same instrument as was used in the previous study).[3]

The frequency of vibration in the handpiece was 25,000 cycles per second, and the magnitude was 0.001 inch in the direction of the long axis of the handle.[3] The technic of use was to place and compact each pellet by hand pressure and then to compress it into place with the ultrasonic tip. The foil seemed lumpy and hard under hand pressure, but, when the ultrasonic was activated, the gold softened and settled to place with no resistance.

The size of the cavity was kept as small in diameter as possible in order to avoid heat loss away from the thermocouple area. The diameter was slightly more than 1 mm, and the depth of the cavity was 3 to 5 mm. Although the space confined the foil, as many pellets were extruded from the cavity by the vibration as were kept in it. Compaction by three operators produced the same results.

The temperature recording chart showed that an average of ten to fifteen seconds was required for adequate compaction of the one-sixty-fourth and one-thirty-second pellets with both the pneumatic and the ultrasonic. The time for each pellet was forty seconds when the operator annealed just before insertion, but this procedure was discontinued when it was found that the pellets were forty to

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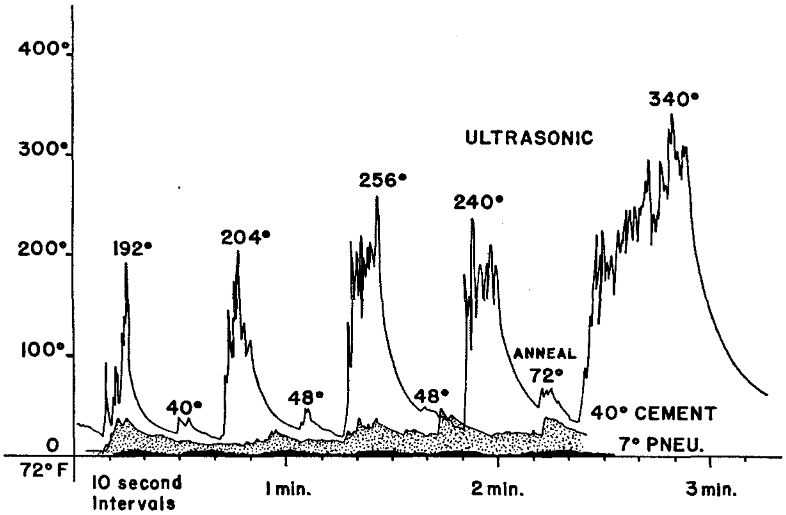
*Clevedent-Hollenbeck, Cleveland Dental Mfg. Co., Cleveland, Ohio.

**Number 506 Spotwelder, Rocky Mountain Metal Products Company, Denver, Colorado.

***Electronik 19, Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

††Morgan, Hastings and Co.



Temperature Record Tracings: The 192 to 340 degree ultrasonic temperature rises were produced by compaction of foil against the thermocouple. (For actual temperature, add 72 degrees.) Hot pellets produced the 40 to 70 degree "anneal" increase. The temperature was fairly consistent at 40 degrees under the cement base (stippled curve). The pneumatic condenser raised the temperature an average of 7 degrees at each impact.

seventy degrees above room temperature when they were placed in the cavity. The effect of the hot pellet was shown in the ultrasonic tracing by the small sharp peaks just preceding the higher compaction curves. The temperature was raised through the thickness of two gold foil pellets by two hundred degrees Fahrenheit during compaction with the ultrasonic. Finally, when held on the filled cavity for forty seconds, the ultrasonic condenser gave an ultimate increase of three hundred fifty degrees. By comparison, the pneumatic condenser recorded an average seven degree rise at each impact and the heat was immediately dissipated.

It was decided to try to overcome the ultrasonic temperature problem by placing a zinc phosphate cement lining between the gold and the thermocouple with a measured thickness of 0.25 mm. The temperature rise was reduced to a fairly consistent range of forty to fifty degrees. Judging from the temperature recorded for annealed pellets, the biologic effect on the tooth might be likened to placement of an occasionally warm pellet during regular procedures.

After finding that the temperature increase could be attenuated with a cement base, it was decided to study the microstructure of specimens prepared in the manner of Class V restorations. This was considered to be an intermediate step toward temperature measurement in natural teeth if the structure compared favorably with previous studies on hand and pneumatic compaction. The thermocouple was omitted in order to facilitate sectioning and etching for the microscope and also to eliminate the nonclinical situation of working around the wires, even as small as they were.

Rectangular cavities of 2x3 mm were cut to a depth of approximately 1 mm in acrylic blocks. The cavities were filled with hand rolled one-sixty-fourth and one-thirty-second pellets. The taper of the 1 mm diameter condenser point from the temperature rise experiments did not adapt well to the walls of the cavity, so the sides of the point were made parallel by grinding, but the diameter was reduced to 0.7 mm on repolishing. The smaller point caused shredding of the foil, even when the peripheral edges were slightly rounded. A new point was used to make a cylinder of 1.5 mm diameter, and the compaction improved markedly. Further refinement was obtained by shortening and grinding the 0.7 mm point to a square face with 1.1 mm sides for better adaptation to line angles.

The amount of vibration observed in the narrow cavities for temperature measurement was greatly increased in the broader and shallower Class V cavity forms. Pellets were spun out of the cavity by surprisingly strong vibrations that were transmitted throughout the specimen. The amplitude of vibration increased proportionally with the increase in mass as the cavity was filled.

Because of the vibration, an instrument was used to hold the compacted portion in the cavity whenever a new pellet was being smoothed into place. A technique of placement was developed in which one-sixty-fourth pellets were added alternately at each end of the 2x3 mm cavity. This created an overlap of thin edges in the center. Often it was difficult to start the foil in the bottom of the cavity, but when the pellets went to place systematically, the compaction was very good. However, it was necessary to hold the gold in the cavity every time the ultrasonic was applied, even when smoothing the cavosurface.

In cross section under the microscope, the layers of pellets were smoother, and the density under the condenser was thicker and more uniform than in hand or pneumatic compacted specimens. There was no doubt that ultrasonic vibration gave better compaction than hand or pneumatic methods, with the added advantage of requiring no force beyond holding the handpiece. For this reason it was considered to be worthy of further investigation in the laboratory.

Mat gold and Goldent specimens were prepared in the 2x3 mm cavities for microscopic examination of the effects of ultrasonic compaction.[5] It was much easier to handle the mat gold in the cavity than either the gold foil or Goldent, and the density was highly improved. Although the residual, continuous, and ultra fine porosity around the small dendritic crystals remained a problem, it looked as if satisfactory results might be obtained if the gold could be applied in thin layers. The greatest improvement was the formation of smoother layers with greater surface density than is usually seen in mat gold.

At this point in the research, it is impossible to recommend or predict the use of ultrasonic compaction for pure gold restorative materials. The results from these preliminary studies indicate that vibration effects may prevent clinical use of the method, even though it has produced the best results of all the compaction methods tested. It may be possible that technics and methods from clinical dentistry could help to overcome the problem of vibration. Some factors to be considered are the design of the cavity and condenser point, the use of thermal and vibration insulators, and the use of different golds. Although measurements in the research laboratory provide needed quantitative information, dentists in private practice are well qualified to conduct similar tests on an empirical basis. One Academy member made such studies previous to the work reported here.[6] The need still remains, however, for a facile method of gold compaction.

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