Compaction Properties of Various Pure Gold Restorative Materials

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THE FINAL CONDITION of a pure gold dental restoration is the result of compaction; the techniques of which are related to the design of the cavity and the mass and shape of the gold. Sufficient compaction must be applied from suitable directions, with appropriate force or vibration, to settle the particles of gold into the closest possible relationship. The optimum procedure for gold foil is different from the procedures for mat or granular golds simply because the shapes are different.

Density in the finished restoration is related to two factors. The first is the mass of the material itself, the gold, and second is the amount of void space or porosity surrounding the gold. The structural mass or density of the particles or sheets is essentially the same for foil, mat, or granular golds since all are made from highly refined gold, but the pellet density varies according to the type of gold selected. The density of the restoration depends on how much gold can be packed into the cavity preparation. Differences in compacted specimens made with the various golds are found in the different configurations or shapes of the void spaces between particles and are related to the shapes of the gold particles and size of pellets as used for compaction.

The optimum goal would be to achieve restorations without porosity, but hardness tests and microscopic observations have shown that none are completely solid.[1] All gold restorations contain porosity, but porosity does not preclude success as dental restorations.

The location of porosity is more important than mere presence in the success or failure of restorations. Experienced operators identify

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porosity and voids by visual and tactile examination with an explorer or burnisher. There is a tendency to achieve better density in areas along walls or line angles in cavity preparations, such as the Class III, where the access is better from one direction than another, and to have porosity in areas that are difficult to reach.

Pressure variation during compaction prevents the production of restorations with uniformly good qualities throughout. Resistance to compaction is offered by bridging of the gold, wall friction, and strain hardening. Bridges are formed by the wedging of particles over void spaces.[2] Mat gold, particularly, has this characteristic. The same effect is found in the strain hardening of layers of gold foil over voids. In all cases, plastic deformation occurs when pressure is applied, either by impact or by burnishing, until strain hardening prevents the use of more force because of harm to the tooth.

Force alone does not determine the quality of a restoration. Careful stepping and systematic coverage of each pellet have produced dense specimens in gold foil. No pressure at all was used in the ultrasonic method to produce good specimens of mat gold. Final results were related to the shape of the golds when proper and adequate methods of compaction were used.

The restorative golds are named from their shapes. Gold foil, essentially, is a two-dimensional sheet until it is rolled into a three-dimensional pellet. Mat gold is named for the interlocking or matting of the fern-like crystals that grow by precipitation from solution. The so-called powdered golds more properly should be termed granular or spherical gold. The granules may be wrapped in gold foil by hand or machine. They may be sintered into clumps or aggregates to facilitate wrapping.

Granular or "powdered" gold is difficult to place in maxillary restorations, and a product is marketed in which the particles are wrapped with gold foil into small bundles or pellets. The wrapping may be facilitated by clumping the tiny spheres together through a process of sintering. Sintering is the welding of materials together at points of contact under heat, but without the occurrence of melting. Such "cohesion" takes place when small particles are packed closely together over a sufficient period of time at an elevated temperature that is held below the melting point of the material. The alignment between the planes of atoms at the interface of the particles is never perfect in sintering, but there is sufficient ordering to form a meniscus which, then, becomes a grain boundary. If the process is continued long enough, the grain boundary will migrate through the larger particle and bring with it the bulk of the smaller particle, which is absorbed, and the large particle grows at the expense of the small one.[3]

The sintering may be stopped when enough gold granules are fused to hold the mass together. The clumps can then be broken into convenient sizes and wrapped in two or three layers of foil.

In theory, the sintered aggregates should break apart under compaction and roll into place when the foil covering is torn apart under the condenser. The spongy texture of the sintered granules in the foil wrappings must be broken down to allow spreading in a layer thin enough to weld the granules to the underlying compacted and burnished layers through deformation and plastic flow. Experience has shown the aggregate clumps to be resistant under all types of compaction. The best specimens were produced with hand malleting and methods which promoted spreading of the pellets during compaction.

Mat gold responded best to ultrasonic vibration. The tiny particles of gold settled into dense layers without effort. Unfortunately, the use of the ultrasonic instrument is contraindicated for compacting dental restorations because there is considerable risk that teeth may be damaged or extracted during insertion of the material. An additional hazard was the temperature increase of 200 to 340 degrees Fahrenheit that was measured under the condenser point.

The best results were obtained in gold foil when the thin folds of the foil pellets were pressed down and welded together by direct blows from the hand or pneumatic condenser. A 0.5 mm point covered an area that was practical in size to permit driving the folds together with force light enough to avoid damage to the tooth. The behavior of mat or granular gold was different under this type of compaction. The microstructure of the individual particles showed them to be thicker and heavier than a corresponding fragment of foil. The crystals did not bend so easily as the foil and greater force was required to weld them together under hand or pneumatic compaction. Gold foil did not compact as well with ultrasonic vibration, although some dense areas were thicker than those produced with hand or pneumatic compaction. It was more difficult to control the pellets and they were spun out of the cavity by the frequency and force of the vibrations.

The maximum density of compacted gold foil was studied by placing sheets of foil together like the leaves in a book. The foil was dense under this condition. Experience proved, however, that it was difficult to place foil in layers in a prepared cavity and obtain adequate marginal adaptation. The usual practice was followed by rolling single sheets into loose pellets to make the specimens, and there was little chance for a significant number of the laminations and foldings in the foil to be lined up as precisely and as close together as in the flat sheets. The specimens were built up in layers as the pellets were pushed down with systematic and consistent malleting.

A point to consider is the quality of the restoration to be expected under optimum compaction, based on the amount, kind and extent of the porosity in the finished product. Foil porosity is created inside the folds of pellets and the voids are distributed randomly throughout a restoration. Voids in the pellets are eliminated in areas of direct contact of the foil layers where they are compressed under the impact of the condenser point. Cohesion of the gold retains the effect of compression by atomic welding of the layers together to maintain the density of the specimen. The depth or penetration of compression is limited by the strain hardening and welding of the gold and is confined primarily to the surface of the pellet insofar as achieving solid density is concerned. Voids in the lower layer of the pellet are compressed but not eliminated. Secondary void spaces occur between adjacent pellets and often are larger than the pellet porosities. These voids are more difficult to compress and may be troublesome in marginal areas of restorations.

The advantage of foil over the other gold materials lies in the potential for unbroken sheets to enclose the voids and seal off the walls of the cavity. The natural cohesiveness of the gold contributes to the sealing properties and strength of foil restorations by closing off voids and forming solid layers in the welded areas. The same effect is impossible to achieve in the granular and mat golds because the smaller and relatively denser particles form spot contacts rather than laminations and a sponge effect is created. Specimens made from particle golds are more absorbent.

Each of the three types of gold requires different handling to achieve maximum compaction. Gold foil is most amenable to impact malleting. The fern-like crystals of mat gold are placed in closest contact with vibratory shaking. The granular golds required spreading and burnishing. In general, the bulk density of restorations is increased by impact, vibratory compaction, pressure and burnishing. Higher pressures cause plastic flow, increased strain energy, and particle fracture; these, in turn, cause further increases in density, so long as the gold remains malleable at forces tolerated by the dental tissues.

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