CHAPTER 17

Direct Filling Gold

Chapter outline

All that glitters is not gold
Often have you heard that told.

—William Shakespeare

This holds true in almost all spheres of life, except in dental practice, wherein all that glitters is actually "gold" regardless of its form, and that is how it has set gold standards for all the other restorative materials. Direct filling gold is one such pioneer restorative material, practised today in its purest form, with ideal properties that has set the norm for the array of other dental materials that have followed.

The quest to search the ideal restorative material has been a challenge for both the researchers and academicians in the fraternity of restorative dentistry. With the rapid advancement in biomaterial science and biotechnology, most of the material properties have drastically improved in the recent years. Among the available restorative materials, direct filling gold (DFG) is the oldest filling material that is still being used in restorative dentistry. The vision to utilize this noble metal for the replacement of lost tooth structure stemmed from the perfect harmony of its biological and mechanical properties, excluding esthetics. Pure gold can be cold welded and made to adhere to each other at room temperature. This property, coupled with strain hardening by cold working or welding, increases the strength and hardness of the material and makes DFG unique.

Placing a gold foil restoration is highly demanding and requires a skilled operator. A well done direct gold restoration can last one's lifetime, in properly selected cases. In spite of many favorable properties, the placement of gold foil restorations is at a decline, both in university-based practice and in private practice globally. In the minimally invasive era, tooth-colored material with both optical and physical properties similar to those of tooth structure is the current emphasis of research. Metallic restorations, including DFG, definitely cannot satisfy the esthetic demands.

However, there is no cost-effective esthetic material that can last functionally and durably as DFG for small lesions. Hence, when indicated for selected posterior teeth where the esthetic demand has been created iatrogenically, DFG is the prudent choice of material. Dr. G.V. Black pointed out in 1908 that there is no restorative material as good as gold foil to take the full advantage of the modulus of elasticity of the dentin. In the light of evidence-based dentistry, DFG does not have any evidence to support; even then, it has proclaimed itself to be one of the most durable materials from 1900 to 1980! Gold foil stands best with its marginal integrity, and with current advancement and availability of mat and precipitated gold it is possible to carry out an exact replica of both cast gold and DFG restoration with the gold foil.

The trend, back to gold, as a restorer of natural tooth structure is in evidence in every possible way. It is an expression of the conviction on the part of the leading minds in the operative field that restoration of function should be given the first consideration.

Characteristics of Gold as a Restorative Material

Gold is one of the first metals used by man, and owing to its varied and remarkable properties and uses as well as its intrinsic value it is recognized as the most noble of metals. From the earliest historic records down through the ages, it has played a prominent part in the development of our present knowledge of metallurgy. The recent introduction of several colloidal forms for therapeutic use in malignant disease is but a revival and development of the crude art of the ancient alchemists who spoke of it in this form as aurum potable (drinkable gold). Gold foil for restoration purposes was introduced in America by **Robert Woffendale** in **1795** (cited in Dwinelle and Watts, 1855). The discovery of its adhesive properties in 1857 is attributed to **Robert Arthur**.

Gold possesses a number of important characteristics which render it of special value as a restoration material. These characteristics maybe summarized as follows:

1. **Cohesiveness to a greater extent than any other metal:** This quality depends largely on purity of gold. The best gold for restoration purposes is about 999 parts in 1000 pure gold.
2. **Softness during manipulation:** This quality depends mainly on purity of gold.
3. **Inertness:** As a noble metal, gold is most biocompatible and remains stable irrespective of heat, moisture, air, and most solvents. It also rarely tarnishes or corrodes in the oral cavity.
4. **Malleability:** It exceeds all other metals in this respect. It may be reduced by beating to 1/250,000th of an inch in thickness. Reaumur is stated to have produced a sheet 0.00000087-inch thick.
5. **Ductility:** It is the most ductile of all metals. One grain of pure gold may be drawn into a wire nearly 500-feet long.

6. **Hardness in bulk form:** Gold is about one-third as hard as diamond. This property is largely increased by alloying and hammering or by rolling. Its **Brinell hardness** number is **48.0**, in comparison with copper is (74.0) and silver (59.0).

> Shore Scleroscope hardness test is associated with the elasticity of the material. It is measured with a durometer, hence it is also known as durometer hardness. Tested on a Shore Scleroscope, the following values were determined by Ward for 24-carat gold: cast gold 4.9, rolled gold 33.0, gold annealed after rolling 5.8.

7. **Tensile strength:** Gold is capable of holding a weight of 7 tons per square inch, according to Hiorns.
8. **Weldability in cold state:** Welding of pure gold under pressure can be done at room temperature (cold welding) because of lack of surface oxides on gold. This results in increased strength.
9. **Minimum tendency to flow:** Minimum tendency of gold to flow is in contradiction to tin.
10. **Coefficient of expansion**: Coefficient of expansion of gold is **14.4**, which is near 11.4, the coefficient of expansion of the enamel.
11. **Thermal and electric conductivity:** The thermal and electric conductivity is 53.20 and 77.96, respectively, as compared with the thermal conductivity of copper, 73.60, and silver, 100; and the electric conductivity of copper, 99.95, and silver, 100.
12. **True density:** It is defined as mass divided by volume. True density of pure gold is **19.3 g/cm^3**. More the density of gold, lesser will be porosity present in condensed gold thus making the restoration long lasting.

Fineness and Purity of Gold

Fineness is the actual gold content in a gold piece and is expressed in **grams** or **troy ounces**. **Karat weight** is a unit of fineness for gold equal to 1/24 part of pure gold in an alloy. For example, pure gold, which is 1000 fine, is 24 karat; a fineness of 750 is expressed as 18 karat. Most types of DFGs are 99.99% or more pure as gold in this highly purified form is cohesive, while gold used for indirect restoration in the form of gold alloys has various other high noble metals such as palladium, platinum, and other hard metals to increase the stiffness.

Application of Gold in Operative Dentistry

Gold is often indicated in children's teeth. It is the ideal material for permanent teeth in the young, if the physical and mental condition of the child, extent of development of the roots, possibility of accessibility, moisture control, and strength of cavity walls permit. No fixed rule as to age can be given. In some children, gold may be used at 10 years of age; in others not until much later. It is not a question of strength of the tooth tissue, since all tooth tissues are substantially resistant, even at 10 or 12 years of age, to withstand the condensation pressure of gold. It is rather a question of physical condition and local surroundings. One factor should always be remembered before placing foil in teeth of children—if the tooth is not completely formed, then the periodontal membrane also is undeveloped. Hence, the attachment of the surrounding tissues to the tooth root is not secure—insistence on foil here may result in destroying that development and consequently result in quick exfoliation of the tooth.

INDICATIONS/APPLICATIONS Gold is the material of preference in all Class I cavities, where sufficient access is obtainable. The only cavities of this class which are really difficult to access are the buccal and occlusal cavities on third molars.

1. It is the ideal material in Class V cavities with easy access and where it will not be exposed to view.
2. Class III direct gold restorations can be used on the proximal surfaces of anterior teeth where the lesions are small enough to be treated with esthetically pleasing results.
3. Class II direct gold restorations are an option for restoration of small cavitated proximal surface carious lesions in posterior teeth in which marginal ridges are not subjected to heavy occlusal forces (e.g., the mesial or distal surfaces of mandibular first premolars and the mesial surface of some maxillary premolars).
4. Class VI direct gold restorations may be used on incisal edges or cusp tips.
5. A defective margin of an otherwise acceptable cast gold restoration also may be repaired with direct gold.

CONTRAINDICATIONS

1. It is usually not indicated in disto-occlusal cavities in molars, where it is difficult to apply correct angles of force in adapting it to cavity walls.
2. Teeth with very large pulp chambers.
3. Severe periodontally weakened teeth with poor prognosis.
4. When economics is a limiting factor.
5. If the skill of the operator is questionable, then gold fillings should not be attempted.
6. Handicapped patients who are unable to sit for the long dental appointments required for this procedure.
7. Root canal filled teeth are generally not restored with direct gold because these teeth are brittle.

From the above descriptions of the characteristics of gold and its clinical performance, it is obvious that the material has a very wide range of usefulness in modern practice, when it is desired to render the highest standard of service. Discussions of gold and gold alloys in this text are limited to those used in operative dentistry for restoring tooth structure.

Classification (Based on the Mode of Supply)

I. **Foil**
   A. Sheets can be cohesive or noncohesive
   B. Ropes
   C. Cylinders
   D. Laminated gold
   E. Platinized gold

II. **Electrolytic precipitate**
   A. Matt gold
   B. Matt foil
   C. Gold cadmium alloy

III. **Granulated gold**

Physical Properties of DFG

The physical properties of gold are highlighted in Table 17.1.

Table 17.1 Physical properties of different forms of gold.[a]

Material and Technique	Transverse Strength		Apparent Density (g/cm³)[b]
	MPa	psi	
Mat gold			
1. Hand	163	22,000	14.2
2. Mechanical	167	23,100	14.6
3. Combined	166	24,000	14.7
Powdered gold			
1. Hand	160	22,800	14.5
2. Mechanical	157	22,400	14.4
3. Combined	132	27,000	14.3
Gold foil			
1. Hand	298	42,000	15.8
2. Mechanical	266	37,400	15.7
3. Combined	273	34,000	15.9
Mat gold and gold foil			
1. Hand	133	28,500	15.0
2. Mechanical	207	23,000	15.2
3. Combined	222	32,000	15.0

[a]Adapted from Richter and Cantwell, Journal of Prosthetic Dentistry (1965).
[b]Density is weight by volume.

Note: Hand and mechanical methods have been described in the heading of compaction/condensation of gold.

Manufacture of Gold for Restorative Purposes

The history behind manufacture of gold for restoration purposes is interesting. According to the available records, the first one to prepare gold especially for dental use was Marcus Bull in the goldbeating business at Hartford, Connecticut, USA. He shares this honor with his apprentice, later his partner, J.T. Abbey. The old-time goldbeater received his pay by being allowed all the metal which was beaten outside of the mold.

Gold Foil

Beating and rolling

The foils are made from pure metal by beating and rolling. All lightweight foils are produced by beating, while heavy foils are produced by rolling. Absolute purity is essential in the manufacture of foils.

The bullion (pure metal) is first melted and poured into ingots of suitable size. These are then rolled by machinery into thin ribbons about 1-inch wide and a little thicker than ordinary paper. The thickness is regulated by the weight of the foil to be produced. The ribbons are then cut into 1-inch squares, each weighing 3, 4, 6, or 10 grains, depending on the weight of the foil desired.

These squares (1 inch) are then laid between sheets of goldbeater's skins made from intestines of bullocks or of vellum paper. These skins or vellum papers are cut into 5-inch squares, and many of these are piled one upon the other, with squares of rolled gold interposed. The pile is now wrapped in heavy parchment and bound in such way that all the edges are well protected.

The wrapped package is then placed upon a heavy polished stone block, approximately 3-feet high by 15-inches square, and the block resting upon a foundation which is set 3 or 4 feet into the ground to give it solidity. With a large, round-faced mallet, the package is then beaten with heavy blows, being turned slightly after each stroke of the mallet. The time consumed in the beating process is usually from 2 to 3 hours.

After the foil has been beaten to the desired thickness, the leaves are removed, trimmed, and placed in paper books, ready for dispensing. Rolled gold is made by passing it through specially prepared rolling mills until the required thickness is obtained.

Annealing

After beating or rolling, all foils become noncohesive. The cohesive property is developed by slow heating or annealing. Dr. W.H. Dwinnelle of New York called attention to the advantages of the contour gold restoration in 1854, while Dr. Robert Arthur suggested the use of cohesive foil in 1855.

Varieties of Gold for Restorative Purposes

Gold for restorative purposes is categorized based on its microscopic structure into two varieties:

1. Fibrous gold/gold foil
2. Crystalline gold

Fibrous Gold

When ~~are~~ examined under the microscope, the fibrous forms are seen to consist of numerous fibers interlacing each other in every direction. For this reason, the fibrous forms make stronger restorations, although they have a tendency to draw away from cavity walls while being manipulated, owing to a certain amount of resilience or spring in the fibers.

Fibrous gold is supplied in the form of sheets about 4 inches square, ranging in numbers 2, 3, 4, 5, 6, 8, and 10. The higher numbers are rolled by the manufacturers from an ingot, while the lower numbers are beaten by machinery. These numbers indicate the number of grains to the sheet, e.g., No. 4 foil contains 4 grains, No. 10 foil contains 10 grains, etc. These sheets are available in thickness as low as 0.6 μm, the numbering system referring to weight and thickness of the standard sheet. They are also dispensed in the form of rolls and cylinders, or pellets of various sizes or weights.

Fibrous gold is classified as (a) cohesive, (b) semicohesive, and (c) noncohesive.

Cohesive gold

The cohesive foil, which is used extensively today, is annealed by heat and put up in books containing 1/10 ounce, or in packages containing rolls or cylinders. The gold foil that the manufacturer supplies to the dentist is essentially free of any surface contaminants and can be placed directly in the cavity preparation. This type of gold is called **cohesive gold**. Although it is free of surface contaminants, some of the gases may still get adsorbed during storage, thus degassing is required.

Hence, annealing before packaging plus the purity of the gold used enables it to be welded to itself under pressure to form a solid mass and a dense surface. Several types of cohesive gold foils are described here:

1. **Soft-type cohesive foil** is annealed before trimming and is treated in **ammonia fumes** to **reduce cohesion**. After this type is cut and rolled into the desired sizes, the ammonia gas is driven off (by annealing in the flame of the alcohol lamp or over an electric annealer) to restore its entire cohesion. It may then be condensed into the cavity.
2. **Dead-soft-type foil** is soft due to the fact that it has not been annealed. It is softer and much less cohesive than the soft-type but may be rendered cohesive by careful annealing.
3. **Extra- or special-soft foil** has been deliberately alloyed with a **trace of silver** to **limit** its **cohesiveness**. It is moderately cohesive when annealed.
4. **Platinized soft gold foil** has been alloyed with platinum, usually by placing a layer of platinum foil between two layers of gold, and then malleting again until the original thickness is established. It is indicated on the incisal edges of anterior teeth as a protection against abrasion (class IV preparations). It is moderately cohesive when annealed, but its working qualities are a little harsh. The motive behind adding platinum is to increase the hardness and wear resistance.

The commonest type of cohesive gold now used is the No. 4 soft-type gold foil. This is prepared in the form of books with sheets 4 inches square. Each sheet is rated on the basis of the number of grains of gold it contains. For example, No. 4 soft-type contains 4 grains of foil in each sheet and is approximately 1/20,000 of an inch thick. No. 2 is the thinnest and weighs 2 grains per 4-inch sheet, with a thickness of about 1/40,000 inch.

> It is the only dental material that, if carefully placed and finished, can approximate the cavosurface margin with zero marginal gap, and lasts longer than any other dental material. For comparison, average marginal gaps are 30–50 μm for amalgam, 25–100 μm for direct composites, 100 μm for indirect composite, 100–200 μm for all ceramic restorations, and as low as 20 μm for cast gold restorations. The advantage of the lower marginal gap is primarily that it allows less opportunity for continued degradation, stain, and secondary caries.

The advantages and disadvantages of cohesive gold as a restorative material are as follows.

ADVANTAGES

1. Insolubility in the oral fluids
2. Perfect adaptability to cavity walls, if properly worked
3. Perfect weldability in a cold state
4. High density, crushing resistance, and edge strength
5. Low tendency to molecular change, since it is free from objectionable shrinkage or expansion
6. Capability of receiving and maintaining a high polish
7. No intercementing substance necessary

DISADVANTAGES

1. Inharmonious color
2. High conductivity
3. Difficulty in manipulation: The chief disadvantage of cohesive gold is the difficulty in learning to manipulate it properly and the strain on patient and operator.

Cohesive gold is more extensively used on account of its greater crushing resistance, its ability to be contoured and to be built over long bevels as well as thin edges, and also on account of greater familiarity on the part of modern operators with its working properties.

Semi-cohesive gold

Some foils are supplied as semicohesive. In these, the cohesive property is not developed to its fullest extent. By controlling the annealing, any degree of cohesiveness may be obtained. These foils are preferred by some operators. This type of gold is protected after manufacture by subjecting its surface to chlorine and ammonia gases. Although these gases will make the surface temporarily noncohesive, they can be eliminated immediately before inserting the gold into the cavity preparation by use of heat. It is necessary to treat the gold surfaces with ammonia or chlorine since these gases react with polluting elements to prevent them from permanently contaminating the gold surfaces. They themselves can be eliminated very easily with thermal energy.

Noncohesive gold

The noncohesive foils have certain nonvolatile substances, such as salts of iron, sulfur, ammonia, or phosphorus, deposited on their surfaces which permanently destroy their cohesive property. Noncohesive gold maybe used, on account of its rapidity of manipulation, in simple cavities with four strong walls, located on surfaces not subject to wear. It may also be used in combination with cohesive gold for beginning restorations on the gingival wall in proximo-occlusal cavities, or on the pulpal wall in occlusal cavities, as a timesaver. It is not indicated on surfaces subjected to stress of mastication or for contour work.

The noncohesive and semicohesive forms are also supplied in rolls, cylinders, or in 1/10-ounce books containing sheets or foils, the numbers running the same as for the cohesive foils.

Crystalline Gold

Made by *chemical precipitation* or *electrodeposition*, the crystalline forms appear more granular in character. In contrast to fibrous gold, the crystalline forms do not possess the tendency to draw away from the cavity walls and are more easily manipulated. But they are deceptive and treacherous for students' use, on account of their easy working properties.

Other Types of Gold Foil

Corrugated/carbonized gold foil

Corrugated gold is made by burning gold-foil sheets between paper in the absence of air. This type was discovered in 1871 after the Chicago fire but has questionable value in dentistry.

Supply of gold foils

Gold foil is supplied in four forms:

1. **Plain gold foil:** It is the product of cold working procedure without any modification (Fig. 17.1).
2. **Corrugated gold foil:** It is manufactured by placing thin leaf of paper between two sheets of gold foil after which the container

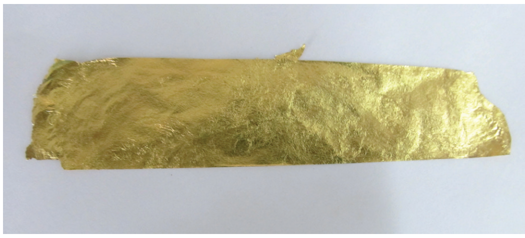

Figure 17.1 Gold foil sheet.

containing the paper leaves and gold foil is ignited.

3. **Platinum gold foil:** It is an old type of gold foil.
4. **Laminated gold foil**
   a. It is produced by combining two or three leaves of gold, each of different ingots which have been cold worked in different directions.
   b. The laminates are now available as preformed but can be made in the dental office by placing a number of sheets on top of each other and then cutting the laminates of desired sizes.

Gold foil cylinders They are ~~is~~ produced by rolling cut segments of No. 4 foils into desired width, usually 3.2, 4.8, and 6.4 mm using a modified No. 22 tapestry needle.

Extrapliable gold foil The purpose of this is to make gold more cohesive. This material is produced by wrapping a loosely formed, regular gold rope with an extra sheet of gold foil. The rope is then used as it is or cut into pellets. It can also be heated and condensed in the same manner as other gold.

Electrolytic precipitated gold

Sponge gold, a crystalline form, was introduced into dentistry in 1853. This is manufactured by amalgamating the gold with mercury and then driving off the mercury by heat.

1. **Mat gold**
   a. It is precipitated through electrodeposition and is accumulated in the form of strips or cones. These strips are cut by the dentist into desired sizes.
   b. Mat gold is placed in a mold at room temperature to become compacted and is then sintered in an oven.

   ADVANTAGES It is of sponge type and adapts well to cavity walls.

   USES It is used for building up the internal bulk of the restoration.

2. **Mat foil**
   a. Sandwich of mat gold between sheets of No. 3/4 gold foil.
   b. Sandwich is sintered by heating below melting point of gold and cut into strips of differing widths.

   ADVANTAGES
   1. Ease of placing gold in retention forms
   2. Reduction in placement time especially in larger preparations

   DISADVANTAGE Greater tendency for voids which show as pits on outer surface of the restoration.

Electralloy

Electralloy is a combination of **gold and calcium; calcium** content is **1%**.

ADVANTAGE Product form provides stronger restoration.

DISADVANTAGES
1. Inharmonious color
2. High conductivity
3. Difficulty in manipulation

Powdered gold (Fig. 17.2)

Powdered gold is also known as **EZ gold**. It is a blend of atomized and precipitated powder

Figure 17.2 Powdered gold.

embedded in a wax-like organic matrix. It is available in pellets of various sizes which are enclosed in gold foil wrappers and packaged for use. Prior to its condensation, the matrix is burned away leaving only pure gold to be packed in the cavity.

Goldent

Goldent is a combination of **powdered gold** and **gold foil**. The ratio is 95% powder to 5% foil. It is provided in cohesive form.

Uses It is used in many types of restorations. It can be purchased in assorted 1/10 ounce plates.

ADVANTAGE The envelope holds the powdered particles during condensation, making handling easier.

Annealing/Degassing of Gold Foil

The gold is heated as a precautionary measure to **remove any surface gases** and to ensure a totally clean surface. Consequently, the term **annealing** is a misnomer. A more appropriate term would be **desorption**, because the objective is to remove adsorbed ammonia gas and other surface impurities.

As the gold is forced and compressed into a tooth preparation, succeeding increments cohere to those previously placed. For successful welding to occur during restoration, the gold must be in a cohesive state before compaction, and a suitable, biologically compatible compacting force must be delivered. Although cohesive gold is annealed by the manufacturer, it quickly becomes contaminated by the presence of carbonic acid, sulfurated hydrogen, and other gases in the atmosphere of poorly ventilated or unhygienic rooms or surroundings. Carbonic acid gas is derived from the exhalations of the lungs and other sources, while sulfurated hydrogen gas, as well as phosphoric acid gas, results from decaying animal or vegetable matter, such as blood, pus, and other substances left on soiled linen, in the fountain cuspidors, or in receptacles in the dental office. Sulfurous acid and phosphoric acid gases also are derived from burning matches, and the former emanates from sulfurous coal gases in the air and from rubber and vulcanite.

All DFG products are degassed immediately before use, except when noncohesive foil is specifically desired. Underheating during degassing is to be avoided, because it fails to render the gold surface pure. Overheating should also be avoided, because it may cause the gold to become brittle or melt and render it unusable. The annealing temperature ranges from **650°C to 700°C** depending on the selection method and heating time. The idea behind this is to heat the gold until it exhibits a dull red color to drive off the adsorbed ammonia gas.

Degassing is accomplished by heating the gold foil on a mica tray over a flame or on an electric annealer or by heating each piece of gold over a pure ethanol flame.

Alcohol Flame

With this method, it is important to use the middle zone of the flame (the high-energy reducing zone). Each piece of gold is held in such a zone for 3–5 seconds before inserting it into the cavity preparation.

To anneal the foil, the pellets should be held by the point of "a carrier."

How to make the foil carrier Take a piece of piano wire 1½ inches in length by ½ mm in diameter and mount in a broach holder, ½ inch being inside the holder. Place the protruding wire flat in a tiny groove on a smooth wooden surface and with the flat surface of a gold file bring it to a long tapering sharp point. Bend this wire to an angle of 12½ centigrade just 3/8 inch from its point.

The pellets are held by the carrier and passed individually through the clean flame of an alcohol lamp. The angle of the wire portion of the carrier is passed through the flame first. This is then immediately followed by the pellet. Both angle and pellet should pass just beneath the apex of the flame. The pellet should be heated just for a color change, NO MORE! Each pellet is annealed immediately before placement; other methods are relatively less satisfactory.

Piece method (by an open alcohol flame)

The open alcohol flame is the most practical method of annealing. It can be accomplished by using simple alcohol flame and gold foil carrier. The acetone-free denatured alcohol must be used to avoid possible contamination from the source. The wick of the lamp should be pointed and should be ¼ inch long. The gold foil is picked up with a tip of the carrier and brought to the hot cone of the flame, long enough to change it to dull red color. The middle zone of the flame is used (high-energy reducing zone). Each piece of pellet is held for 2–5 seconds before inserting into the cavity. But for fibrous gold foil this is instantaneous. Encapsulated powder gold has a flammable indicator. Pellet is held in the flame until indicator burns off and gold appears dull red. All the pieces must be held temporarily before carrying to the oral cavity.

Bulk Annealing

Bulk annealing can be done by using mica tray or electric annealer (Fig. 17.3).

Mica tray

In this method, mica tray is used to hold the gold over a flame. It is done for 5 minutes.

ADVANTAGE Takes less time than piece method.

DISADVANTAGES

1. Sticking of gold pellets to the tray
2. Unequal heating of pellets

Electric annealers

Electric annealers are also available for annealing, which controls time and temperature. The estimated time for pellets of gold required for the restoration placed on the surface of the annealer at **650°F is 5 minutes**. The powdered gold pellets take 15–20 seconds, whereas gold foil and electrolyte pellets require only 1–2 seconds. The surface of the heater is divided into small compartments, each accommodating a piece of direct gold. This eliminates the possibility of cohesion of pieces before they are inserted into the cavity preparation.

Figure 17.3 Bulk annealing: Gold foils placed on a mica tray over the flame.

ADVANTAGES

1. Convenient method
2. No need of an assistant

DISADVANTAGES

1. More wastage
2. Danger of overheating which can lead to strain hardening of gold foil
3. Sticking of pellets
4. Inability to select from annealed gold a piece of desired size that can fix the cavity
5. Greater exposure to condensation
6. Air current affects heat uniformity
7. Over sintering

Condensation/Compaction of DFG

Objectives of Condensation

Condensation of DFG material during placement is done for the following reasons:

1. Wedging initial pieces between dentinal walls, especially at starting points

2. Weld the gold pieces together by complete cohesion of their space lattices
3. Minimize the voids in general and eliminate them from critical areas such as the margin and surfaces
4. Strain hardening of gold materials that is accomplished due to cold working during condensation
5. Adapt gold materials to the cavity walls and floors

Rationale of Condensing Gold Foil

Pieces of annealed cohesive gold readily cohere to each other when brought in contact. With great power or "load," rapid friction, and small thin layers of gold, it would be possible to build gold restorations by burnishing with smooth burnisher. The smaller the surfaces and thinner the layers, the less the load and speed required to accomplish the operation. This would, however, be a laborious process for both the patient and the operator; consequently, instruments called **condensers** are used to compact the gold against the cavity walls.

Condensers

Gold condensers are made with numerous serrations on the nib; the serrations are wedge (Fig. 17.4) or pyramidal in shape. They are designed as a series of pyramids, which act as multiple wedges, exerting great lateral pressure on their polished sides. The handle of the instruemnt is angulated for better control, while the nib is either perpendicular or oblique faced to the handle (Fig. 17.4). In both the type of condensers, the force directed will be parallel to the handle regardless of the angulation.

Methods of condensation In condensing cohesive gold, the application of the force required to weld and condense it is accomplished by means of hand pressure, hand mallet, or some form of mechanical mallet; the most recent and, to date, the most satisfactory being the **pneumatic mallet** developed by **Dr. George M. Hollenback**.

During condensation, care should be taken to avoid slipping of the point of the condenser over the gold or turning the condenser on its axis during its manipulation.

Hand pressure and hand malleting The use of hand pressure alone is contraindicated, except for anchoring the gold in point or convenience angles and in placing it in localities where the direction of force required will not allow the use of the other methods. Even under these circumstances a point of very small diameter, 0.5 mm, which does not require great power in its manipulation must be used. Dr. Black and many of his followers recommend the hand mallet used by an assistant, the dentist directing the point and holding it in proper contact and relation with the gold being built.

The hand mallet for percussion was originally introduced into dentistry by Dr. E. Meritt of Pittsburgh in 1838. This was before the introduction of cohesive gold. It was later reintroduced by Dr. W.H. Atkinson in 1863. This method is still in use by many excellent operators and is valuable because of the "deal" nature of the blow delivered, which seems to produce less strain on the patient. However, it has been largely superseded since the introduction of mechanical mallets.

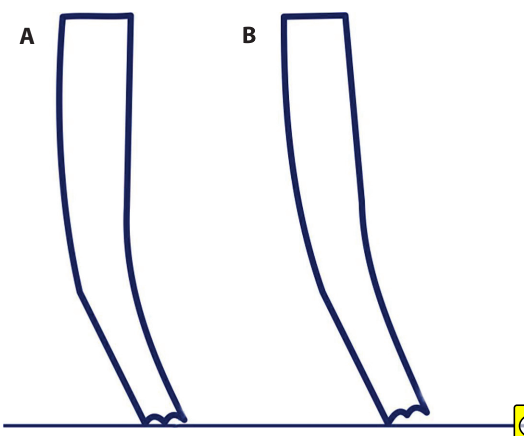

Figure 17.4 Condenser angulation. **(A)** Monoangled: Perpendicular to the handle. **(B)** Oblique faced: Angle other than 90° to the handle.

Mechanical malletting Various types of mechanical mallets introduced from time to time include pneumatic, engine, automatic, and electric mallets.

The **automatic mallet** in which the blows are delivered by releasing a spiral spring is a useful instrument, but has the disadvantage of having the blow descend before full pressure has been applied.

The **Hollenback pneumatic mallet**, mentioned previously, has a soft blow, which may be regulated both as to its strength and its regularity. This pneumatic mallet consists of a small electric engine and air condenser. The air is carried through a thin rubber tube to the handpiece, which holds the desired point. The speed of the engine, which may be regulated by the rheostat button, also establishes the speed of the number of blows. The heaviness of the blow is regulated at the tube end of the handpiece. The inside of the handpiece is so constructed that the blow does not fall until pressure is placed on the condenser point. Then it continues until released. Even the quick releasing needed for stepping stops the blow, while the engine continues running. Specially fitting condenser points are designed for the pneumatic mallet (Fig. 17.5).

The **electrical mallet (McShirley electro mallet)** accommodates various shapes of condenser points and has a mallet in the handle itself.

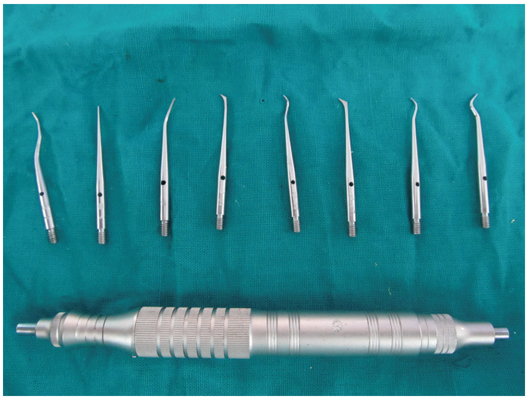

Figure 17.5 Pneumatic condenser with various tip shapes.

The vibrating condenser head can have intensity from 12 to 15 pounds and 360–3600 cycles/minute. It is one of the most efficient condensers that can be used in a controlled way.

The use of the condenser, then, is after all a system of burnishing, designed to lessen the strain of the operation on the operator and the patient. Care should be taken to avoid slipping the point over the gold or turning the condenser on its axis during its manipulation.

Factors Influencing Condensation of DFG

1. **15 lb/sq inch** of force should be exerted on the condenser nib; less force is needed for small condenser nibs than for larger ones.
2. Force of condensation must be at **45° to cavity walls and floors**.
3. Stepping procedure for compaction of gold should be carried out.
4. Use the maximal thickness of pellets possible provided that the condenser will not penetrate it. The thin cross-section of each increment will facilitate easy condensation. This will prevent crazing of enamel rods.
5. When inserting DFG, condensation should be either from one periphery of the increment to the other or from the center to the periphery.
6. The condensation of precipitated types of direct gold should be started by hand.

Technique of Compaction/ Condensation of DFG

To condense the gold properly and cause least pain to the patient, the mallet force should be combined with a certain amount of hand pressure:

1. The nib of the condenser should be first placed firmly in contact with the gold in such a manner as to condense it slightly and also to render tense the fibers of the periodontal membrane and prevent too much jarring of the tooth.

2. Then two blows of the mallet should instantly follow in rapid succession, when the point is moved one-half the diameter of its nib and the procedure is repeated, continuing in this manner until a layer of gold is condensed. This procedure is readily accomplished with the hand mallet but may be copied with practice with the automatic and the pneumatic condensers.
3. In cases where a direct line of force cannot be applied, hand pressure or the use of reverse-action condensers with the hand or automatic mallet is necessary.
4. Reverse-action condensers have always been difficult to master and have been avoided by some otherwise excellent foil operators. The pneumatic condenser (Hollenback) now solves this difficulty in that it is provided with an angled condenser handpiece with accompanying points. Thus, the use of the cumbersome reverse-action condensers can be dispensed off with entirely.

Clinical Considerations

Cavity Preparation

The ideal depth of the preparation should be **2–3 mm** and **into dentin**. The shape of the preparation could be circular, pear shaped, or triangular depending on the operator's choice. The ideal depth is then made using a **flat-ended bur**; the walls are smoothed and retention is achieved using a **34 inverted cone bur** at the base of the preparation (Fig. 17.6A). The final step of the preparation is to use a **7901 finishing bur** to smooth the outline and remove any unsupported enamel rods. This step also places a very small bevel and helps create a sharp cavosurface margin (Fig. 17.6B). This allows the operator to visualize the margin as the excess gold foil is removed and gives the preparation a smooth and flowing outline form.

If after removal of the existing restoration the depth of the cavity is deeper than 3–4 mm, a base should be placed to protect the pulp, limit the amount of gold foil utilized, and allow the ideal depth to be achieved.

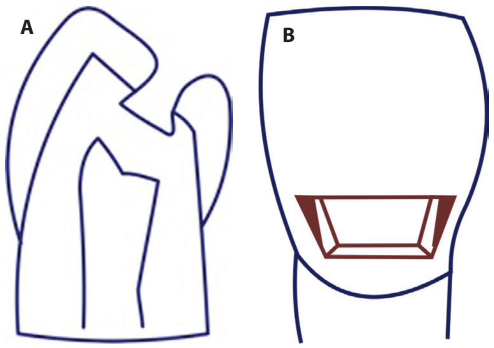

Figure 17.6 (A) Illustration of a class I cavity with converging walls and undercuts in dentin. (B) Class V cavity preparation with sharp cavosurface margins.

Use of Liners and Bases

Polycarboxylate or zinc phosphate cement is a material that has been used successfully as a base for cavities of this size; the material can be placed easily if mixed to a thick base consistency and cemented using a thinner second mix. This allows the cement to flow into all parts of the cavity, leaving no voids after condensing with an amalgam condenser.

Gold Placement and Condensation

The steps involved in DFG restorations are as follows:

- **Step 1—Degassing:** Using a placement instrument, a pellet of E-Z Gold is placed on the top of an alcohol flame. The pellet should be held in the flame until the wax is burned off (2–3 seconds).
- **Step 2—Condensation/compaction:** The pellet is then carefully placed in the cavity and gently pushed in place using a condenser or parallelogram (Fig. 17.7A and B). At this point, the gold must be made as dense as possible using any of the condensation methods.

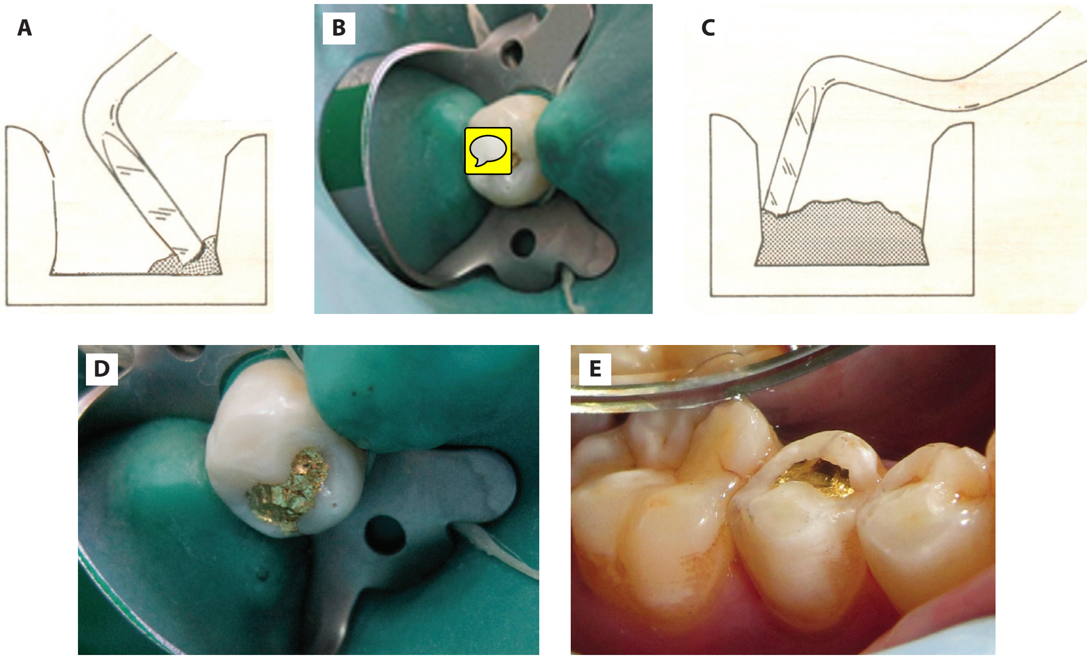

Figure 17.7 (A) The first increment is wedged into the internal point angle and condensed into place. (B) Photograph depicting the first increment wedged and condensed into place. (C) Compaction of the rest of the increments with overlappings of the condenser point. (D) Slightly overfilled cavity. (E) Final finish and polish of the restoration.

The simplest method is using just hand condensation with amalgam condensers. Using a fair amount of pressure, the gold should be pushed as far into the cavity as possible, leaving no air space. Other classic methods of condensation that can be used are various condensers and hand malleting, an electro mallet, or a pneumatic condenser. Whichever method is used, the E-Z Gold should be condensed against the walls in a circular path around the cavity, making sure no contact is made between the condenser and the cavosurface margin. Additional pellets of E-Z Gold are then placed and condensed into the cavity (Fig. 17.7C) until it is slightly overfilled (Fig. 17.7D). The entire cavity can be filled using only E-Z Gold, or the final layers could be placed using gold foil. Gold foil can be rolled in small pellets that will allow the operator more precision at the cavosurface than the E-Z Gold. If properly condensed and finished, gold foil may give the restoration a more highly polished surface. Following completion of gold placement, a foot condenser can be utilized to condense the foil surface firmly as well as identify any soft spots.

- **Step 3—Burnishing:** A **beavertail burnisher** is then used to burnish and harden the surface of the soft gold. The burnisher should always be used in a direction from gold to the tooth.
- **Step 4—Finishing:** Finishing is defined as leveling the gold with the tooth surface in three planes. This can be accomplished using sandpaper disks with air spray for cooling or hand instruments such as gold knives and cleoid discoids, and can also be completed more quickly and efficiently using a high-speed round bur with water spray. Being very careful not to touch the cavosurface margin, the excess gold is peeled away slowly using the round bur with water. This can be followed by using a fine finishing bur to remove

small surface irregularities. If any small amount of excess gold remains, a cleoid discoid can be used, at the same time creating anatomy, if desired.

- **Step 5—Polishing:** The final step is making the surface very smooth and removing any excess that may be causing reflection from the margins (Fig. 17.7E). A mix of **pumice** and

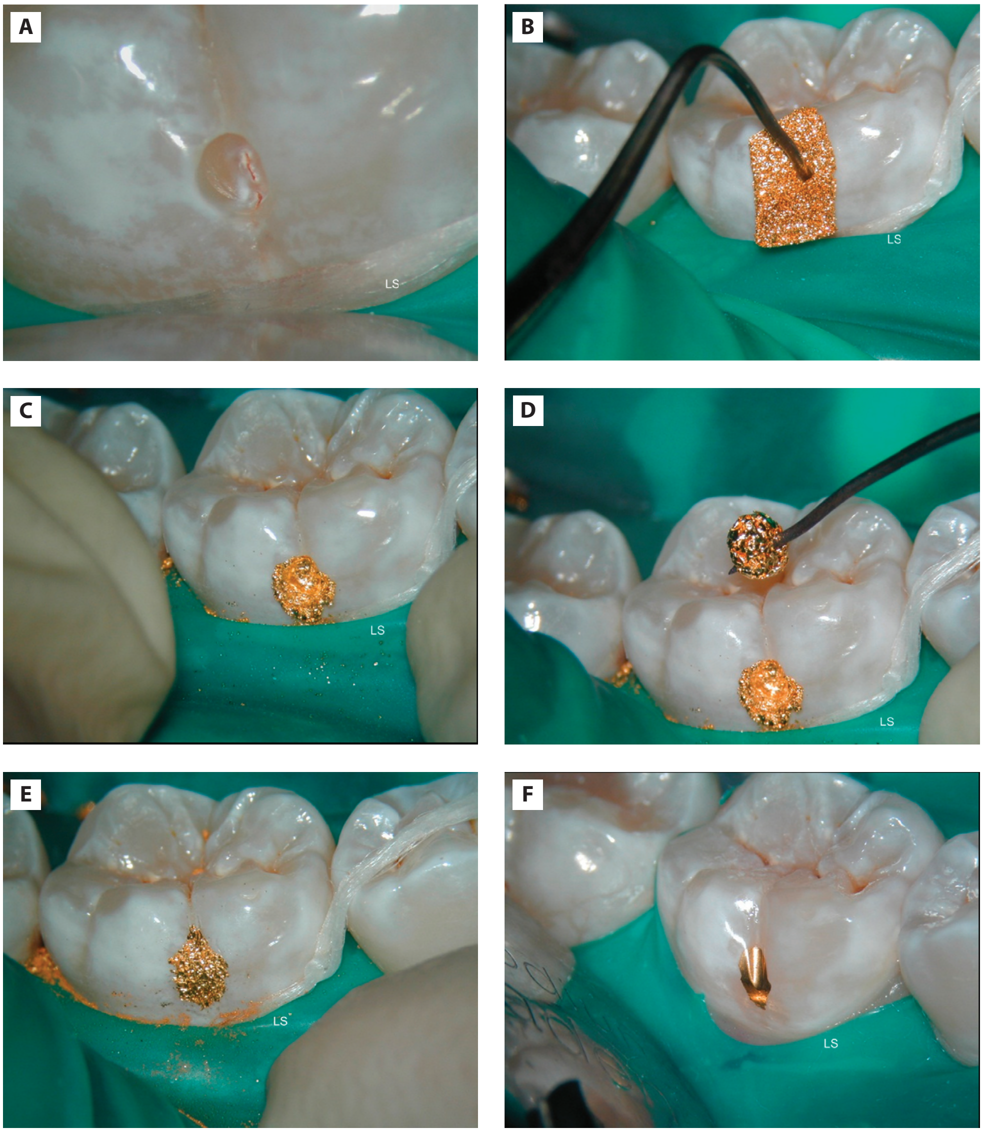

Figure 17.8 Buccal pit restoration in lower right molar (*Courtesy:* Prof. Dr. med. dent. Liviu Steier, London). **(A)** Class I buccal pit conservative cavity preparation in lower right molar. **(B)** The first gold foil is placed in the cavity and condensed in a circular path to properly adapt the foil to the cavity walls. **(C)** The well-condensed gold with the excess foil covering over the margins of the cavity. **(D)** A second foil is then inserted. **(E)** The gold should be properly condensed to adapt and cold weld to the previous increment resulting in a dense and slight overfilling. **(F)** The finished and polished restoration showing the well-adapted, highly polished, and smooth contour of the surface.

aluminum oxide powders can be used with ribbed rubber cups, but this step can also be accomplished in small restorations using brownies, greenies, and super greenies. Using light pressure with higher speeds, always with an air stream, a highly polished surface can be achieved quickly.

ADVANTAGES OF A DIRECT GOLD RESTORATION A direct gold restoration of good quality is superior to all presently available restorative materials. Without gold restorative material, the practice of dentistry would be changed significantly. Compared with other materials, properly inserted direct gold restoration provides a reasonably long clinical service. An ideal cavity preparation and restoration of a conservative class I buccal pit using gold foil is depicted in Figure 17.8. Such well-adapted, finished, and polished direct gold restoration is well tolerated by the tissues, has the finest margins, does not corrode, and is long lasting. Whenever we speak of the advantages of direct gold for restoration, the quotes go back as far as G.V. Black.

The advantages of direct gold restorations include:

1. Conservative
2. Durable
3. Kind to the tissues
4. Finest margins
5. Long-lasting restorations
6. Does not tarnish or corrode in the oral cavity
7. Insoluble
8. Coefficient of thermal expansion close to that of tooth
9. Does not cause tooth discoloration
10. Adapts well to the cavity walls
11. No cementing medium is necessary for retention of restoration
12. Easy to polish
13. High wear resistance
14. Low tendency of molecular change

DISADVANTAGES OF A DIRECT GOLD RESTORATION There are only three minor disadvantages:

1. Color
2. Thermal conductivity
3. Difficulty of manipulation

Other disadvantages are as follows:

1. Unesthetic, expensive
2. Patient discomfort
3. Limited to small and shallow cavities
4. Cannot be used in deeper cavities
5. Manipulation is difficult—it is technique sensitive and high condensation force may injure the tooth and supporting tissues

Conclusion

Gold foil is the most underused restorative material in dentistry, and contrary to popular belief, it is still being used in many dental practices. Its use develops and demands cleanliness, exactness, precision, concentration, patience, and perseverance and produces, as no other material or procedure in dentistry will do, a zeal, a joy, and a spiritual uplift from the accomplishment of a fine piece of work well done. Perfection of its technique will reduce the strain of the operation on both the patient and the operator. Moreover, its proper use, in cases where it is indicated, will also greatly minimize its shortcomings, if they can be called such.

Although the technical skill of an operator is paramount, a direct gold restoration of good quality presents a gold standard for all presently available materials and can be said to be the undisputed “king” amongst all restorative materials.

Questions

Essay

1. Classify direct filling gold. Enumerate the indications, contraindications, advantages, and disadvantages. Describe the procedure of gold placement and condensation in detail.

Short Notes

1. Crystalline gold
2. Annealing of gold
3. Technique of compaction of direct filling gold
4. Electromallet