# Materials for permanent fillings

1. Cements:
- a) zinc phosphate (Unifas, Adhesor Original);
- b) silicate (Silicin, Fritex);
- c) silicate-phospate (Silidont);
- d) polycarboxylate;
- e) glass ionomer.

2. Amalgams (silver, copper)
3. Polymers:
- a) acrylic and epoxy resins;
- b) composites.

4. Compomers (Dyrakt)

# DENTAL AMALGAM

- Dental amalgam is a mixture of mercury and an alloy containing silver and tin with added copper and zinc. The alloy and mercury are held together in a capsule, with the two components separated by a plastic diaphragm. When the diaphragm is broken and the capsule is placed in the mixing machine (amalgamator), the two components are mixed together (triturated) to form a silver-coloured paste. This paste is then condensed into the cavity.

- Amalgam is weak in thin section so cavities have to be cut suitably deep (2 mm) and because amalgam does not adhere to tooth tissue, the cavity must be undercut.
- Dental amalgam continues to be used despite concerns about health and the environment because it has high clinical success, known performance, relatively low cost and is easy to manipulate.
- Despite the high usage of this material it is not ideal and suffers from several problems including marginal breakdown, fracture and poor appearance. Secondary caries is the most common reason given for the replacement of amalgam restorations but this diagnosis may not necessarily always be correct.

- The strength of dental amalgam is developed slowly. It may take up to 24 hours to reach a reasonably high value and continues to increase slightly for some time after that. At the time when the patient is dismissed from the surgery, typically some 15–20 minutes after placing the filling, the amalgam is relatively weak. It is necessary, therefore, to instruct patients not to apply undue stress to their freshly placed amalgam fillings.

- ***Thermal properties***:
- Amalgam has a relatively high value of thermal diffusivity, as would be expected for a metallic restorative material. Thus, in constructing an amalgam restoration, an insulating material, dentine, is replaced by a good thermal conductor. In large cavities it is necessary to line the base of the cavity with an insulating cavity lining material prior to condensing the amalgam. This reduces the harmful effects of thermal stimuli on the pulp.

- ***Biological properties***: Certain mercury compounds are known to have a harmful effect on the central nervous system. The patient is briefly subjected to relatively high doses of mercury during placement, contouring and removal of amalgam fillings. A lower, but continuing, dose results from ingestion of corrosion products.
- Another potential problem concerns allergic reactions to mercury in dental amalgam. Such allergic reactions, usually manifested as a contact dermatitis or lichenoid reaction, are well documented and can normally be explained by previous sensitization of the patient with mercury-containing medicaments.

# POLYMER MATERIALS (DENTAL POLYMERS)

- Polymer material (polymer) is a material whose mechanism of curing takes place by polymerization reaction. This reaction is a connection of many small molecules (monomers) into one big molecule (polymer). There are two classes of polymer filling materials: self-curing cold setting plastics and composites.
- Self-curing cold setting plastics
- There are two types of self-curing cold setting plastics. One type is based on acrylic (methyl methacrylate) or epoxy resins. Nowadays these materials are used mostly in prosthetic dentistry, for instance, for temporary crowns but not for filling cavities because of the following negative features:
- ► low strength;
- ► high polymerization shrinkage, which leads to violation of marginal seal;
- ► irritation of the pulp;
- ► high water absorption, etc.

# Composite filling materials (composites)

- Composites were developed in the US in the late 1950s by Dr. Rafael L. Bowen. The first composite materials were launched by 3M company in 1964. These were chemical curing (self-curing) composites as light-cured composites were introduced later.
- As defined R.W. Philips (1973), a composite is a three-dimensional combination of at least two chemically different materials that have a clear interface; this combination has better properties than either of the components individually.

- According to the international standard (ISO), the main features of composites are:
- ► polymer matrix, usually based on copolymers of acrylic and epoxy resins;
- ► inorganic filler accounting for more than 50% of weight;
- ► particles of filler are covered by surfactant substances (silan) which provides a chemical bond with the polymer matrix.

- Composition of composites
- Thus, the basic components in composite are the polymer matrix, filler, silane. Let us discuss in detail the properties of each of the 3 parts (or phases as they are called).

## 1. *Polymer matrix*

- The most common organic matrix is the product of interaction of acrylic and epoxy resins. This compound is described by Dr. Rafael L. Bowen from the United States. In 1958, he found that bisphenol glycidyl methacrylate (Bis-GMA) sets in 3 minutes in the presence of catalyst, producing a shrinkage of only 5% (compared to 21% polymerization shrinkage of self-curing plastics).
- This monomer Bis-GMA is the basis of most modern composites.

- Another monomer used in composites is urethane-dimethyl-meta-acrylate (UDMA). It performs the same role as Bis-GMA, but shows a lower polymerization shrinkage, higher density and strength.

- The polymer matrix includes not only the monomer but other components, the main ones are listed below:
- ► monomer;
- ► polymerization inhibitor for longer working time and shelf life extension;
- ► catalyst to initiate polymerization;
- ► activator (photoinitiator of polymerization) to initiate polymerization process (only in light-cured composites).

# 2. *Filler*

- The inorganic (mineral) filler is an important part of modern composites. A large amount of filler ensures improved properties:
- ► decrease in polymerization shrinkage (to 0.5-0.7%);
- ► preventing deformation of the organic matrix;
- ► reduced thermal expansion coefficient;
- ► reduced water absorption;
- ► increase in hardness of the material, its resistance to stress;
- ► improved aesthetic properties.

- The main properties of filler influencing the quality of the composite are as follows.
- ► Particle size. This indicator is the most important parameter in determining the properties of the material. In various composites, it ranges from 45 microns to 0.04 microns.
- ► Material of filler: fused and crystalline quartz, borosilicate and aluminosilicate glass, various modification of silicon dioxide, diamond dust, artificially synthesized substances, etc.
- ► Particle shape. The filler may be of different shapes: powder, spheres, chips, etc.

- Variation of particle size, shape and material of filler allows adjustment of composite properties.

- 3. *Silane*

- It provides a stable chemical bond between the filler and polymer matrix. If this bond is not strong enough, the filler easily stands out from the matrix. It will cause coloration of restoration surface. To avoid this, the filler surface is treated with special binders - silanes. Due to the presence of silanes composites have improved properties:
- ► filler particles are water-repellent;
- ► reduced water absorption of composite;
- ► increased strength and durability.

# Classification of composite restorative materials

- Modern classification of composite materials is based on a number of points.

1. Size of filler particles.

- • Macrofilled composites (particle size: 8-45 microns).
- • Microfilled composites (particle size = 0.04-0.4 microns).
- • Minifilled composites (particle size = 1.5 microns).
- • Hybrid (a mixture of particles of different sizes).

2. Curing method.

- • Chemically cured.
- • Light-cured.

3. Consistency.

- • Traditional composites with regular consistency.
- • Liquid (fluid) composites.
- • Condensable composites.

4. Purpose.

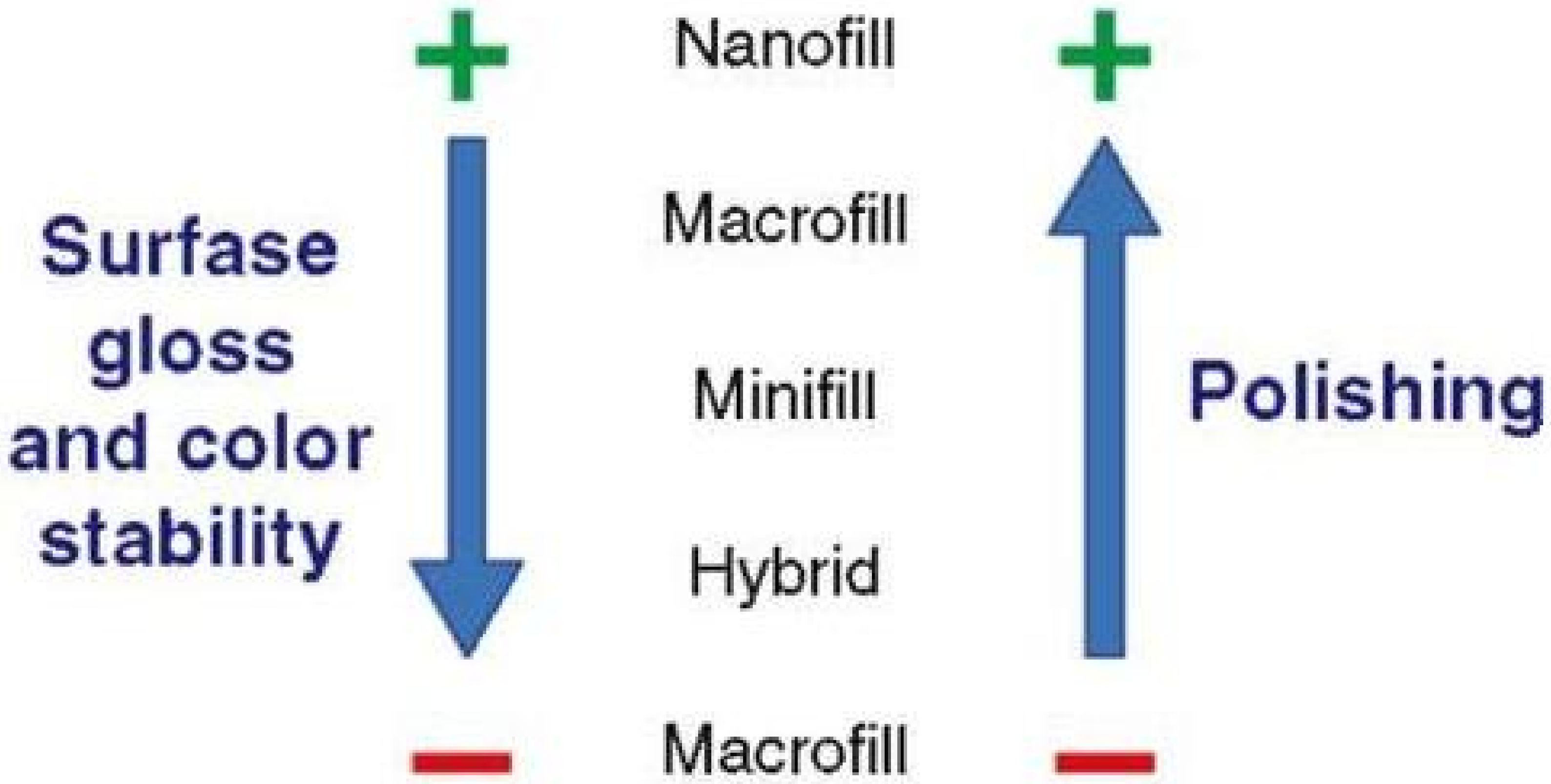
- • For filling of posterior teeth.
- • For filling of anterior teeth.
- • Universal composites.

- It should be noted that this classification is approximate and does not fully reflect the entire diversity of modern composites. The important thing is that a dentist working with composites understands the effect of filler particle size on material properties.

- <u>Macrofilled composites</u>
- Macrofilled composites contain filler with particles of a large size (8-45 microns, and sometimes up to 100 microns). The filler typically is quartz, glass, ceramics.
- Advantages: high strength, acceptable optical properties compared with cements.
- Disadvantages: low polishing; pronounced surface roughness; poor color stability. Indications: cavities class I and II, core build-up for artificial crown.

- Microfilled composites
- Higher aesthetic requirements for filling materials resulted in development of microfilled composites. They contain a filler with very small particle size of 0.04-0.4 micron.
- Advantages: good polishing, stable glossy surface, high color stability, good aesthetic qualities.
- The major disadvantage is low mechanical strength.
- Indications for use of microfilled composites: high aesthetic requirements to the restoration, cavities class III, IV and V.

- Hybrid composites
- Hybrid composites contain a mixture of filler particles of different sizes (0.04-5 microns) and show a different chemical composition (barium and strontium glass, silica, etc.).
- Advantages of hybrid composites: acceptable aesthetics, sufficient strength, surface quality better than in macrofilled composites.
- Disadvantages: surface quality worse than in microfilled composites.
- Changing the ratio of large and small particles, varying their chemical composition and shape allow a modification of properties of the composite (aesthetics, polishability (small particles); strength (large particles).
- Hybrid composites are considered universal filling materials. A change in particle sizes yields different types of hybrid composites as microhydrid or nanohybrid. These materials show improved esthetic parameters (color, polishability, translucency, etc.).



+ Nanofill +

Macrofill

Surfase gloss and color stability

Minifill

Polishing

Hybrid

− Macrofill −

# Polymerization of composites

- Reaction of polymerization includes the following phases: initialization, chain growth, chain termination. The polymerization is initiated by free radicals, which may be formed in the following ways:
- ► thermal reaction (heating);
- ► chemical reaction;
- ► photochemical reaction.

- *Polymerization by heating* is mostly used in prosthetic dentistry.
- *Chemically activated* composites (self-curing composites) are two-component (paste-paste) systems. One component contains a chemical activator, and the other - a chemical polymerization initiator. Upon mixing of these components free radicals are formed that start the polymerization reaction. Advantages of chemical activation are as follows: polymerization of material is uniform regardless of layer thickness and cavity depth. Disadvantages: after polymerization reaction some residual activator (tertiary amine) could be found in restoration. This will cause staining of restoration (amine staining); polymerization begins immediately after mixing, so the working time is limited.

- Most dentists reject self-curing composites and prefer *light-cured composites.*

# Light-cured composites

- Light-cured composites are one paste system. The mechanism of setting is also reaction of polymerization but it is initialized by light energy.

- Light-cured composites have several advantages compared with self-curing composites:
- ► they do not require mixing of components;
- ► a longer working time to allow restoration modeling;
- ► start of polymerization is under the dentist's control;
- ► easier to control the quantity of material because you do not need to mix components («no waste», i.e. take only as much material as you need):

- ► no restoration staining because of residual chemical activator;
- ► photopolymerization allows a higher degree of polymerization.
- Disadvantages of light-cured composites are as follows.
- ► The patient spends more time in dental chair because light-cured composite requires a layering technique of application while self-curing composites are placed in cavity in one portion.
- ► High cost of fillings (light-cured composite is more expensive and we need to buy a photopolymerization lamp).
- ► The light from photopolymerization lamp is harmful to eyes (requires use of protective screen and/or glasses).
- ► It must be remembered that the working time of light-cured composites is not unlimited. Slow polymerization can be initiated by sunlight, electric ceiling or dental light.

# Photopolymerization lamps

- In composites there is a light-activated ingredient, dimethacrylate. Most light-cured dental materials contain photoinitiators, such as camphorquinone, with a light absorption peak at 470 nm.
- For the polymerization of light-cured composites it is necessary to use special photopolymerization lamps giving high-intensity blue light (wavelength 400-500 nm, peak is about 460 nm).
- First photopolymerization lamps were UV-lamps. The most common light-curing units used for the polymerization of composite resins are Quartz-Tungsten-Halogen units (QTH), which are the gold standard of curing with an output intensity of 400-2800 mW/cm$^2$.

- The advantages of this device include its low cost and wide range of radiation, and its disadvantages can be the limited depth of cure, long exposure time, and reduced light intensity over time.
- To overcome such problems with QTH units, light-emitting solid-state diodes (LEDs) have been used to cure composite resins. These devices use the semiconductor, indium gallium nitride, which produces a blue light and a narrow range with a maximum radiant point of 470 nm (450-490).
- The advantages of these devices include reduced curing time and a lamp life up to 10,000 hours. In addition, these devices use minimum energy; they are light and portable, and they have an ergonomic design and are resistant to shock and vibration. They use semiconductor doping instead of a halogen incandescent filament, so they have low heat and do not need a fan. Polymerization of one composite layer by halogen lamp needs 40 seconds, and by LED-lamp from 5 to 10 seconds (depending on intensity and manufacturer's recommendations)

- It is recommended to use photoprotective screens or glasses with orange filter. We do not recommend to look at the end of the optical fiber even through a screen, and at the light reflected from the teeth surfaces. Avoid contact of fiber guide tip with non-polymerized material as sticky composite remnants on the tip could decrease light intensity. The distance between the optical fiber tip and restoration should be minimal and not more than 5 mm. Optimal thickness of composite material layer is 1.5-2 mm.

# Polymerization shrinkage

- All composites have polymerization shrinkage (about 2-5% of the volume). The reason for it is decreasing of distance between monomer molecules during polymerization reaction.

- In self-curing composites shrinkage occurs more or less in the direction of the center of cavity. In light-curing composites shrinkage occurs in the direction of light source (polymerization lamp). After shrinkage the contraction stress of restoration can cause debonding of composite from the cavity wall. One of the most popular methods to reduce the negative effect of polymerization shrinkage is directed polymerization: first the curing light beam should be directed to material through the enamel or cutting edge, or a thin cavity wall.

- If in the process of filling the cavity is permeated by blood, saliva or gingival fluid, the properties of inhibition layer get disrupted and even after thorough drying it loses the ability to connect with the next composite layer. This case requires 10 second etching and applying an adhesive system, after which the process of filling proceeds.