L. N. PALIANSKAYA, A. H. HOTAIT

RESTORATIVE MATERIALS

Minsk BSMU 2018

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2-я КАФЕДРА ТЕРАПЕВТИЧЕСКОЙ СТОМАТОЛОГИИ

Л. Н. Полянская, А. Х. Хотайт

РЕСТАВРАЦИОННЫЕ МАТЕРИАЛЫ

RESTORATIVE MATERIALS

Учебно-методическое пособие

Минск БГМУ 2018

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MOTIVATIONAL CHARACTERISTIC OF THE THEME

Total time: 70–90 minutes (seminar).

Restorative dental materials are used to prevent or repair teeth lesions caused by oral disease or trauma. An understanding of the physical, electrical and mechanical properties of materials used in dentistry is of tremendous importance. First, materials used to replace missing portions of teeth are exposed to attack by the oral environment and subjected to biting forces. Second, the restorative materials are cleansed and polished by various prophylactic procedures. As a result, their properties are the basis for the selection of materials to be used in particular dental procedures and restorations. A factor significantly contributing to the failure of restorations is the inappropriate use and abuse of dental materials. This problem can be minimized by ensuring a thorough understanding of the composition and chemistry of dental materials and an appreciation of their physical and mechanical properties.

The purpose of the seminar: to integrate knowledge of the properties of the modern restorative materials, indications and contraindications for their use.

The tasks of the seminar. The student should know:

1. Classification of the modern restorative materials.
2. Composition, properties, indications for use of all groups of the materials for direct teeth restorations.
3. Rationale for the choice of modern restorative materials.

Requirements for the initial level of knowledge. For full understanding of the topic the student must revise:

– from human anatomy: anatomical features of different groups of teeth;

– from histology, cytology, embryology: histological structure of enamel, dentine and cementum;

– from general dentistry: composition and basic properties of restorative materials;

– from therapeutic dentistry: diagnosis and clinical features of caries and non-carious lesions, dental examination and treatment of dental diseases.

Control questions from related disciplines:

1. Anatomical structure of the tooth.
2. Blood supply and innervation of teeth.
3. Histological structure of enamel, dentine and cementum.
4. Dental materials: composition and basic properties.

Control questions for the seminar:

1. Classification of the modern restorative materials.
2. Dental amalgam: composition, properties, indications and contraindications for use.
3. Glass-ionomer cements. Classification, composition, properties, indications for use.
4. Resin-based composites. Classification, composition, properties, indications for use.

5. Comparative characteristics of the restorative materials based on their filler size, viscosity, resin matrix and cure type.

6. Contraindications for use of resin-based composites.

7. Rationale for the choice of restorative materials in different clinical situations.

DENTAL AMALGAM

Dental amalgam is a mixture of a silver alloy with the liquid element mercury. The alloy used in the traditional dental amalgams consists of silver, tin, copper and sometimes zinc and/or mercury (table 1).

Table 1

Constituents of a typical dental amalgam alloy

Constituent	% of total
Silver (Ag)	65–74
Tin (Sn)	25–28
Copper (Cu)	0–6
Zinc (Zn)	0–2
Mercury (Hg)	0–3

Silver is the main constituent, present in combination with tin as the intermetallic compound Ag_3Sn, known commonly as the γ phase. The setting reaction between the Ag-Sn alloy and the mercury is initiated by a vigorous mixing of the two ingredients:

Ag_3Sn	+	Hg	→	Ag_3Sn	+	Ag_2Hg_3	+	Sn_7Hg
γ	+	mercury	→	**γ**	+	γ_1	+	γ_2
Powder	+	liquid	→	unreacted alloy	+	amalgam matrix		

γ_2 phase is the weak link within the amalgam structure as it is soft and corrosion-susceptible.

The development of silver alloys with higher (12 % to 30 %) copper proportion has replaced traditional amalgams because it resulted in a modification of the setting reaction. The first reaction is the same as for the traditional alloys, but this is followed by a second reaction:

γ_2 + Ag-Cu → Cu_6Sn_5 + γ_1

Thus, the final amalgam contains little or no γ_2. It has higher compressive strength, more rapid set, reduction in creep and reduced susceptibility to corrosion.

Particles of the silver alloy powder can be either irregularly shaped, spherical, or a mixture of the two (fig. 1).

The shape of these particles will significantly influence the setting reaction and manipulation of the amalgam. Amalgams containing irregular particles require greater packing forces during placement, but produce better proximal contacts and are easier to carve. Spherical amalgams require less mercury, less condensation force and set somewhat faster.

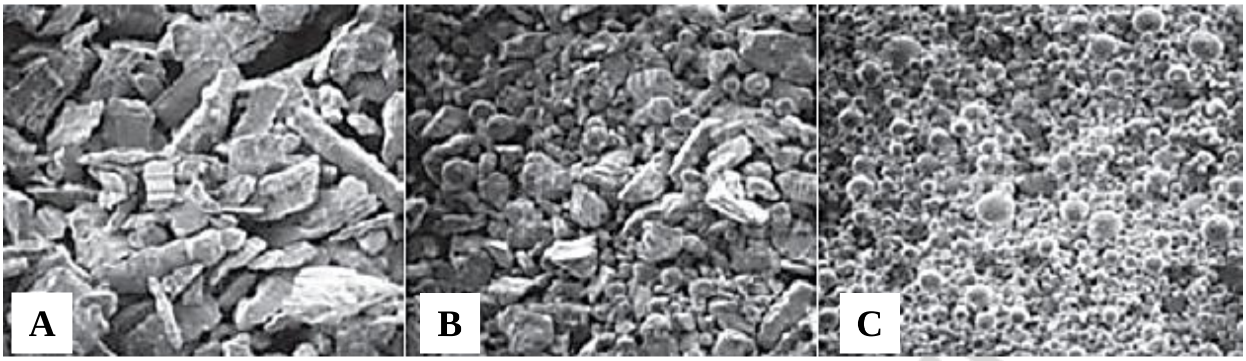

Figure 1. Scanning electron micrographs of silver alloy particles used in dental amalgam: *A* — irregular; *B* — “admixed”; *C* — spherical

The laboratory and clinical evidence indicates that an admixed zinc-containing, high-copper content amalgam is the preferred choice. In today’s dental practice, the use of precapsulated amalgam is mandatory.

Modern dental amalgams have many **advantages**:

– high mechanical strength and wear resistance;
– durability;
– lower cost compared to other restorative materials;
– simple and fast filling technique;
– lower sensitivity to moisture;
– lower sensitivity to oral hygiene level;
– possibility to create tight contact point;
– high radiopacity.

However, dental amalgams also have a number of **shortcomings**:

– poor esthetics;
– high thermal conductivity (varnishes or liners are needed);
– galvanic effects;
– lack of adhesion (the need for retentive cavity design that requires removal of sound enamel and dentine);
– mercury waste management.

In 2011 World Health Organization (WHO) committee called for a worldwide reduction in the use of dental amalgam to cut the flow of mercury into the natural environment.

Indications for use of amalgam:

1. Moderate to large restorations in Class I and Class II cavities.
2. Class V restorations (when esthetics is not important).
3. Core build-up.

Amalgam is a preferable restorative material for the patients with bad oral hygiene, in cases when moisture control is difficult and when economic reasons are of the prime concern.

Contraindications for use of amalgam:

1. An allergy to any metal element of amalgam.
2. High esthetic requirements to restoration.

Thus, dental amalgam will continue to be one of the most convenient restorative materials for posterior use. Nevertheless, aesthetic demands from patients, desire on the part of the dentist to preserve tooth structure and ecological concerns will drive down the use of this material in dentistry.

GLASS IONOMER CEMENTS (GICs)

GIC is a true acid-base material, where the base is a fluoroaluminosilicate glass with a high fluoride content, and this interacts with a poly(alkenoic) acid. The polyacids most frequently used in current formulations are copolymers of acrylic and itaconic acid or acrylic and maleic acid. The result is a cement consisting of glass particles surrounded and supported by a matrix arising from the dissolution of the surface of the glass particles in the acid (fig. 2).

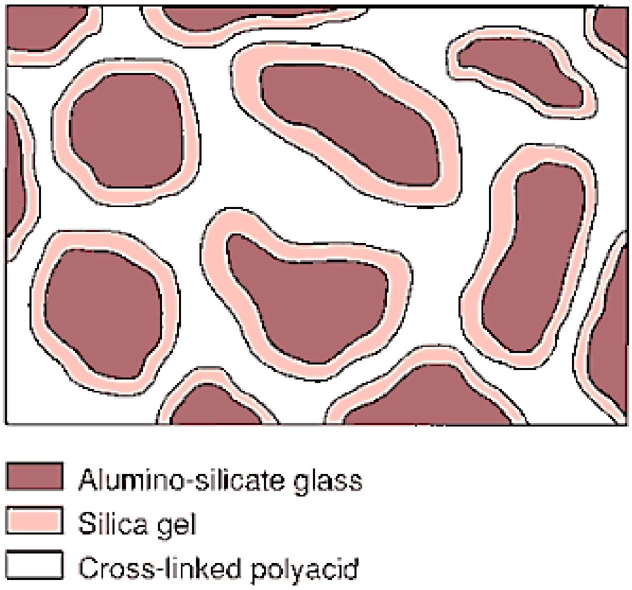

Fig. 2. The structure of a GIC

At the same time some of the fluoride is released from the glass in the form of micro-droplets that lie free within the matrix, but play no part in its physical make-up. More fluoride is retained in the matrix, bonded to aluminium, and most of the subsequent fluoride release is the result of ion-exchange reactions. Thus the fluoride is able to leach out of the restoration as well as return into it with no modification at all of the physical properties of the set restoration. This means that GIC, in any form, can be regarded as a fluoride reservoir.

Properties of GICs

Chemical adhesion. One of the most attractive features of GICs is their ability to bond directly to dentine and enamel, forming hydrogen bond type of adhesion to the collagen combined with an ionic bond to the apatite (fig. 3).

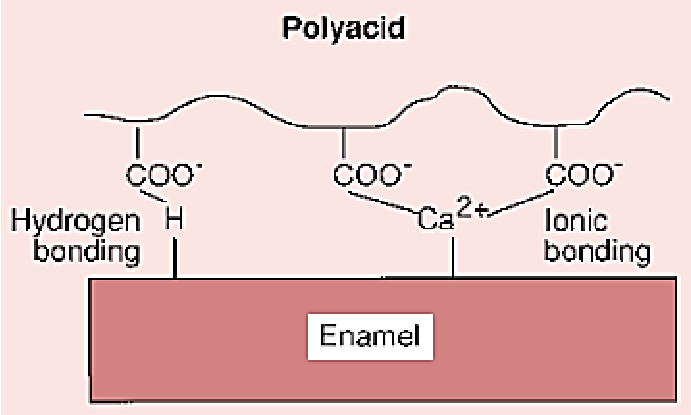

Fig. 3. Adhesive mechanisms for GICs

Caries protective effect. It's still a matter of debate weather fluoride release or other factors (e.g. the release of other ions, antibacterial properties and adhesive capabilities) have a role to play in the anticariogenic characteristics of GICs. Nevertheless, these materials are widely recommended for patients with a high risk of caries.

Biological compatibility. It has been shown that the dental pulp demonstrates a very high level of tolerance to the presence of GIC. The poly(alkenoic) acids of the system are relatively mild acids with long and complex molecular chains, which will not readily penetrate dentine tubules, and the dentine itself is a very effective buffer to acids in general. Therefore, GIC can be placed in very close proximity to the pulp without the risk of developing an irreversible pulp inflammation.

Solubility. Dissolution of immature cement occurs before the material is fully set which can take up to 24 h. The temporary protection of GIC surface with waterproof varnish should be sufficient to minimize this effect.

Physical properties. GICs have expansion coefficient comparable to that of tooth structure. Their modulus of elasticity is similar to that of dentin. GICs have rather good compressive strength, but their fracture resistance and abrasion resistance are relatively low. They are still not recommended for rebuilding cusps, marginal ridge or incisal corner.

Aesthetics. In GICs the color is produced by the glass. This can be controlled by the addition of color pigments. Whereas color does not present a major problem, the translucency of some GICs is inadequate. One more problem is insufficient polishing, which doesn't provide the quality of the surface close to natural tooth. That's why aesthetic appearance of GICs has always been considered inferior to that of composite resins.

Classification of GIC by composition:

1. Traditional GICs (auto cure):
– classical;
– anhydrous;
– cermets (ceramic-metal mixtures).
2. Resin-modified GICs (RMGICs).

Traditional GICs are 2-component auto cure materials. In *classical* ones powder is a F-Al-Si glass, liquid is a water solution of polyacids. *Representatives*: Fuji II (GC), Ionofil Plus (VOCO), Ketac Universal (3M).

In *anhydrous* cements the glass powder is blended with freeze-dried polyacid and tartaric acid powder. The cement is formed by the addition of the correct amount of distilled water. *Representatives*: Aqua Ionofil Plus (VOCO), ChemFil Superior (Dentsply).

In *cermets* the glass particles are covered with a fine layer of metallic silver. This leads to improved handling properties and abrasion resistance. Compressive strength and fracture resistance have also been improved to a limited extent. *Representatives*: Argion (VOCO), Ketac Silver (3M), MiracleMix (GC).

The main difference of *RMGICs* is the addition of resins and photo-initiators to the auto cure materials so that they can be light-cured on command immediately after placement in the cavity. These materials are immediately resistant to water uptake and can be contoured and polished as soon as they are set. Their physical properties are generally better and esthetic features are also improved. *Representatives*: Ionogem LC (DCL), Fuji II LC (GC), Photac-Fil Quick (3M), Ionolux (VOCO), Geristore (DenMat), Vitremer (3M).

Classification of GICs by clinical indications:

Type I: Luting and bonding GICs

– For cementation of crowns, bridges, inlays and orthodontic appliances as well as bonding of composite resins and amalgam.

– Fast set, with early resistance to water uptake or light-activated.

– Ultimate film thickness 20 μm or less.

– Radiopaque.

Type II: Restorative GICs

II.1: Restorative esthetic GICs

– For any application requiring an esthetic restoration with minimal occlusal load.

– Excellent shade range and translucency.

– Auto cure cements have a prolonged setting reaction and remain subject to water loss and water uptake for at least 24 hours after placement; they require immediate protection from the oral environment.

– Resin-modified materials are immediately resistant to water uptake or water loss; they do not require sealing.

– Most materials are radiopaque.

II.2: Restorative reinforced GICs

– For use where aesthetic considerations are not important, but a rapid set and high physical properties are required.

– Fast set with early resistance to water uptake; can be trimmed and polished immediately after initial set; remain susceptible to dehydration for 2 weeks after placement.

– Radiopaque.

Type: III Lining or base GICs

– Can be auto cure or resin-modified.

– Can be used as either a lining or a base, depending on the powder-liquid ratio used.

– Physical properties improve as the powder content increases.

– Radiopaque.

Indications for use of GICs:

1. Restorations of Class III and V cavities in permanent teeth. Small Class I cavities in non-occlusal areas.
2. Non-carious cervical lesions.
3. Root caries.
4. Temporary restorations of permanent teeth.
5. Use as a liner or a base in “sandwich technique”.
6. All classes of cavities in deciduous teeth.
7. Atraumatic restoration technique (ART).
8. GIC-protection of fissures.
9. Use as a sealer in endodontic treatment.
10. Luting procedures.

GICs are preferable restorative materials in patients with bad oral hygiene and high caries risk, in subgingival cavities with challenging moisture control and in situations when resin composites are contraindicated.

Hence, GICs have had a major impact on restorative dentistry. A wide variety of formulations are now available, designed for a broad range of applications. The new RMGICs have produced materials with superior properties. However, these improvements are as yet insufficient for them to compete with the resin composites in high-stress-bearing areas in the permanent dentition.

RESIN-BASED COMPOSITES (RBCs)

A composite, as the name implies, consists of a mixture of two or more materials. Each of these materials contributes to the overall properties of the composite.

RBC restorative materials that are used in dentistry have three major components:

– an organic resin matrix;

– an inorganic filler;

– a coupling agent.

The resin is chemically active component of the composite. It is initially a fluid monomer but is converted into a rigid polymer by a radical addition reaction. The most commonly used monomers are Bis-GMA and UDMA. They are highly viscous fluids because of their high molecular weights. To overcome this problem, low-viscosity monomers (EDMA, TEGDMA) are added. Resin matrix also contains the activator/initiator systems for achieving the cure.

Quartz, lithium aluminum silicate, and barium, strontium, zinc, or ytterbium glasses have been used as fine fillers. Microfine fillers are colloidal silica particles. The fillers improve mechanical properties of the material, control various esthetic features, provide radiopacity and reduce the shrinkage, as the filler does not take part in the polymerization process.

To achieve strong bond between the resin and the filler silane coupling agents are used.

Classification of RBCs

By filler size:

1. Macrofilled (8–12 μm and more).
2. Microfilled (0.01–0.1 μm):
3. Hybrid (0.01–10 μm):
4. Nanocomposites:

– nanofilled (1–100 nm);

– nanohybrid (nanoparticles + hybrid filler).

By resin matrix:

1. Pure methacrylates (traditional composites).
2. Acid modified methacrylates (compomer).
3. Inorganic-organic matrix (ormocer).

By viscosity:

1. Regular.
2. Flowable (low viscosity).
3. Packable (high viscosity).

By cure type:

1. Auto cure.
2. Light cure:

– incremental;

– bulk-fill.

3. Dual cure.

Macrofilled RBCs contained glass filler particles with a mean particle size of 10 μm or more. These composites had the disadvantage that the surface finish was very poor, with the surface having a dull appearance due to filler particles protruding from the surface as the resin was preferentially removed around them. This group is not used much anymore.

Microfilled RBCs contain colloidal silica microfine particles with high surface areas. The small size of the filler means that the composite can be polished to a very smooth surface finish and exhibits good optical characteristics. However, only 35 % to 50 % by volume of these particles can be used with the resin matrix and still produce a paste of acceptable viscosity. That’s why microfilled RCs are weaker, often insufficiently radiopaque, and perform poorly in the posterior region. They are indicated for Class III and V restorations. *Representatives:* Renamel Microfill (Cosmedent), GemLite II Micro (DCL).

*Hybrid RBC*s contain different-sized filler particles ranging from very small submicron size to several microns in average diameter. The microfine filler particles fit in spaces between the fine filler particles, producing a total filler load of 70 % by volume, which results in improved properties. Modern methods of grinding have allowed introduction of composites with an average particle size of less than 1 μm. These materials are called *microhybrids* and are most common today. They combine good mechanical properties with desirable esthetic features and can be used for **“all-purpose” indications:**

1. Correction of the esthetic parameters of the tooth:
   a) correction of shade;
   b) remodeling of shape and size;
   c) adjustment of tooth position in dentition.
2. Restoration of carious, non-carious and traumatic lesions of teeth:
   a) restoration of tooth crown after traumatic injuries;
   b) Classes I–VI restorations.
3. Teeth splinting.
4. Core build-up.
5. Repair of direct and indirect restorations.
6. Indirect restorations (inlays, onlays, veneers).

Nanocomposites are defined as materials that include filler particles less than 100 nm. *Nanofilled* materials include solely nanoparticles, partially agglomerated in clusters with the size of 0.6 to 1.4 μm (fig. 4). *Representatives:* Filtek Ultimate, Filtek Bulk Fill Posterior (3M). In *nanohybrid* composites nanoparticles are combined with larger filler particles (up to 3 μm). *Representatives*: Premise (Kerr), Ceram-X (Dentsply), Synergy Nano Formula (Coltène Whaledent), Grandio (VOCO).

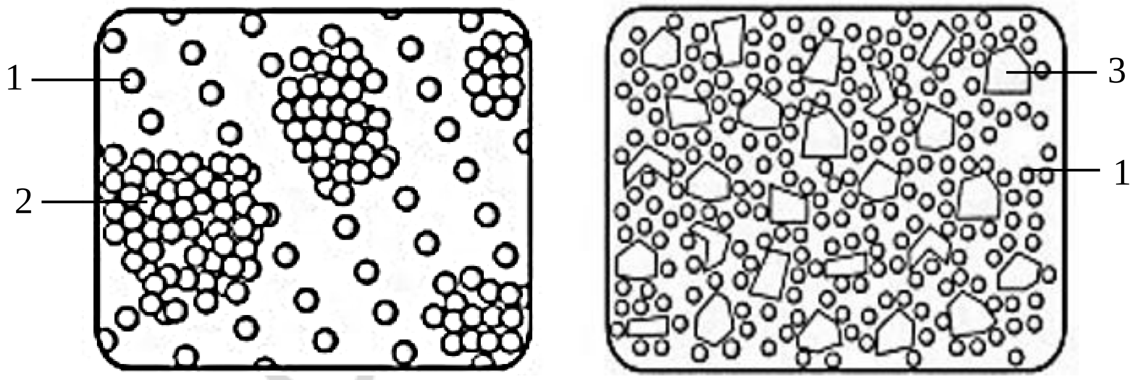

Fig. 4. The difference between nanofilled and nanohybryd composites:
1 — nanoparticles; *2* — nanoclusters; *3* — microparticles

Due to the high filler load new nanocomposites have less polymerization shrinkage and better physical properties. They also produce a better polish because a nanosized particle is larger than the wavelength of light that is not reflected by the particle, so the material appears more translucent. Nanocomposites are used for “all-purpose” indications.

COMPOMERS

Compomers contain monomers modified by polyacid groups with fluoride-releasing silicate glasses and are formulated without water. Among current products, the filler-volume percentage ranges from 42% to 67%, and the average filler-particle size ranges from 0.8 to 5.0 μm. Compomers are packaged as single-paste formulations in compules and syringes. Setting occurs primarily by light-cured polymerization, but an acid-base reaction also occurs as the compomer absorbs water after placement.

The amount of fluoride release and its duration are lower than those of GICs. Also, compomers do not “recharge” from fluoride treatments. Unlike GICs, compomers do not have a natural affinity for enamel and dentine and must be used in combination with a dentine adhesive.

Compomers are mostly used for restorations in low-stress-bearing areas: Class III and V cavities in permanent teeth and all cavities in deciduous teeth. *Representatives:* Glasiosite, Twinky Star (VOCO), Compoglass F (Ivoclar Vivadent), F2000 (3M), Dyract eXtra (Dentsply Sirona).

ORMOCERS

Whereas methacrylate-based resin matrices consist of purely organic material, an alternative type of inorganic-organic copolymer resin was introduced more than 20 years ago. This developed into the ORMOCER®, which stands for ORganically MOdified CERamic. It consists of organic reactive species with carbon double bonds for polymerization, which is bound to an inorganic Si–O–Si network (fig. 5).

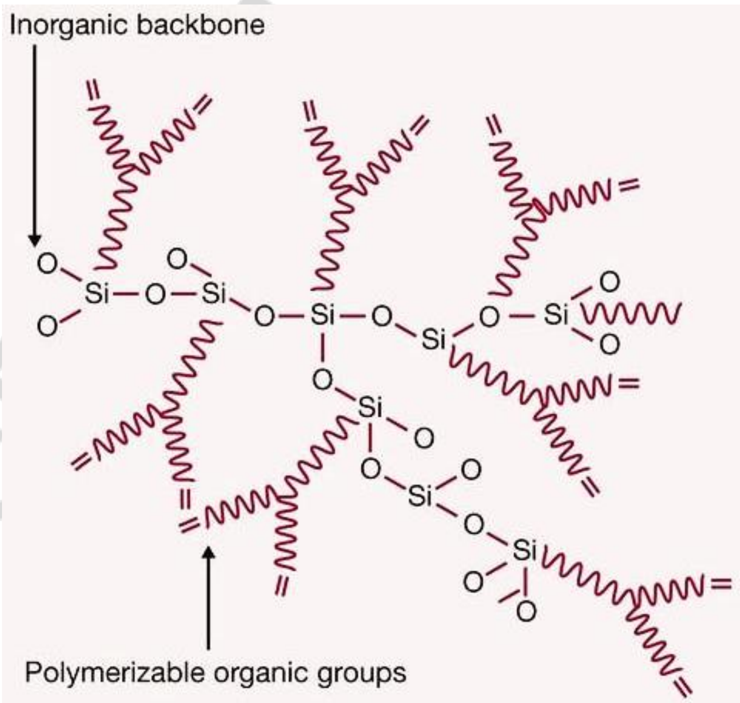

Fig. 5. Ormocer chemistry

Ormocer has better biocompatibility compared to traditional methacrylate-based composites. Sufficient mechanical properties and satisfactory esthetics make it an “all-purpose” material. *Representative*: Admira (VOCO).

FLOWABLE RBCs

In order to produce low-modulus flowable RBCs, the manufacturers have reduced the filler loading to 42–53 % by volume. The low viscosity of these composites allows them to be dispensed by syringe for easy handling. These materials ideally suit for small preparations due to their good adaptation properties. They **are indicated** for:

1. Restoration of minimally invasive preparations of Class I (out of occlusion), III and V cavities.
2. First (“adaptive”) layer of composite restorations.
3. Preventive resin restorations (for pits and fissures).
4. Teeth splinting with fiber glass tape.
5. Margin repairs.
6. Elimination of undercuts for indirect restoration technique.

Nevertheless, flowable composites exhibit higher polymerization shrinkage and lower strength and wear resistance than microhybrids. These materials are not recommended for situations involving high levels of stress or wear.

Representatives: Esthet Xflow (Dentsply Sirona), Tetric EvoFlow (Ivoclar Vivadent), Premise Flowable (Kerr), Filtek Ultimate Flowable (3M), Charisma flow (Kulzer).

PACKABLE RBCs

Packable composites have handling characteristics similar to those of dental amalgams due to increase in filler loading of 1–2 vol. % and a change in the rheology. This is not as easy as it sounds since the filler loading of most composites has already been maximized and simply adding more filler will make the composite crumbly and cause cracking. The increased viscosity can be accomplished in a number of different ways:

– by increasing the filler particle size range, which improves the packing density, such as a trimodal particle size distribution (fig. 6);

– by modification of the filler particle shape such that particles have a tendency to interlock;

– by modification of the resin matrix such that stronger intermolecular attractions are created;

– by the addition of dispersants (rheological control additive), which lower the viscosity and allow an increase in the filler loading.

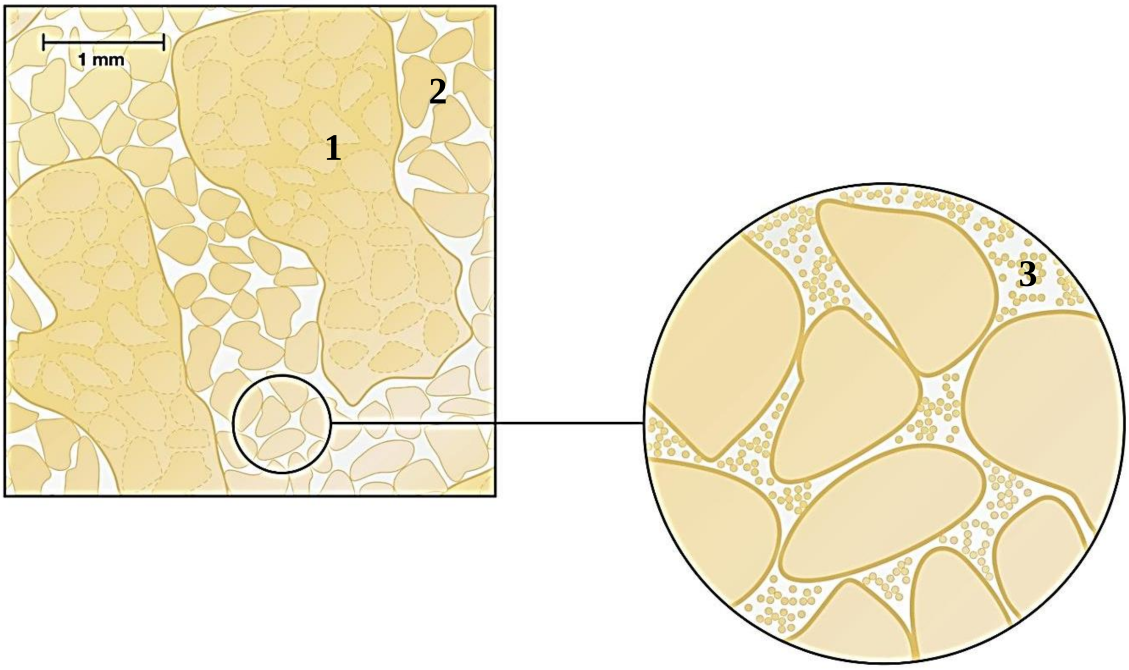

Fig. 6. Trimodal particle size distribution:
1 — pre-polymerized filler; *2* — microfiller; *3* — nanoparticles

Important properties include high depth of cure, low polymerization shrinkage, radiopacity, and low wear rate. However, these materials tend to be more opaque and their adaptation can be a problem due to the high viscosity. Therefore packable composites have a limited range of applications and are most suitable for posterior restorations, such as Class I and II preparations. *Representatives*: Filtek P60 (3M), Aelite LS Posterior (Bisco), QuiXfil (Dentsply), Alert (Pentron), X-tra fil (VOCO).

BULK FILL RBCs

Most of the light-cured RBCs require incremental technique of cavity filling in order to control depth of cure and shrinkage. In order to simplify and speed-up the placement of large posterior RBCs, manufacturers have produced a range of materials which can be placed in larger increments (up to 4–10 mm), known as bulk-fill composites. They differ most from conventional composites in their increased depth of cure, which could mainly be attributed to an increase in translucency. There are two categories of bulk-fills: low viscosity flowables (e.g., SDR, Filtek Bulk Fill Flowable, X-tra Base, Venus Bulk Fill), and high viscosity restoratives (e.g., Tetric EvoCeram Bulk Fill, X-tra Fil, SonicFill). Flowable bulk-fill material is placed at the bottom of the preparation as dentine replacement and should be covered with a layer of conventional composite (fig. 7).

High-viscosity bulk-fill doesn't need any additional capping. To date, more clinical studies that specifically focus on bulk-filling deep and large restorations are definitely required to fully explore the clinical benefits of these composites.

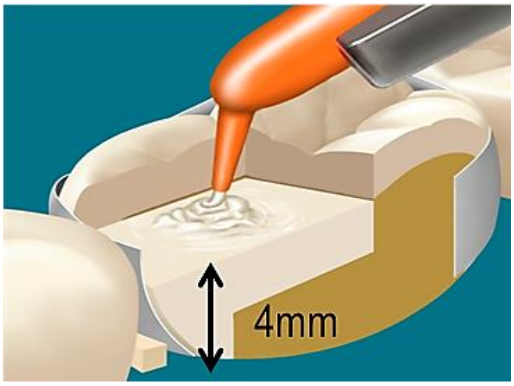

Fig. 7. Schematic illustration of dentine replacement with flowable bulk-fill composite

CONTRAINDICATIONS FOR USE OF RBCs

Absolute contraindications:

1. Allergic reaction to any component of RBC material.
2. Inability to adequately isolate the operation field.
3. If the patient has a heart pacemaker implant the dentist needs to consult with the cardiologist about the possible use of the light curing unit.

Relative contraindications:

1. Poor oral hygiene.
2. Deep subgingival cavities.
3. Occlusal overload of restoration (bruxism, orthodontic abnormalities, teeth attrition, large restorations, etc.).

The introduction of resin-based composite restorative materials has had a major impact on the practice of restorative dentistry. Their clinical applications are numerous and varied, and will continue to grow as further improvements in their properties are achieved. However, there are certain limitations for the use of this group of materials and it is important that these should not be disregarded.

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