МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
КАФЕДРА СТОМАТОЛОГИЧЕСКОЙ ПРОПЕДЕВТИКИ И МАТЕРИАЛОВЕДЕНИЯ

# ПОЛИМЕРИЗАЦИЯ ФОТООТВЕРЖДАЕМЫХ МАТЕРИАЛОВ. ПОЛИМЕРИЗАЦИОННЫЕ УСТРОЙСТВА

# POLYMERIZATION OF PHOTO-CURED MATERIALS. POLYMERIZATION DEVICES

Учебно-методическое пособие

Минск БГМУ 2025

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Представлены современные композитные материалы, их состав и особенности. Описаны процессы полимеризации композитов, полимеризационные стоматологические устройства, их виды, строение, преимущества и недостатки.

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# MOTIVATIONAL CHARACTERISTICS OF TOPIC

**Topic of the lesson:** Polymerization. Polymerization devices. Methods for reducing polymerization shrinkage.

**Total class time:** 225 minutes.

Polymerization is the process of formation of a high molecular weight substance due to the combination of monomer molecules with the help of active oxygen ions and free radicals. The formation of free radicals occurs under the influence of heat, chemical and photochemical reactions. Polymerization that occurs under the influence of light is called photopolymerization. A dental polymerization lamp is one of the main devices used in restorative dentistry, which initiates the polymerization of composite materials based on light-curing resins.

Prevention of polymerization shrinkage associated with photopolymerization devices consists of using special polymerization lamps with a “soft start” and transdental illumination as the first stage of seal polymerization.

**Purpose of the lesson:** to study the types, structure, and operating techniques of polymerization devices. Methods for reducing polymerization shrinkage of composite materials.

**Objectives of the lesson.** After completing the lesson, the student should:

1. Select photopolymer composite materials for fillings according to classification and application.
2. Be able to work with various polymerization devices.
3. Know the methods of reducing polymerization shrinkage of composite materials.

**Requirements for the initial level of knowledge:**

1. Filling materials. Classification, properties. Composition, properties, application.
2. Types, structure and operating techniques of polymerization devices.

**Questions for control in related disciplines:**

1. The concept of the biological compatibility of dental materials and tooth tissues.
2. Physical properties of dental materials.
3. Chemical properties of dental materials.

**Questions for control on the topic of the lesson:**

1. Dental polymerization lamps (types of devices, characteristics, advantages and disadvantages).
2. Dental polymerization lamps (structure, operating features).
3. Mistakes when working with polymerization devices.
4. C-factor. Methods for reducing polymerization shrinkage.

**Assignments for independent work.** To prepare for the lesson, the student must review the educational material from related disciplines, then familiarize himself with the educational material of this manual. For more effective mastering the material, the student is recommended to keep notes of questions and comments, which can later be clarified during independent work with the literature or in consultation with the teacher.

For self-control of the topic mastering, it is recommended to use the test tasks presented after the educational material. The work on the topic is completed with control questions, answering which the student can successfully prepare for the lesson.

## INTRODUCTION

In modern dentistry, new approaches to the treatment of caries and restoration of destroyed dental tissues are constantly being improved and introduced into practice. Today, the development of high-quality and highly aesthetic direct restorations of hard dental tissues is impossible without the use of light-curing filling materials, in particular composites.

These materials successfully satisfy both the increased demands of the population for the aesthetics of restorations and constantly increasing demands of dentists. They have become particularly popular due to a wide range of color shades, the possibility of modeling and layer-by-layer application, and long working time. They are used in their practice by both dental therapists for the restoration of non-carious and carious cavities of all classes according to Black, and orthopedic dentists for the restoration of plastic and ceramic veneers, the creation of a tooth stump, and the fixation of ceramic and composite inlays. In orthodontic practice, they are used to fix braces.

However, the use of even such modern and promising materials as photocomposites does not solve all existing problems in the restoration of hard dental tissues. The impairment of the marginal attachment of restorations, which over time leads to the appearance of defects at the filling-tooth junction and the development of secondary caries, incomplete conversion of composites and the presence of residual monomer in restorations, leading to the development of allergic reactions, are still relevant problems.

In addition to the materials themselves, the quality of the created composite restorations is influenced by the technical characteristics of the photopolymerization devices used and the methods of their application. The scientific literature contains conflicting information about the influence of such factors as the intensity of the outgoing light flux, exposure duration, the thickness of the material layer and its color, the distance from the light guide to the illumination surface, the ambient temperature, and the characteristics of the curing material itself on the effectiveness of the restoration of hard dental tissues.

The restoration of hard tooth tissues with filling materials has a long history. During this time, there have been many changes in the structure of materials for more successful clinical use. However, scientific research is still being carried out to reduce polymerization shrinkage and polymerization stress, increase wear resistance and biocompatibility, improve adhesive technology, and search for alternative components for the organic matrix, fillers, and polymerization initiators. This material corresponds to the curriculum and can be used for teaching 1st and 2nd year students of the Faculty of Dentistry and the Faculty of Medicine for international students studying in Russian in the specialty “Dentistry”.

# COMPOSITE MATERIALS

Composites are substances consisting of several heterogeneous components. In dentistry, composites are commonly referred to as substances consisting of a polymeric organic polymer matrix. The presence of more than 50 % by weight of an inorganic filler and a binding layer (silane), allow to make a chemical bond with the polymer matrix.

In the early 60s, composite materials were first developed in the USA and described by Dr. Rafael I. Bowen. These materials differed from the previous generation, acrylic plastics, in their composition: the new monomer Bis-GMA, synthesized from epoxy resin and methacrylic acid esters.

Fine quartz was used as a filler, and silanes were used as a binder. The first generation of composites was characterized by satisfactory physicochemical properties, slight shrinkage, adhesive properties to tooth tissue, and tight marginal fit. Two-component composites are polymerized by mixing the base paste with the catalyst paste at room temperature.

Long-term clinical observations revealed the main disadvantage of the first generation of composites: a significant change in the color of the filling material in the oral cavity.

This problem was solved in the 70s by introducing microfilled composites into dental practice. The term “composite” by R. W. Philips was based on the understanding of the spatial three-dimensional combination of two chemically different materials that have a clear interface.

Thus, the created combination demonstrated better properties than each of the components separately. High color stability, a wide choice of colors and the natural shine of the enamel are the advantages of this generation of materials used for the aesthetic and functional restoration of anterior teeth.

## FEATURES OF MODERN COMPOSITE MATERIALS

Features of modern composite materials are:
- high mechanical strength;
- formation of a chemical bond with dental tissues (enamel, dentin, cement);

– bonding of materials in fragments (composite — composite, composite — compomer, composite — glass ionomer cement, etc.);

– biological tolerance of materials (adhesive systems of the third, fourth, fifth generations, high degree of polymerization, release of fluoride into the surrounding dental tissues);

– identity with natural dental tissues due to physical properties (strength, thermometric expansion, color, opacity, abrasion resistance, water absorption);

– stability and lack of solubility in oral fluid;

– the possibility of restoring teeth with defects of various shapes and origins (there is no need to carry out classical preparation according to G. V. Black).

The fundamental difference between composites and plastics is the presence of a third component that combines substances of dissimilar chemical structure (matrix and filler) into one material.

Composites designed for filling front teeth may not be radiopaque, but most of these materials are radiopaque. Almost all modern composites are used in combination with adhesive systems.

A common problem of all composites is shrinkage, which occurs due to polymerization and amounts to approximately 2–5 vol.%. In order to prevent the peeling of the composite material from the walls of the carious cavity and the formation of a marginal gap, special attention should be paid to enamel-dentin adhesive systems that are compatible between hydrophobic materials and hydrophilic tooth tissues.

The main components of composite filling materials are an organic monomer and inorganic fillers, in addition polymerization initiators, stabilizers, dyes and pigments that determine the quality of composites.

## STRUCTURE OF COMPOSITE MATERIALS

### Organic matrix

The organic matrix (phase) determines the plasticity of the composite, its adhesive properties, and biocompatibility; it influences the strength, color stability, and degree of the composite polymerization. The amount of shrinkage and other characteristics depend on the volume of organic matter.

Bis-GMA monomer is used as an organic matrix of composite materials. This monomer has a high molecular weight and is capable of forming very long chains that “envelop” filler particles. It hardens at room temperature and in the presence of a catalyst in just 3 minutes. Polymerization shrinkage is 5 %. Bis-GMA forms the basis of almost all modern dental composites. Bis-GMA modifications such as urethandimethacrylate, triethylene glycol dimethacrylate, etc. are also used to impart certain properties to composites. Some manufacturers use oligomethacrylates as the basis of the organic matrix. The composition of the organic matrix also includes initiators and inhibitors of polymerization, catalysts, UV absorbers, and some other substances.

Multifunctional, most often bifunctional, methacrylates are used for the manufacture of composites.

In simple terms, a monomer is represented by the formula MA-R-MA, in which MA is a methacrylic acid ester moiety and R is an organic intermediate link.

*Structure of methacrylate.* Typically the organic matrix is based on methacrylic monomers such as: 2,2-bis-[4-(2-hydroxy-3-methacryloyloxypropyl)phenyl] propane (Bis-GMA or Bowen monomer), ethoxylated Bis-GMA (EBPDMA), 1,6-bis-[2-methacryloyloxyethoxycarbonylamino]-2,4,4-trimethylhexane (urethane dimethacrylate or UDMA), dodecanodiol dimethacrylate (D3MA), triethylene glycol dimethacrylate (TEGDMA).

Modern commercial restorative composites contain mixtures of various crosslinking dimethacrylates, fillers, initiating systems and special additives. Research on the modification of composite compositions is focused on reducing the effects of polymerization shrinkage, improving biocompatibility, wear resistance and manufacturability of application. These qualities are achieved by using new cross-linking monomers and optimizing the size, shape, and composition of filler particles.

## Inorganic fillers (inorganic phase)

It is the filler for composite dental materials that determines such properties of composites as strength, shrinkage, water absorption, abrasion resistance, radiopacity, and color stability.

There is a fundamental difference in determining the amount of filler by mass and by volume. An inorganic filler is heavier than a liquid monomer, so its mass fraction always exceeds the volume fraction by 10–15 %.

The physical properties of the composite are better characterized by the volume ratio of the matrix and filler. The amount of shrinkage and other characteristics depend on the volume of organic matter. When comparing materials, it is necessary to take into account the same type of indicators.

The particle size of the filler can vary from 0.01 to 45 microns. The larger these particles are, the more of it can be introduced into the composite, the higher the strength of the material, the less shrinkage with unchanged plasticity. However, large particles form a rough, lusterless surface and contribute to increased abrasion of the seal. Small particles make the composite polishable and more resistant to abrasion. It is impossible to introduce a large amount of fine filler into the composition of the material, since small particles have a large surface area. In materials with small filler particles, basic physical indicators such as strength, water absorption, and color stability also deteriorate. To preserve plasticity and strength, all filler particles must be “wrapped” in an organic matrix.

The shape of the filler particles also has a huge impact on the properties of the composite. Just as in amalgam, a needle-shaped, irregular filler becomes the basis of high strength, and a rounded, round filler allows the composite to be polished better and makes it more plastic.

*Surfactants (silanes).* The binding layer is most often represented by silane, which is applied to the surface of the inorganic filler in the factory before mixing with the organic part. Silane is an organosilicon compound, a bipolar binding agent. It forms a chemical bond, on the one hand, with the inorganic filler, and on the other, with the organic matrix. Due to this connection, the structure of the composite becomes homogeneous, its strength and wear resistance increase, and water absorption decreases.

## POLYMERIZATION OF COMPOSITE MATERIALS

Polymerization is the process of formation of a high molecular weight substance by repeatedly attaching molecules of a low molecular weight substance to active centers in a growing polymer molecule. The monomer molecule, which is part of the polymer, forms the so-called monomer unit. Polymerization that occurs under the influence of light is called photopolymerization.

Polymerization of composite dental material occurs due to the connection of monomer molecules with each other with the help of active oxygen ions and free radicals. The formation of free radicals occurs under the influence of heat, chemical and photochemical reactions.

Heat activation is used in the manufacture of inlays, onlays, and veneers in dental laboratories.

In chemical curing composites, an initiator system consisting of benzoyl peroxide activated by tertiary aromatic amines is used for this purpose.

An important moment in the history of the development of composites is the introduction of completely new initiator polymerization systems, allowing polymerization of the material under the influence of the energy of light rays.

In photopolymers, external light energy is used to form free radicals from the photoinitiator. Under the influence of light, it undergoes photofragmentation with the formation of active radicals that have an affinity for monomers.

During this reaction, polymerization can be inhibited by oxygen since the reactivity of oxygen to radicals is higher than that of monomers. As a result, a layer of underpolymerized material ("oxygen-inhibited layer") is formed on the surface of the composite in contact with oxygen, the thickness of which depends on the depth of oxygen diffusion. Some substances with similar activity can also attach to the active groups of monomer molecules instead of oxygen, but in this case the chain of polymer formation is interrupted, since subsequent monomer molecules do not attach to such a molecule.

Consequently, such substances inhibit the polymerization reaction of the composite material. Eugenol, a substance from the group of phenols, has similar properties; it combines more actively with glycidyl methacrylate through oxygen than bisphenol.

During the polymerization of a composite, two phases of shrinkage are distinguished: pre-gel and post-gel.

The first phase — pre-gel — at this stage the material is still pliable, stress compensation occurs due to deformation of the free surface of the filling. The second phase — post-gel — at this stage no compensation can be achieved. Today, all developments of methods for minimizing polymerization shrinkage are aimed at trying to lengthen the pre-gel phase, to the detriment of the post-gel phase. Light-curing materials have the shortest first phase of shrinkage, while self-hardening materials have the longest. Thus, the rate of the polymerization reaction directly affects the amount of stress in the material, and in chemically cured composites it is less.

Polymerization shrinkage and polymerization stress are one of the main disadvantages of modern composites. At first the difference between the concepts of polymerization shrinkage and polymerization stress is not visible. We try to find a material with low polymerization shrinkage assuming that this will solve all problems. However, those negative consequences created by shrinkage are only a consequence of the polymerization stress of the material.

## POLYMERIZATION DEVICES IN DENTISTRY

The dental polymerization lamp is one of the main devices used in restorative dentistry. The device generates bright light, which initiates the polymerization of composite materials based on light-curing resins. Modern light-curing composites are sensitive to visible light with a wavelength of 350–600 nm. Lamps differ in technical characteristics and design features of the device shape, which determine the convenience of working with them. Modern polymerizers are equipped with a flow wavelength regulator. For halogen, plasma-arc and laser models, the wavelength can be adjusted in the range from 410 to 490 nm. LED lamps have a narrower spectrum of wavelength changes. Therefore, when choosing an LED device, you should focus on what photoinitiators are contained in the material used. The power of the light flux determines how well the materials will harden. The optimal operating power of the light flux is considered to be 450 W. However, the selection of power in the lamp should be based on which photopolymers will be used in the work.

Power dissipation density. The higher the power dissipation density, the faster and deeper the material will harden. The minimum value should be 1000 mW/cm$^2$.

**Depending on the power source, curing lamps for dental work are available in two configurations:**

1. Wired (stationary). Such lamps are built directly into the dental unit. Therefore, when choosing them, it is important to pay attention to the compatibility of the lamp and installation. The main advantage of stationary models is that they do not need to be charged. Their work is carried out from the network.

2. Wireless (portable). These polymerizers are compact and have a small size and weight. They are more convenient to use since they do not have wires. In terms of functionality, wireless models are not inferior to wired ones. However, they need to be charged periodically. The capacity of the battery will determine how long you can work with the lamp before it is discharged. Therefore, it is recommended to choose a device with a capacious battery or a model that can continue to be used while charging.

**Types of polymerization lamps.** There are 4 types of polymerization lamps, each of which has its own special characteristics:

– halogen lamps;
– LED lamps (LED);
– arc plasma lamps;
– laser lamps.

## HALOGEN LAMP

Halogen lamp is an incandescent lamp consisting of a tungsten thread sealed into a compact transparent flask, filled with a mixture of inert gas with a small amount of halogen, such as iodine or bromine. Light is obtained using a thin tungsten thread through which electric current flows. Then this resistor is heated to a temperature of about 3000 K, becomes incandescent and emits infrared and electromagnetic radiation in the form of visible blue light with a wavelength between 400 and 500 nm and an intensity of 400–600 mW/cm. A small glass flask can be enclosed in a large outer glass flask for greater configuration; temperature the outer flask will be much lower and safer, it also makes it possible to protect the hot lamp from harmful contamination. To transmit the blue spectrum of radiation from a halogen lamp to a sealing material, a fiber or monolithic light guide is required. Light, passing along a fiber-optical cable, stands out at the tip of the fiber. The highest light intensity is located in the center of the fiber, therefore contamination of the end part of the fiber with filling material and mechanical damage — chips, cracks cause dispersion of light, reducing its power. Therefore, the tip of the fiber should be clean. It is also necessary to measure periodically the power of light using a built in or autonomous radiometer. It is possible to transform the performance characteristics, leading to a decrease in the main indicators of the lamp: the energy luminosity of the outgoing flow decreases with an increase in the specific power of ultraviolet and infrared radiation, which can lead to damage to the skin of the doctor's and assistant's hands.

*Advantages* of a halogen lamp:

– relatively low cost of the device and consumables;

– the studied action and extensive experience in using the device;

– radiate a wide range of wavelengths (400–500 nm), due to which they are able to photopolymerize a wide range light-cured dental materials.

*The disadvantages are:*

– long exposure time of the material (up to 40 seconds);

– high power consumption;

– a limited effective lamp service life (40–100 hours);

– interference filter needs to be regularly replaced (at least 1 once a year). Bandpass filters are used to produce blue light, while the remaining light radiation is external energy and dissipates as heat, which leads to deterioration of the components of the bulb over time and a decrease in curing efficiency;

– high heat generation. It is necessary to have a built-in cooling fan due to the increase in the thermal component, which can lead to overheating of the pulp;

– increased noise due to the cooling fan;

– the infrared component of the light flux with prolonged exposure can also cause burns and pulp necrosis;

– under the influence of thermal radiation, the physical characteristics of photographic materials containing the initiator camphorquinone deteriorate, and the photopolymerization process also changes, which leads to a deterioration in the characteristics of the filling material and a deterioration in the clinical and aesthetic parameters of the restoration is observed.

Dental photopolymerization devices (DPD): "Astrolux" (Russia), "Aurora-200", "Optilux-150", "Polofil Lux", "Megalux CS", etc.

Dental photopolymerization devices (Fig. 1) consist of the following main components:

– adaptor;

– polymerization process control unit;

– halogen incandescent lamp;

– selective light filter;

– light guide;

– heat removal systems.

Additional components include protective screens and caps, luminous flux intensity monitoring devices.

The polymerization process *control unit* allows to perform the following functions: set time to turn off the polymerization light in 10–90 seconds, turn on the continuous polymerization mode.

*Fig. 1*. Halogen lamp

The halogen incandescent lamp is the most important structural element in most photopolymerizers; it has a power of 75 W. There is selective light filter for transmiting light in the range of 400–500 nm.

*The lightguide* of the photopolymerizer is designed to supply the light flux to the material being polymerized. The following types of lightguides are available:

– the standard ones at the angle 60 degrees;

– the straight-large ones diameter;

– dual lightguides, for simultaneous delivery of light flux to different tooth surfaces;

– turbo lightguides, for enhancing the power of the light flux;

– mini lightguide;

– flexible lightguide;

– disposable lightguides for risk group patients.

The exhaust system of most halogen photopolymerization devices is provided by a compulsory cooling fan. The compulsory cooling system can operate in two ways:

– to work constantly from the moment of turning on the lamp;

– to turn on and turn off when certain temperature level is reached.

Lamps have two main characteristics of polymerization light:

1. *Energy luminosity* is the density of the power of the luminous flux, which is responsible for the filling material polymerization completeness.

2. *Infrared component* is the density of thermal power stream, the excessive level of which can lead to a heat damage of the pulp.

Commonly accepted optimal indicators of the energy luminosity are considered value of at least 300 mW/cm², and infrared component should not exceed 50 mW/cm². It is necessary, to check the parameters of the lamp, at lest weekly, according to their results of which to carry out maintenance.

Polymerization is carried out in two stages: a light reaction, occurs during illumination, and a dark reaction continuing after turning off light for at least 24 hours. It is believed that during a light reaction of curing occurs by 40 % or 50 % in the next 24 hours and by 10 % during the next 10 days.

In case of photopolymerization of compositional material, light guide should be as close to the seal as possible, but not interact with it. The maximum distance from the light to the seal should be 3 mm. Maximum portion thickness of compositional material is 2 mm.

## PLASMA-SPIRIT LAMPS

In 1998, plasma-spirit lamps were developed. They are based on a high intensity light source — a fluorescent lamp containing plasma.

Plasma-spirit lamps are used to cure resin composites and whiten teeth. Usually, their heat flux density is more than 2000 mW/cm², and the wavelength is 380–350 nm. Most dental plasma arc lamps have several different lighting modes, including step and whitening modes. Curing is often completed in less than 5 seconds. Some devices have a built-in radiometer to ensure optimal energy use. And a variety of regular and turbo tips are available for any curing or whitening procedure that needs to be done any number of teeth at the same time.

*The advantages* of plasma-spirits lamps are:
– high power (promotes fast curing);
– wide spectrum of radiation.

*The disadvantage* of plasma-spirits lamps are:
– big and bulky (larger than halogen lamps);
– weak type of lighting;
– filtering required;
– heat generation requires a fan.

## LED LAMP

LED lamps (LED) — light sources, based on lighting diode. LED (or lighting diode) — semiconductor device with an electron-hole transition, creating optical radiation when passing through an electric current in the right direction.

The light radiated by the LED is in the narrow range of the spectrum. In others words, his crystal initially radiates a specific color (if we are talking about the visible range) — unlike a lamp emitting a wider spectrum where the desired color can only be obtained by using external Light filter. The radiation range of the LED mostly depends on chemical composition of the used semiconductors.

Over the past few years, several types of LED light-harding installations generations have been put into practice.

The 1st generation of LED lamps were usually low-intensity and the materials did not completely cure. Diodes were intended for activations of the initiator of camphorquinone were radiated waves of about 460 nm long. However, alternative photoinitiators used in the ultra-light colour and translucent shades of composites, as well as in sealants and binders, are not activated by these blocks of "blue light".

The 2nd generation of LED light-harding installations (Bluephase, Elipar Freelight 2, L. E. Demetron 1, Radii, Allegro, Smartlite IQ, The Cure) have one powerful diode with several radiation zones. These blocks have a large surface of the radiation and high output energy.

The 3rd generation of LED light-harding installations (Ultralume 5) have two or more diode frequencies and radiate light in various ranges for activating camphorquinone and alternative photoinitiators.

In LED lamps, a lot of attention is paid to structures similarity. The most preferable structure of the lightguide, providing bend at an angle of 90° and a small length for light intraoral access, as well as to provide the necessary radiation power for photopolymerization of restoration.

*The advantages of LED lamps are:*

– the service period of the LEDs is more than 10,000 hours. The light practically does not change from reducing energy production as the device ages;

– an effective narrow spectrum of light radiation leads to a very small heat and excludes the need for fans or filters;

– relatively low energy consumption makes these devices suitable for wireless carrying (e.g., for work from battery).

*The disadvantage* of these polymerization lamps is that they can not cure turn off materials containing non-standard alternative photoinitiators, such as lucerin or 1-fenil-1.2-propandion.

Alternative sources of blue light have appeared — Light Emitting Diodes (LEDs), the emission spectrum of which coincides with the absorption spectrum of camphorquinone. The spectrum of an LED emitter has neither thermal nor ultraviolet components — all radiation energy is in the blue range and is involved in the process of photopolymerization. At the same time, the service period of LEDs is tens of thousands of hours of operation without loss of energy parameters.

Two types of light guides are produced — multi-fiber (Fig. 2) and mono-fiber (Fig. 3).

*Multifiber lightguide* is used much more often and always has a black, brown or opaque surface. These lightguides a significant advantage that the light appears only at the tip and therefore there is no loss as it travels. This is of great importance with halogen lamps, which always scatter some UV light, but it is less important with LED emitters.

The choice in this case is based on easy use. The disadvantage is the reduction in active surface area since each fiber has a dark, non-conductive surface. Since reducing the active surface area can reduce lamp power by 20 %, miniLED prefers a monofiber light guide.

*Fig. 2.* LED Lamp

*Fig. 3.* LED curing box

*Monofiber lightguide* rarely have a black surface (they look like a glass rod). Their disadvantage is the relative inconvenience for the operator, which, however, is easy to adapt to. The advantage is the illumination of the inner surface of the oral cavity, which reduces the light contrast between the tooth and almost dark oral cavity.

There are three main polymerization modes:

1) *fast cure mode* produces maximum light in minimum time. It is characterized by the occurrence of maximum shrinkage. This mode can be used when applying the composite layer-by-layer, or using layers of smaller thickness;

2) *"soft" start mode* is the slowest. It provides the greatest reduction in internal composite mass. To do this, the light intensity is slowly increased until it reaches a plateau, giving the molecules time to position themselves and optimize their connection. This results in a higher polymerization percentage;

3) *intermediate mode — pulsed.* It is based on the study of polymerization using a pulsed laser system. The phase with the absence of light (between two pulses) provides repositioning of the molecule, as in the soft mode, but less efficiently. In terms of time-quality ratio, the mode represents a good compromise.

All of the above modes (fast cure mode, soft and pulsed) are implemented in miniLED.

*Advantages* of using an LED emitter as a light source:

– LED emission spectrum practically coincides with the absorption spectrum of camphorquinone — high efficiency;

– no periodic replacement of the emitter is required;

– stability of the luminous flux over time;

– the radiation spectrum does not have a thermal component, which eliminates the possibility of overheating of the hard tissues of the tooth, periodontium, and photocomposite material;

– absence of a fan, and as a result, of noise and vibration;

– low power consumption — possibility of using batteries, wireless designs.

*Disadvantages* of LED lamps:

– due to the narrowing of the emission spectrum of the LED in relation to the currently standardized spectrum of halogen lamps, it is possible to increase the requirements for the purity of the photoinitiator (camphorquinone);

– the necessity to replace the battery after 1–1.5 years of operation is a feature of the wireless design;

– relatively high price, constantly decreasing as production technologies improve;

– the emission spectrum of a halogen lamp is slightly wider (400–500 nm) than that of LEDs (460–475 nm).

## PLASMA ARC LAMP (PAC)

The source of radiation in these polymerizers, as a rule, is a powerful xenon lamp, which also emits in a “narrow spectrum”, although not as narrow as LED lamps (hence, the heat generation is also greater) (Fig. 4).

*Fig. 4.* Plasma arc lamp

Due to the high power, polymerization is even faster than LED polymerizers (some researchers report a 10-fold difference, some a two-fold difference).

Another advantage is that most of these emitters have a built-in autocalibrator, which guarantees a constant radiation power.

### LASER LAMP

An argon laser lamp, the active medium of which is argon gas, emits light at two wavelengths (Fig. 5). Blue light at 488 nm is commonly used to initiate the polymerization of reductive composite materials. Blue-green light with a wavelength of 514 nm has a maximum absorption capacity in tissues composed of pigmented molecules such as hemosiderin and melanin. Both wavelengths of the argon laser are poorly absorbed by unpigmented and hard tissues. This laser is often used for Grade 2 composite restorations, bleeding control in gingival surgery, and to detect cracks and decay on the surface of teeth using the transillumination technique.

*Fig. 5.* Laser lamp

*The advantages* of laser lamps are:

- fast curing;
- excellent collimation of light.

*Disadvantages* of laser lamps:

- high cost;
- cannot cure all materials;
- not practical for daily curing of materials.

## MISTAKES WHILE WORKING WITH PHOTOPOLYMERIZING DEVICES

Mistakes while working with photopolymerizing devices can be divided into the following groups:

- errors associated with photopolymerization devices;
- errors associated with the polymerization technique.

Errors in working with photopolymerizing devices can lead to the following complications:

- separation of the filling material from the walls of the tooth cavity and micro-leakage at the filling/tooth interface, resulting from polymerization shrinkage of the material (which can be from 2 to 4 volume percent) as a result, the development of recurrence of caries and its complications;

– an increased content of unreacted composite monomer (the maximum conversion of the composite occurs by 75–80 %), leading to a toxic effect on the dental pulp, periodontal tissues and oral mucosa, as well as to a general allergization of the body;

– patients' complaints about post-filling pains in the tooth arising from debonding and morphological changes in the dental pulp, resulting from a violation of the polymerization technique and under the influence of the infrared thermal component of the light flux (halogen polymerizers);

– deterioration of the mechanical characteristics of the filling material (plasticity, hardness), resulting in a noticeable deterioration in the clinical and aesthetic parameters of the restoration;

– dryness in the oral cavity after prolonged exposure to an activating lamp, for example, when performing large restoration work, when whitening teeth, which is associated with a damaging effect light on the minor salivary glands;

– the presence of ultraviolet and infrared ("parasitic") radiation can lead to the development of conjunctivitis, retinal atrophy, clouding of the lens, burns of the cornea of the patient, the doctor and his assistant, damage to the skin of the hands of the doctor and the assistant holding and guiding the light guide.

*Prevention of polymerization shrinkage* associated with photopolymerization devices (type of photoinitiator, its concentration and wavelength, with polymerization rate) consists in:

1. The use of special polymerization lamps with "soft start" (Soft-start polymerization), in which the intensity of the emitted light is initially very low (100–150 MW/cm$^2$), but gradually increases to values of 700–800 MW/cm$^2$. Lamps that provide prolongation of the pre-gel phase of polymerization can be divided into 3 groups in accordance with the principle used to increase the radiation intensity to the maximum value:

– a rapid increase in intensity (Elipar HighLight — ESPE, Degulux soft-start — Degussa);

– a gradual increase in intensity (Elipar TriLight — ESPE, Astralis 7-Ivoclar/Vivadent);

– extended intensity increase (VIP-Bisco).

2. Transdental light as the first step in the polymerization of the filling. In this case, the intensity of the emitted light after passing through the dental tissue is somewhat weakened. However, in the second step, the filling must always be subjected to direct, radiation of sufficient intensity.

The tension that occurs at the points of contact between the material and the walls of the tooth can be so great that it can lead to undesirable consequences in the form of fracture and white lines, debonding of restorations, microleaks, and postoperative sensitivity.

The factors that contribute to the occurrence of these stresses are:

– the geometry of the cavity, mainly characterized by what is called the "configuration factor", or "C-factor";

– composition of the composite material;

– the percentage of conversion of monomers, that is, more or less complete polymerization reaction;

– what is connected with the previous factor — the method of light irradiation.

## CONFIGURATION FACTOR (C-FACTOR)

The C-factor, which is one of the main stress parameters caused by polymerization, corresponds to the ratio of the number of composite material surfaces bonded to the cavity walls to the number of free surfaces (which are not in contact with the tooth).

If we imagine the volume of the composite as a cube that does not have contact with any surface (all sides are free), fluidity is possible in all directions, there is minimal risk of stress development. In this case, the C-factor is 0. If one of the six sides of the cube has contact with the surface of the object, then five surfaces constitute a free area: the C factor is 0.2. Stress in the contact area is low. If the cube is in contact with the object with two of the six surfaces, the C factor is 0.5 (Fig. 6).

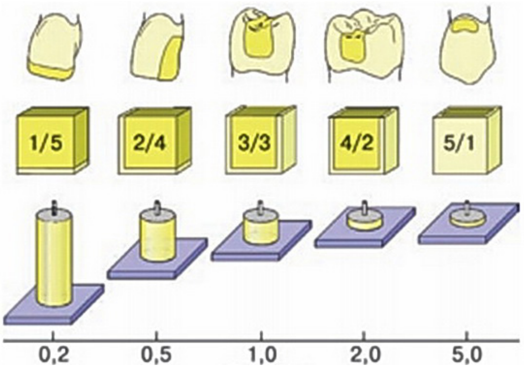

*Fig. 6.* C-factor

In order to reduce the risk of formation of microgaps in cavities where it is impossible (or only to a small extent) to redistribute the resulting stresses by the surrounding tissues — as in Class 1 and V cavities according to Black — it is recommended to use composites that cause low stresses during polymerization or material combination techniques.

# TEST QUESTIONS

**1. The optimal operating power of the light flux is considered to be:**

a) 450 W; b) 750 W; c) 1000 W.

**2. The maximum distance from the light guide of the polymerization lamp to the filling material during polymerization:**

a) 0,5 mm; b) 2 mm; c) 4 mm.

**3. The basis of polymerization is the reaction:**

a) accession; b) decomposition; c) exchange.

**4. Maximum thickness of a traditional photopolymer portion for adequate polymerization:**

a) 0,5 mm; b) 2 mm; c) 4 mm.

**5. The photopolymerization reaction of composite materials occurs with a displacement:**

a) to the center of the filling;
b) to the occlusal surface;
c) to the light source.

**6. In what range can the wavelength be adjusted for halogen, plasma-arc and laser polymerizers:**

a) from 410 to 490 nm;
b) from 510 to 550 nm;
c) from 700 to 800 nm.

**7. Which polymerization mode is characterized by the occurrence of maximum shrinkage:**

a) intermediate;
b) fast cure mode;
c) soft start mode.

**8. Specify the types of polymerization lamps:**

a) halogen lamps;
b) LED laps;
c) plasma arc lamps;
d) laser lamps.

**9. Dental halogen photopolymerization devices consist of the following main components:**

a) power supply;
b) polymerization process control unit;
c) halogen incandescent lamp;
d) selective light filter;
e) light guide;
f) heat removal systems;
g) all of the above.

**10. Indicate the advantages of a halogen lamp:**

a) relatively low cost of device;
b) long term of experience;
c) emit a wide range of light wavelengths.

**11. Compared with other types of curing lamps, the light emitted by light guide is in:**

a) narrow spectrum range;
b) wider range.

**12. The disadvantage of LED curing lamps is:**

a) expensive;
b) cannot cure materials containing non-standard alternative photoinitiators;
c) energy-intensive.

**13. Plasma arc lamps are used for:**

a) curing of composites based on synthetic resins;
b) teeth whitening.

**14. The wavelength in plasma-arc lamps is:**

a) 400–450 nm; b) 400 nm; c) 380–350 nm.

**15. The disadvantages of plasma-arc polymerization lamps are:**

a) large and bulky;
b) weak type of lighting;
c) filtering is required;
d) heat generation requires a fan.

**16. Emission spectrum of LED polymerization lamp:**

a) 400–500 nm; b) 460–475 nm; c) 550 nm.

**17. Emission spectrum of an argon laser lamp:**

a) 488 nm; b) 514 nm; c) 380 nm.

**18. Indicate the cavities according to Black with the highest C-factor:**

a) 1;
b) 2;
c) 3;
d) 4;
e) 5.

**19. To what indicator corresponds C-factor in the 1 class cavities by:**

a) 0,2;
b) 0,5;
c) 1;
d) 2;
e) 5.

**20. The use of polymerization lamps with a “soft start” helps reduce polymerization shrinkage:**

a) no; b) yes.

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