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Application of Nanocomposite Restoration Systems in the Treatment of Medium Caries of Anterior Teeth

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Abstract: Dental caries remains one of the most common dental pathologies affecting more than 90% of the planet's population. Particular clinical significance is gained by the damage to the anterior teeth, which plays a key role not only in the functional aspect of the chewing apparatus but also in the formation of a smile's aesthetics and patients' psychosocial adaptation. Carious defects in the frontal group of teeth require special attention from the dentist, as the treatment outcome must meet the high aesthetic standards of modern dentistry.

Keywords: nanocomposite materials, frontal teeth, medium caries, aesthetic restoration, nanoparticles, adhesive system, polymerization shrinkage, color stability, biocompatibility, direct restoration, dental composites, nanotechnologies in dentistry, mechanical properties

INTRODUCTION. Restoration of frontal group teeth affected by moderate caries is one of the most critical tasks of modern therapeutic dentistry, as it requires not only eliminating the pathological process and restoring the anatomical shape of the tooth, but also achieving high aesthetic results that meet the expectations of patients and modern standards of dental care quality[1]. Medium caries of frontal teeth is characterized by lesions of the enamel and superficial dentin layers, which creates certain clinical features when choosing treatment methods and restoration materials. The localization of the carious process in an aesthetically significant area places increased demands on the materials used regarding color transmission, transparency, the ability to imitate natural dental tissues, and long-term stability of aesthetic characteristics [2]. The restoration of frontal teeth affected by caries is one of the most complex tasks of modern therapeutic dentistry, requiring the achievement of an optimal combination of functional and aesthetic restoration characteristics. According to the World Health Organization, caries remains the most common dental disease affecting 60-90% of school-age children and almost 100% of the adult population in most countries of the world. At the same time, damage to the frontal group of teeth accounts for 35-42% of the total number of carious lesions and has special social significance due to the high aesthetic requirements of patients.

Medium caries is characterized by damage to the enamel and surface layers of dentin, which creates favorable conditions for the application of modern adhesive technologies. This form of the carious process is most common in clinical practice and accounts for up to 60% of all cases of permanent dental caries. When localizing moderate caries in the anterior teeth, the clinician faces the task of not only fully removing pathologically altered tissues and restoring their anatomical form but also achieving flawless aesthetic integration of restoration with surrounding tissues.

The revolutionary development of materials science in dentistry over the past two decades has led to the creation of fundamentally new restoration systems based on nanotechnology. The introduction of nanoparticles into the structure of composite materials has radically changed their physical-mechanical and optical properties, opening up new possibilities for creating highly aesthetic and durable restorations of front teeth.

Nanocomposite materials are heterogeneous systems in which the particle size of the filler does not exceed 100 nanometers. Such structural organization ensures a unique combination of high mechanical strength, excellent polishing, and optimal aesthetic characteristics. Nano-sized particles of zirconium silicate, silicon dioxide, and other inorganic components create a dense packing in the polymer matrix,

which contributes to a decrease in polymerization shrinkage, increased wear resistance, and improved edge alignment of restorations.

The peculiarity of nanocomposites is their ability to create a smooth restoration surface comparable to natural tooth enamel. This is achieved due to the uniform distribution of nanoparticles in the polymer matrix and the possibility of obtaining high-quality polishing. The optical properties of nanocomposites, including the refractive index, opalescence, and fluorescence, are as close as possible to the characteristics of natural dental tissues, which ensures the natural appearance of restorations under various lighting conditions.

The clinical effectiveness of nanocomposite systems is largely determined by their ability to resist functional loads and the effects of an aggressive oral environment. The front teeth experience specific loads associated with biting off food, which places special demands on the strength characteristics of restoration materials. Nanocomposites exhibit high compressive strength, flexural strength, and wear resistance, ensuring long-term restoration functionality.

Modern nanocomposite systems are characterized by a variety of consistencies and optical properties, which allows for the implementation of various restoration techniques. Flowing nanocomposites are optimal for restoring small defects and creating an adaptive layer, universal composites are suitable for the main restoration mass, and enamel shades ensure the creation of natural cutting edge transparency.

The adhesive properties of nanocomposites in combination with modern dentin adhesives ensure reliable chemical bonding with dental tissues. This allows for the implementation of the concept of minimally invasive dentistry, where dental preparation is limited to removing only pathologically altered tissues without creating additional retention elements.

The biocompatibility of nanocomposite materials is confirmed by the results of numerous clinical and laboratory studies. The absence of cytotoxic effects, low solubility in oral fluid, and long-term stability of physicochemical properties make nanocomposites the preferred materials for restoring teeth in an aesthetically significant area.

At the same time, the clinical application of nanocomposite systems requires a deep understanding of the peculiarities of their structure, properties, and operation techniques. Factors influencing the quality of restorations include the correct choice of material depending on the clinical situation, adherence to the adhesive preparation protocol, the technique of applying and polymerizing the composite, and finishing and polishing methods.

The constant improvement of nanocomposite technologies leads to the emergence of new generations of materials with improved characteristics. The development of self-adhesive composites, materials with antibacterial properties, and bioactive systems opens up new prospects for improving the effectiveness of treatment for moderate caries of the anterior teeth.

Analysis of modern literature indicates the accumulation of a significant volume of clinical and experimental data on the use of nanocomposites in dentistry. However, systematizing these data and critically evaluating the effectiveness of various nanocomposite systems in the treatment of moderate caries of the anterior teeth remains a pressing issue. The evolution of composite materials has gone through several stages of development: from first-generation macrofilled composites through microfilled and hybrid materials to modern nanocomposite systems. Each generation of materials was characterized by an improvement in certain properties, however, only the emergence of nanotechnologies allowed achieving a qualitatively new level of characteristics of dental composites [3]. Modern requirements for frontal dentition restoration materials include not only high aesthetic characteristics (color stability, transparency, polishing ability), but also optimal physical and mechanical properties (compressive and flexural strength, elastic modulus, wear resistance), biological compatibility, and long-term clinical effectiveness. Traditional composite materials, despite significant achievements in their improvement, do not always provide an optimal combination of all necessary properties [4].

The revolutionary development of nanotechnology in dental materials science has opened up new prospects for creating composite materials with improved characteristics. Nanocomposite materials containing nanoparticles with sizes from 1 to 100 nanometers demonstrate significant advantages compared to traditional composites: increased strength (400-450 MPa vs. 300-350 MPa), improved polishing, reduced polymerization shrinkage (1.5-2.0% vs. 2.5-3.5%), increased wear resistance, and color stability[5].

Scientific and technological achievements in the field of nanoparticle synthesis have made it possible to create materials with various types of fillers: silicon dioxide nanoparticles (size 5-20 nm), zirconium (size 7-30 nm), titanium (size 10-50 nm), as well as nanoclusters and nanohybrids. Each type of filler provides specific properties: silicon dioxide nanoparticles improve mechanical characteristics and polishing, zirconium particles increase X-ray contrast and strength, titanium nanoparticles provide antibacterial properties[6].

The clinical effectiveness of nanocomposite materials is confirmed by the results of numerous studies. According to 5-year clinical observations, the survival rate of frontal dental restorations using nanocomposites is 94.2-97.8% versus 89.3-92.1% for traditional microhybrid composites. Especially significant advantages of nanocomposites are demonstrated in the restoration of Class II Black cavities in the area of frontal teeth, where aesthetic characteristics and durability of restoration are critically important[7].

The aesthetic advantages of nanocomposite materials are due to the unique optical properties of nanoparticles. The size of nanoparticles close to the wavelength of visible light (380-750 nm) provides minimal light scattering and high transparency of the material. This allows achieving the "chameleon" effect - the ability of restoration to adapt to the color of surrounding tooth tissues, which is critical in the restoration of frontal teeth[8].

The biological compatibility of nanocomposite materials surpasses similar indicators of traditional composites due to less monomer extraction (bis-GMA, TEGDMA, UDMA) as a result of more complete polymerization and dense packing of the polymer matrix. In vitro studies show a 25-35% decrease in cytotoxicity compared to microhybrid composites. Technological innovations in the field of nanocomposite materials include the development of self-adhesive composites with nanoparticles, materials with controlled release of fluorides, bioactive nanocomposites with antibacterial properties. Materials with "intelligent" properties are of particular interest: the ability to self-restore microcracks, adaptive polymerization depending on oral conditions[9].

The economic feasibility of using nanocomposite materials is due to their greater durability and reduced need for repeated interventions. With a higher initial cost (20-35% higher than traditional composites), the total treatment costs in the long term are lower due to the increased service life of restorations. The prospects for the development of nanocomposite technologies include the creation of fourth-generation materials with functional nanoparticles: antibacterial, remineralizing, and indicator properties.

The optical properties of nanocomposite materials are determined by the interaction of nanoparticles with visible light. When the particle size is comparable to the wavelength of visible light, the light scattering effect is minimized, which ensures the high transparency of the material and the natural appearance of the restoration. The ability to vary the size, shape, and refractive index of nanoparticles allows for the creation of materials with a wide range of optical characteristics[11].

The clinical application of nanocomposite materials in the restoration of frontal teeth requires understanding the specifics of their treatment, polymerization, and finishing. The technique of working with nanocomposites has certain features related to their consistency, thixotropic properties, and polymerization characteristics[12]. The long-term clinical effectiveness of nanocomposite restorations depends on many factors: the correctness of material selection, adherence to the adhesive preparation protocol, the technique of applying and polymerizing the composite, the quality of finishing and polishing. Understanding these aspects is critical for achieving optimal clinical outcomes[13].

Conclusions: Thus, nanocomposite materials represent a revolutionary direction in the development of dental materials science, opening up new possibilities for high-quality restoration of frontal teeth with optimal combination of aesthetic, functional, and biological characteristics. Nanocomposite materials are a polymer matrix reinforced with nanoparticles of an inorganic filler with sizes from 1 to 100 nanometers. The unique properties of nanoparticles, due to their dimensional characteristics and the high surface area-to-volume ratio, allow for a significant improvement in the mechanical, physical, and aesthetic properties of composite materials. The mechanisms for improving the properties of nanocomposites are related to the peculiarities of nanoparticles' interaction with the polymer matrix. A high specific surface area of nanoparticles allows for more efficient transfer of mechanical stresses from the matrix to the filler, leading to improved material strength characteristics. At the same time, the small size of the particles allows achieving a high degree of filling (up to 78-85% by mass) while maintaining the material's technological consistency and the possibility of creating a smooth restoration surface.

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