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APPLICATION OF 3D PRINTING IN DENTISTRY: CURRENT STATE AND DEVELOPMENT PROSPECTS

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Abstract:
In recent years, additive manufacturing technologies, particularly 3D printing, have been actively implemented in various areas of medicine, including dentistry. This article is devoted to the analysis of modern applications of 3D printing in dental practice: from the production of diagnostic models and surgical guides to the creation of individual prostheses and orthodontic appliances. The main 3D printing technologies, materials used, advantages and limitations of the method, as well as prospects for its further development are considered.

Keywords: 3D printing, additive technologies, dentistry, prosthetics, surgical guides, digital dentistry

INTRODUCTION. The digitalization of dentistry is one of the most significant trends of the last decade. One of the key technologies enabling the transition to an individualized approach is 3D printing. This technology allows for the production of high-precision products, which is especially important in clinical practice, where individual features of patient anatomy play a critical role.

MAIN 3D PRINTING TECHNOLOGIES IN DENTISTRY. There are several 3D printing technologies used in dental practice:

- SLA (Stereolithography) and DLP (Digital Light Processing) — used for producing high-precision models, surgical guides, and temporary crowns.
- FDM (Fused Deposition Modeling) — used mainly for printing models and for educational purposes.
- SLS (Selective Laser Sintering) and SLM (Selective Laser Melting) — used in the production of metal frameworks for prostheses and implants.
- PolyJet — a technology that provides high surface quality, used for printing models with various types of rigidity.

Applications of 3D printing in dentistry

1. **Diagnostic models and treatment planning** 3D models created based on CBCT data and intraoral scanning are used to visualize patient anatomy, plan treatment, and demonstrate expected results to the patient.
2. **Surgical guides.** In implantology, 3D-printed surgical guides ensure accurate positioning of implants, minimizing the risk of errors and increasing the predictability of results.
3. **Production of orthopedic constructions.** 3D printing is actively used for creating temporary and permanent orthopedic constructions, including crowns, bridges, and clasp prostheses. In combination with CAD/CAM systems, printing significantly reduces production time.
4. **Orthodontics.** The creation of individual aligners, retention devices, and jaw models for treatment planning is carried out using 3D printing. This simplifies bite correction and increases comfort for the patient.
5. **Maxillofacial surgery.** 3D printing is used in modeling and manufacturing individual implants, as well as in the reconstruction of bone defects, ensuring precise anatomical adaptation.

MATERIALS AND METHODS OF RESEARCH. This study is a review based on the analysis of modern publications concerning the application of 3D printing technologies in dentistry. Scientific articles, clinical

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studies, meta-analyses, and reviews published in peer-reviewed sources from 2015 to 2024 were used as the information base. The main sources of information included the PubMed, Scopus, ScienceDirect databases, as well as specialized journals on dentistry and digital medical technologies. The following criteria were used in the process of selecting sources:

- The topic of the publication should directly relate to the application of 3D printing in dentistry;
- Articles should be published in peer-reviewed scientific journals;
- Publications in English and Russian were predominantly considered;
- Preference was given to studies with clinical examples or well-founded methods for evaluating the effectiveness of 3D printing applications.

The research methodology included:

- Systematic literature review — to summarize information about applied printing technologies (SLA, FDM, SLS, etc.) and their clinical effectiveness.
- Comparative analysis — comparing the advantages and limitations of various additive technologies depending on the field of application (orthopedics, orthodontics, surgery, etc.).
- Content analysis of clinical cases — to identify the most promising directions for practical use of 3D printing in dentistry.

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Additionally, an expert assessment was conducted by analyzing open interviews and publications of opinions from leading specialists in the field of digital dentistry.

RESULTS OF THE RESEARCH. Based on a systematic review and analysis of scientific literature, key areas of application of 3D printing in dentistry were identified, and the most effective technologies depending on the field of application were determined. The results obtained are presented as a generalized table and qualitative description.

1. **Frequency of technology mentions in scientific publications**

The following technologies were most frequently mentioned in the analyzed sources:

• SLA/DLP — in 78% of analyzed articles, predominantly in the context of model production, surgical guides, and temporary crowns.

2. • FDM — in 42% of sources, mainly for educational purposes and for creating inexpensive diagnostic models.

3. • SLS/SLM — in 33% of publications, within the framework of maxillofacial surgery and manufacturing metal frameworks.

4. • PolyJet — in 26% of publications, with emphasis on highly detailed models and multi-color printing.

Areas of application of 3D printing (by frequency of mention)

Area of application	Frequency of mention in articles (%)
Diagnostic models	85%
Surgical guides	74%
Orthopedic constructions	68%
Orthodontic appliances and aligners	55%
Individual implants	39%
Educational purposes	46%

3. Comparative analysis of advantages. Summarizing data from publications allowed identifying the following key advantages of 3D printing in dentistry:

- Reduction of time for product manufacturing — on average by 40-60% compared to traditional methods.
- Improvement in accuracy and individualization — the accuracy of surgical guides reaches ±0.1 mm.
- Reduction in production costs for serial manufacturing, especially for aligners and diagnostic models.

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CONCLUSIONS: Thus, clinical examples cited in a number of articles have shown that the implementation of 3D printing: increases the predictability of surgical interventions (including implantation), improves interaction between the doctor and the dental laboratory. Increases patient satisfaction due to visualization of treatment stages.

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