УДК 004.92:61

Абдураззокова Х.А. ассистент
Самаркандский государственный медицинский университет
Узбекистан, Самарканд

Маматкулова У.И. студентка 1 курса
Самаркандский государственный медицинский университет
Узбекистан, Самарканд

Кобилова Н.К. студентка 1 курса
Самаркандский государственный медицинский университет
Узбекистан, Самарканд

Шайманова О.Ш. студентка 1 курса
Самаркандский государственный медицинский университет
Узбекистан, Самарканд

Ахроров Ф.М. студент 1 курса
Самаркандский государственный медицинский университет
Узбекистан, Самарканд

ПРИМЕНЕНИЕ 3D-ТЕХНОЛОГИЙ В МЕДИЦИНЕ

Аннотация. *Трёхмерные технологии связывают медицинские изображения с интерактивной визуализацией, физическими анатомическими моделями и изготавливаемыми изделиями, а их ценность зависит от клинической или образовательной задачи и качества исходных данных. В данном целевом нарративном обзоре на основе первичных исследований и официальных технических рекомендаций рассматриваются отдельные области применения 3D-технологий в медицине: хирургическое планирование, медицинское образование, производство медицинских изделий и биопечать. Отобранные исследования подтверждают улучшение понимания анатомии и изменение планов лечения в сложных случаях; виртуальная реальность может быть полезна при обучении анатомии, хотя её превосходство над традиционным обучением неоднозначно; биопечать демонстрирует экспериментальный прогресс, но не доказывает возможность рутинной замены целых органов человека. Внедрение должно опираться на измеримые результаты, валидированные рабочие процессы, компетентность персонала и реалистичную оценку затрат. 3D-технологии являются ценным дополнением, когда их возможности соответствуют чётко определённой медицинской потребности.*

Ключевые слова: *трёхмерные технологии, медицинская визуализация, 3D-печать, хирургическое планирование, виртуальная реальность, биопечать.*

Abdurazzoqova X.A. assistant
Samarkand State Medical University
Uzbekistan, Samarkand

Mamatqulova U.I. first-year student
Samarkand State Medical University
Uzbekistan, Samarkand

Qobilova N.Q. first-year student
Samarkand State Medical University
Uzbekistan, Samarkand

Shaymanova O.Sh. first-year student
Samarkand State Medical University
Uzbekistan, Samarkand

Axrorov F.M. first-year student
Samarkand State Medical University
Uzbekistan, Samarkand

APPLICATIONS OF 3D TECHNOLOGIES IN MEDICINE

Abstract. *Three-dimensional technologies connect medical images with interactive visualizations, physical anatomical models, and manufactured devices, and their value depends on the clinical or educational task and the quality of the underlying data. This focused narrative review, based on primary research and official technical guidance, examines selected applications of 3D technologies in medicine: surgical planning, medical education, device manufacturing, and bioprinting. Selected studies support improved anatomical understanding and changes in planning for complex cases; virtual reality can provide useful anatomy instruction, although its superiority over conventional teaching is not consistent; bioprinting demonstrates experimental progress without establishing routine replacement of whole human organs. Adoption should be guided by measurable outcomes, validated workflows, staff competence, and realistic cost assessment. 3D technologies are valuable adjuncts when their capabilities are matched to a defined medical need.*

Keywords: *three-dimensional technologies, medical imaging, 3D printing, surgical planning, virtual reality, bioprinting.*

Introduction

Medicine requires clinicians and students to understand structures that extend through three dimensions. Conventional images display this anatomy through sections or projections, which must be mentally integrated. Digital 3D reconstruction offers another way to inspect spatial relationships, while additive manufacturing converts a digital design into a physical object. These approaches address related problems but should not be treated as a single intervention. A screen-based reconstruction, an immersive virtual environment, and a printed surgical model have different requirements and possible uses.

For this review, 3D technologies include anatomical reconstruction from imaging, virtual reality for learning, physical models for planning, and additive manufacturing for medical applications. Bioprinting is considered separately because producing living tissue introduces biological requirements beyond geometric accuracy. The central question is therefore not whether 3D technology is innovative, but whether a particular application improves a defined decision, learning outcome, or manufacturing process.

This article aims to explain representative applications and critically interpret their evidence. It also proposes practical evaluation criteria for hospitals and medical universities considering adoption. The analysis distinguishes published findings from implementation proposals and avoids assuming that better visualization necessarily leads to better patient outcomes.

Materials and Methods

This article uses a focused narrative review design, not a systematic review or an original clinical experiment. Targeted web searches were performed on 15 October 2026 using combinations of “3D printing medical devices,” “3D printed models congenital heart disease,” “virtual reality anatomy randomized trial,” and “3D bioprinting collagen heart.” Primary studies were verified through PubMed

records, publisher material, or institutional repositories. Official US Food and Drug Administration guidance was consulted for manufacturing considerations.

Sources were selected purposively for direct relevance to a representative application and a clearly identifiable publication or issuing organization. The core evidence comprises a multicentre surgical-planning study, a randomized anatomy-education trial, experimental bioprinting research, and official manufacturing guidance [1–4]. No claim is made that these sources exhaust the literature or represent all specialties. Commercial promotional claims were not used as evidence of effectiveness.

The synthesis compared intended use, study design, reported outcome, and limits on interpretation. Clinical decision changes, examination performance, technical feasibility, and regulatory guidance were treated as distinct forms of evidence. No pooled effect estimate, formal risk-of-bias score, or statistical reanalysis was produced. The article uses published information only; it reports no newly recruited participants, patient records, or experimental measurements.

Results

Anatomical models and surgical planning

Valverde and colleagues studied 40 patients with complex congenital heart disease across ten international centres. Their prospective case-crossover study compared decisions based on routine images with decisions after inspection of printed anatomical models. The models changed the surgical decision in 19 cases; in the other 21, the decision remained unchanged [1]. This finding supports a role in selected anatomically difficult cases, but it does not demonstrate that printing is necessary for every patient or that a changed plan automatically improves long-term outcomes.

The reported agreement between model and imaging measurements indicates that physical representations can reproduce relevant geometry within the tested workflow [1]. However, a model remains an interpretation of its source

images. Its usefulness should be judged against the question that prompted its creation: for example, whether a spatial relationship is difficult to understand or whether alternative approaches need discussion. Visual realism alone is an insufficient acceptance criterion.

A practical implication is that model requests should specify a clinical question before production. The requesting team can then document whether the finished model clarified that question, altered a plan, or added no useful information. Such documentation would make local evaluation more informative than collecting satisfaction scores alone.

Synthesis of findings

Across the selected sources, evidence supports specific uses more clearly than universal claims. Surgical planning research addresses decisions in complex cases, educational trials address learning tasks, and bioprinting experiments address technical or biological feasibility. These outcomes cannot be combined into a single estimate of "3D effectiveness." Each application requires its own comparator and success criteria.

Discussion

The main implication of this review is that implementation should begin with a problem definition. A hospital might seek better discussion of difficult anatomy, while a university might need reusable resources for spatial learning. These goals require different investments and evaluation methods. Purchasing equipment before defining the goal risks producing attractive models without demonstrating meaningful benefit.

A phased approach is proposed. An institution could first test a limited set of teaching or planning applications, assign a multidisciplinary team, and record production time, failed outputs, user feedback, and objective outcomes. Educational evaluation should compare equivalent teaching time and examine knowledge retention. Clinical evaluation should distinguish a changed decision

from a better outcome and, where feasible, compare similar cases managed with and without the additional technology.

Conclusion

3D technologies can support anatomical understanding, selected surgical decisions, and medical education. Their adoption should be proportional to the evidence for each use. Validated production, purposeful teaching design, and measurable outcomes provide a more credible basis for implementation than novelty alone. Bioprinting should be discussed according to demonstrated experimental capabilities, with clear separation from claims of routine organ replacement.

Использованные источники / References

1. Valverde I., Gomez-Ciriza G., Hussain T., et al. Three-dimensional printed models for surgical planning of complex congenital heart defects: an international multicentre study // European Journal of Cardio-Thoracic Surgery. 2017. Vol. 52, No. 6. P. 1139–1148. DOI: 10.1093/ejcts/ezx208.
2. Koucheki R., Lex J.R., Morozova A., et al. Immersive virtual reality and cadaveric bone are equally effective in skeletal anatomy education: a randomized crossover noninferiority trial // Journal of Surgical Education. 2023. Vol. 80, No. 7. P. 1028–1038. DOI: 10.1016/j.jsurg.2023.04.005.
3. U.S. Food and Drug Administration. Technical Considerations for Additive Manufactured Medical Devices: Guidance for Industry and Food and Drug Administration Staff. Silver Spring, MD: FDA, 2017. URL: https://www.fda.gov/media/97633/download
4. Lee A., Hudson A.R., Shiwarski D.J., et al. 3D bioprinting of collagen to rebuild components of the human heart // Science. 2019. Vol. 365, No. 6452. P. 482–487. DOI: 10.1126/science.aav9051.