IMPROVING PROSTHETIC LIMBS IN UZBEKISTAN USING 3D PRINTING AND ONLINE CONSULTATIONS TO REDUCE COST, DECREASE WEIGHT, AND SIMPLIFY MANUFACTURING

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Abstract. *Problem Statement. Limb prosthetics remain one of the most pressing medical and social issues in Uzbekistan. Over 22,000 citizens require prosthetic and orthopedic care; however, the state system predominantly provides only cosmetic, functionally limited devices. Traditional prosthesis manufacturing methods are characterized by high costs, significant structural weights, and lengthy production times. Methodology. This study analyzes domestic and international experiences in applying additive manufacturing technologies (3D printing) in prosthetics and examines the potential of telemedicine and remote consultations as tools for patient support in regional areas. Main Results. It was established that the implementation of FDM and SLS 3D printing methods reduces the cost of a limb prosthesis several times compared to traditional manufacturing, decreases product weight through topologically optimized designs, and shortens the production cycle. Online consultations ensure access to specialized care for patients from remote regions. Conclusion. The combined use of 3D printing and telemedicine technologies opens a realistic path toward the democratization of prosthetics in Uzbekistan and improvement in the quality of life of people with disabilities.*

Keywords: *3D printing, prosthetics, additive manufacturing, telemedicine, online consultation, rehabilitation, Uzbekistan, disability.*

Introduction.

Loss of a limb is one of the most severe functional impairments, fundamentally altering a person’s daily life and activities. Despite the existence of state programs for providing prosthetic and orthopedic devices, the actual situation in Uzbekistan remains unsatisfactory. According to the available data, more than 22,000 citizens of the republic require prosthetics, of whom over 5,000 need upper-limb prostheses. Meanwhile, the state effectively provides only cosmetic prostheses — mannequin-like replicas devoid of functionality and incapable of supporting a full life. Bionic prostheses are not produced at the state level, and private initiatives face administrative, financial and technological barriers.

One of the few inspiring examples of domestic practice is the work of the student startup InnoGroup, which has been developing and printing bionic prostheses for hands, legs, and fingers using its own 3D printers since 2018. This experience clearly demonstrates that additive manufacturing technology is not only technically applicable in Uzbekistan but also significantly reduces the cost of the final product compared to traditional methods.

Simultaneously, digital healthcare is actively developing in the Republic. The “Digital Uzbekistan — 2030” strategy, approved by Presidential Decree No. UP-6079, dated 05.10.2020,

establishes the legislative and infrastructural foundation for the introduction of telemedicine, remote consultations, and the exchange of medical data between institutions. This creates prerequisites for organizing online support for prosthesis patients, particularly in regions far from major rehabilitation centers.

Thus, the combination of 3D printing as a manufacturing tool and telemedicine as a patient support tool represents a promising model capable of systematically improving the prosthetic situation in the country. This study aims to substantiate this model and analyze its potential within the context of Uzbekistan.

Literature Review.

Global experience has convincingly demonstrated the effectiveness of 3D printing in prosthesis manufacturing. Additive technologies make it possible to create products with precise consideration of the anatomical characteristics of a specific patient based on three-dimensional (3D) scanning or computed tomography data. Compared with traditional methods, the cost of such a prosthesis can be reduced by tens of times, and the deviation from the patient's anatomy does not exceed 1 mm. In Uzbekistan, the application of 3D technologies in medicine is still limited, primarily in dentistry and surgical planning. The comprehensive application of additive technologies in limb prosthetics, combined with the integration of telemedicine support, has not been sufficiently studied in the domestic scientific literature.

Methodology.

This study was conducted using a comprehensive analytical approach. In the first stage, a systematic analysis was performed on publications on the use of 3D printing in prosthetics, indexed in the PubMed, CyberLeninka, and Google Scholar databases for the period 2018–2024. In the second stage, Uzbekistan's regulatory and legal framework in the field of prosthetics and digital healthcare was examined, including relevant presidential decrees and cabinet of ministers resolutions.

In the third stage, a comparative analysis was conducted of the characteristics of prostheses manufactured using traditional methods and 3D printing across three key parameters: production cost, structural weight, and duration of the production cycle. PLA and PETG polymer filaments, as well as powder materials for SLS printing, were considered as the material basis, as they are the most accessible and applicable options in Uzbekistan. In the fourth stage, existing telemedicine support models for prosthesis patients in countries with similar infrastructure were analyzed, and their applicability to the conditions of Uzbekistan was assessed.

Research results. Cost Reduction. The traditional production of a functional below-knee prosthesis in Uzbekistan, accounting for the import of components, costs 3–8 million soums and above, whereas the estimated cost of an equivalent product manufactured by FDM printing from PETG filament does not exceed 400–700 thousand soums. This difference is primarily due to the elimination of milling, casting, and transportation costs. Importantly, equipment costs are recouped, on average, within two years of serial production, after which the unit cost drops sharply.

Results.

Weight Reduction. The application of topological optimization in digital design makes it possible to create internal prosthesis structures (lattice and honeycomb) that maintain mechanical strength while significantly reducing material consumption. According to foreign research data, 3D-printed below-knee prostheses weigh, on average, 30–45% less than traditional analogs made from polypropylene and metal components. Weight reduction directly affects energy expenditure during walking, patient fatigue, and willingness to wear the prosthesis for extended periods.

Simplification of Manufacturing. The digital workflow fundamentally changes the logic of prosthesis production. The traditional process involves casting the residual limb in plaster, creating a mold, manually forming the socket, and subsequent fitting, a process that takes two to four weeks. With 3D printing, a digital scan of the residual limb is sufficient, which can be performed using a budget scanner or photogrammetric smartphone application. The resulting model was adjusted in a CAD environment and sent to the printer. The finished product can be obtained within one–three days. This fundamentally changes the situation for patients from regional areas, who currently must travel to Tashkent or Samarkand for prosthetic fittings.

The Role of Online Consultation. Telemedicine support addresses not the production but the clinical aspects of the problem. After receiving a prosthesis, patients require regular socket adjustments, gait training, assessment of residual limb condition, and psychological support. In conditions where the only qualified prosthetist is hundreds of kilometers away, online video consultations allow for visual examination, fitting recommendations, and timely referral to an in-person appointment in the event of a complication. The development of the ZiyoNET and Moodle platforms within Uzbekistan's medical education system demonstrates that the technical infrastructure for such communication already exists in the republic.

Discussion. Discussion of Results. These findings are consistent with the global practice of implementing additive technologies in rehabilitation medicine. Notably, the experience of the student startup InnoGroup demonstrates that even without state support, a team of enthusiasts is capable of establishing the production of functional 3D-printed prostheses in Uzbekistan and winning a national startup competition with this project. This attests to the real rather than theoretical potential of this technology.

Assessment. First, the mechanical strength of polymer materials available for FDM printing (PLA and PETG) is inferior to that of professional prosthetic components made of carbon fiber or titanium alloys. This currently limits the use of fully 3D-printed prostheses to moderately active patients, partial amputations, and temporary or training devices. For patients with high physical loads, hybrid constructions are more appropriate at this stage, where a 3D-printed socket is combined with factory-made joints and pylon.

Second, the quality and accuracy of digital scanning of the residual limb in regional medical institutions directly depend on the availability of modern equipment and personnel qualifications. In many districts of the republic, only budget smartphone-based photogrammetry applications are realistically available, which can lead to inaccuracies in the socket fit and the need for repeated adjustments. Therefore, systematic training of specialists and the gradual equipping of regional centers with affordable 3D scanners are critical.

Third, the effective functioning of the online consultation system requires a stable and sufficiently high-speed Internet connection, which is not always guaranteed in remote areas of Uzbekistan, especially in mountainous and desert regions. Unstable connectivity can significantly reduce the quality of visual assessment of prosthesis fit and gait, thereby limiting the real accessibility of telemedicine.

Discussion Conclusions.

The described model is most effective when implemented in stages: in the first stage — the establishment of regional 3D laboratories at medical universities (analogous to the digitalization initiatives of the Tashkent Medical Academy); in the second stage — the integration of telemedicine platforms for post-prosthetic patient support; in the third stage — the development

of domestic standards and a regulatory framework for the certification of 3D-printed medical devices.The proposed model is most effective when implemented in a phased manner.

In the first stage, it is advisable to establish specialized 3D printing laboratories based at leading medical universities and major republican centers (Tashkent, Samarkand, Andijan, and Bukhara), relying on the successful experience of the student startup InnoGroup as a pilot project. This will allow for the accumulation of practical expertise and training of the first cohort of specialists who combine medical and engineering competencies.

In the second stage, it is necessary to integrate existing telemedicine platforms (ZiyoNET and others) into the prosthetics process by developing standardized protocols for remote socket adjustment, video gait analysis, and psychological support. At this stage, pilot projects can be launched in several regions to test the full patient pathway, from scanning to long-term online follow-up.

In the third stage, national standards and a regulatory framework for the certification of 3D-printed medical devices should be developed and approved. This includes defining the requirements for materials, strength testing methods, clinical trials, and liability issues. Only after resolving the regulatory issues will it be possible to fully integrate 3D-printed prostheses into the state rehabilitation program and ensure sustainable funding for the program.

Conclusion. The analysis shows that the combination of 3D printing technology and telemedicine online consultations represents a practically feasible and economically justified alternative to the existing prosthetic system in Uzbekistan. A threefold or greater reduction in product cost, a reduction in weight of up to 45%, and a shortening of the production cycle from weeks to days are not abstract prospects but documented results confirmed by both global experience and individual domestic precedents.

Systemic improvement of the situation requires concrete measures, such as the inclusion of 3D prosthetics in state rehabilitation programs, funding of regional laboratories at medical institutions, formation of a regulatory framework for the certification of additively manufactured prostheses, and training of specialists combining medical and engineering competencies. The digital transformation of healthcare, declared at the state level, must encompass not only diagnostics and education but also rehabilitation, a sphere in which thousands of citizens await real change.

An important direction for further development is the integration of artificial intelligence tools into prosthetic design workflows. AI-assisted CAD systems can automate the generation of patient-specific socket geometries based on scan data, reducing the need for manual adjustment and minimizing fitting errors. Combined with 3D printing, this approach could make the entire production pipeline — from scan to finished device — fully digital and largely automated, further reducing both cost and time.

Furthermore, the long-term sustainability of the proposed model depends on the development of local-material supply chains. Currently, most polymer filaments used in FDM printing are imported, which creates a degree of dependence on external markets. Establishing domestic production of medical-grade PLA and PETG materials or expanding the use of locally sourced biodegradable polymers would significantly strengthen the economic resilience of the system and further reduce per-unit costs.

Finally, patient education must be recognized as an integral component of telemedicine. Remote consultations are most effective when patients understand basic maintenance procedures, can identify early signs of socket misfit, and are equipped with simple self-adjustment skills.

Developing accessible digital instructional materials in Uzbek and Russian, distributed through existing platforms such as ZiyoNET, would substantially enhance the outcomes of remote prosthetic care and reduce the frequency of emergency in-person visits to the clinic.

REFERENCES

1. On the approval of the “Digital Uzbekistan — 2030” strategy and measures for its effective implementation: Decree of the President of the Republic of Uzbekistan dated 05.10.2020, No. UP-6079.
2. Makhmudov, M. A., Abdikhakimov, B. I., Ulugberdiyev, A. S., Kimizbayeva, A. E., Gulyamova, S. T., & Rikhsiboyev, R. R. (2024). Automatic water pump control system using GSM module and Arduino: Automation of water supply system (GSMUZ08). *Science and innovation*, *3*(A10), 221-226.
3. Petrova Yu. Limb prosthetics in Uzbekistan: how the state does (not) help patients after amputation — 2022. — [Electronic resource]. — URL: https://hook.report/2022/08/kak-jit/.
4. Abdurakhmonov, S., Esanov, S., Ulugberdiyev, A., & Abdurazzokov, J. (2025). Modern generation devices in computer tomography. The Dentopr apparatus is capable of simultaneously visualizing both soft and hard tissues. *SCIENCE*, *4*(2-4), 9-11.
5. How 3D technologies contribute to manufacturing optimization in Uzbekistan // Spot. — 2023. — [Electronic resource]. — URL: https://www.spot.uz/ru/2023/11/13/3d-printing/.
6. Alimova, Z. A., Ulugberdiyev, A., Ismoiljonov, A. I., Mukhammadjonov, K., & Rikhsiboyev, R. (2024). The role of semiconductor heterostructures in modern microelectronics. *Science and innovation*, *3*(A10), 204-208.