DOI: https://doi.org/10.17816/dent634166

Socioeconomic assessment of investments in dental anthropomorphic robots for practical training of dentistry students

Oleg A. Tsarevskiy[1], Dmitriy I. Grachev[2], Alexander A. Uzhakov[3], Nataliya B. Astashina[4], Kamalutdin G. Akhmedov[2], Sergey A. Arutyunov[2]

[1] Bauman Moscow State Technical University, Moscow, Russia;
[2] Russian University of Medicine, Moscow, Russia;
[3] Perm National Research Polytechnic University, Perm, Russia;
[4] Academician Ye.A. Vagner Perm State Medical University, Perm, Russia

ABSTRACT

BACKGROUND: Robotics is a rapidly evolving area, especially in medical education, where robots improve the results of training and professional qualification of physicians. Dental anthropomorphic robot (DARs) are valuable tools that assist dentistry students in acquiring practical skills, expanding theoretical knowledge, and improving nonverbal communication skills. Given the current practical training issues, the use of such robots becomes increasingly relevant. However, high production and implementation costs require a detailed economic evaluation to assess the practicality of such devices.

AIM: To perform a socioeconomic assessment of investments in DARs for practical training of dentistry students.

MATERIALS AND METHODS: A socioeconomic assessment of the use of DARs for practical training of dentistry students at a medical college was performed. The assessment focused on the cost-benefit analysis of implementing DARs for practical training. Cost-effectiveness was assessed using the net present value (NPV), profitability index (PI), internal rate of return (IRR), and payoff period. The data were acquired from the Dentistry training program of the Russian University of Medicine. The data included training costs, robot purchase and maintenance costs, and organization of studies.

RESULTS: The use of one robot per 10 students results in a positive NPV of 54,279,963 rubles, with a PI of 5.52, an IRR of 70.79%, and a payoff period of approximately one and two years, respectively. These findings confirm the economic efficiency of the project. When using one robot per one student, the values are negative, indicating the economic inefficiency of this scenario.

CONCLUSION: The study showed that the use of DARs for practical training of dentistry students results in a high economic efficiency. High NPV, PI, and IRR values confirm the profitability of the project. Moreover, the robot improves practical skills by increasing the accuracy and speed of dental procedures.

Keywords: dental anthropomorphic robot; educational technology; practical training; robotics in medicine; dentistry education; economic efficiency.

To cite this article:
Tsarevskiy OA, Grachev DI, Uzhakov AA, Astashina NB, Akhmedov KG, Arutyunov SA. Socioeconomic assessment of investments in dental anthropomorphic robots for practical training of dentistry students. *Russian Journal of Dentistry.* 2024;28(6):634–641. DOI: https://doi.org/10.17816/dent634166

Received: 09.07.2024 **Accepted:** 23.10.2024 **Published online:** 28.11.2024

DOI: https://doi.org/10.17816/dent634166

Социально-экономическая оценка инвестиций в использование антропоморфного стоматологического робота-пациента для практико-ориентированной подготовки студентов-стоматологов

О.А. Царевский[1], Д.И. Грачев[2], А.А. Южаков[3], Н.Б. Асташина[4], К.Г. Ахмедов[2], С.А. Арутюнов[2]

[1] Московский государственный технический университет имени Н.Э. Баумана (национальный исследовательский университет), Москва, Россия;
[2] Российский университет медицины, Москва, Россия;
[3] Пермский национальный исследовательский политехнический университет, Пермь, Россия;
[4] Пермский государственный медицинский университет имени академика Е.А. Вагнера, Пермь, Россия

АННОТАЦИЯ

Обоснование. В настоящее время стремительно развивается робототехника, особенно в области медицинского образования, где внедрение роботов способствует улучшению результатов учебных процессов и повышению уровня подготовки специалистов. Антропоморфные стоматологические роботы (АСР) представляют собой эффективные инструменты, которые помогают студентам-стоматологам приобретать практические навыки, углублять теоретические знания и развивать невербальные коммуникативные навыки. В условиях существующих проблем практико-ориентированной подготовки использование таких роботов становится актуальной задачей. Однако высокие затраты на производство и внедрение подобных устройств требуют тщательной экономической оценки целесообразности их использования.

Цель исследования — экономическая оценка инвестиций в использование АСР для практико-ориентированной подготовки студентов-стоматологов.

Материалы и методы. Проведена экономическая оценка использования АСР для практико-ориентированной подготовки студентов-стоматологов на базе медицинского вуза. Основное внимание уделялось анализу затрат и выгод от внедрения АСР в образовательный процесс. Для оценки экономической эффективности использовали показатели чистой приведённой стоимости (net present value, NPV), индекса рентабельности (profitability index, PI), внутренней нормы доходности (internal rate of return, IRR) и сроков окупаемости. Данные были собраны из программы обучения «Стоматология» в Российском университете медицины и включали стоимость обучения, затраты на робота и его обслуживание, а также организацию учебного процесса.

Результаты. Использование одного робота на 10 студентов обеспечивает положительную NPV в размере 54 279 963 руб., PI при этом равен 5,52, IRR составляет 70,79%, а сроки окупаемости — около одного года и двух лет соответственно. Эти показатели подтверждают экономическую рентабельность проекта. Для сценария с одним студентом на робота показатели отрицательные, что указывает на экономическую нецелесообразность такого подхода.

Заключение. Проведённое исследование показало, что использование АСР для подготовки студентов-стоматологов обеспечивает хорошую экономическую эффективность. Высокие значения NPV, PI и IRR подтверждают рентабельность проекта. Кроме того, робот способствует улучшению практических навыков студентов, включая повышение точности и скорости выполнения стоматологических манипуляций.

Ключевые слова: антропоморфный стоматологический робот; образовательные технологии; практико-ориентированная подготовка; робототехника в медицине; стоматологическое образование; экономическая рентабельность.

Как цитировать:
Царевский О.А., Грачев Д.И., Южаков А.А., Асташина Н.Б., Ахмедов К.Г., Арутюнов С.А. Социально-экономическая оценка инвестиций в использование антропоморфного стоматологического робота-пациента для практико-ориентированной подготовки студентов-стоматологов // Российский стоматологический журнал. 2024. Т. 28, № 6. С. 634–641. DOI: https://doi.org/10.17816/dent634166

Рукопись получена: 09.07.2024 **Рукопись одобрена:** 23.10.2024 **Опубликована online:** 28.11.2024

INTRODUCTION

In recent years, the robotics industry has been experiencing rapid growth, including in the field of medical education. This trend reflects a drive to optimize training processes and enhance the quality of professional education [1]. Advanced technologies, including artificial intelligence and high-precision mechanisms, facilitate the integration of robots into the training of future healthcare professionals [2]. Robots have proven to be effective in dental education, helping students practice clinical skills, deepen theoretical knowledge, and improve nonverbal communication, an essential component of successful clinical practice [3, 4].

Modern technological solutions have enabled the development of training systems that promote comprehensive skill development, addressing the limitations of current practice-based education in both undergraduate and postgraduate medical institutions [5]. Conventional dental simulators, which are static mannequins, fail to replicate a real-world clinical setting and do not offer immersive patient care experiences [6, 7]. This limitation contributes to a gap between theoretical instruction and clinical proficiency. In contrast, educational robots capable of simulating patient behavior and offering interactive feedback enhance engagement and support deeper learning [8, 9] (Fig. 1).

Given the high cost of developing and implementing such high-tech devices, a detailed economic evaluation is warranted. This allows institutions to assess the feasibility and potential benefits of adopting these tools and their impact on educational outcomes. The present study examines a case of practice-based training using Russian full-function dental anthropomorphic robots (DARs) [10–14].

Fig. 1. Dental anthropomorphic robot.

AIM: To evaluate the economic feasibility of investing in DARs for practice-based training of dentistry students.

METHODS

Case Model

This study assessed the economic feasibility of incorporating DARs into the clinical training curriculum of a medical university. The analysis focused on evaluating the costs and benefits of integrating DARs into the educational process to enhance student motivation, training quality, and the level of dental care.

Training Parameters and Costs

The primary parameter used to evaluate cost-effectiveness was the tuition cost per student, which serves as a proxy for assessing the financial efficiency of implementing DARs. The tuition fee for the Dentistry program at the Russian University of Medicine is 500,000 rubles per year for a five-year curriculum, equivalent to 1,100 hours annually. This results in an hourly training cost of 455 rubles.

To assess implementation costs, the capital expense of a single DAR and its annual maintenance were analyzed. The robot, designed to substantially improve students' clinical competencies, costs 12,000,000 rubles. Annual maintenance was estimated at 10% of the robot's cost (1,200,000 rubles), based on reference data for high-tech equipment servicing [15].

A 12-year lifespan was adopted for long-term analysis of the costs and benefits associated with DAR implementation.

Training Process

For the economic analysis, it was assumed that students would train with the robot Monday through Friday, from 9:00 AM to 9:00 PM, totaling 12 hours per day, or 2,880 hours annually. Two educational models were considered: group training involving 10 students supervised by an instructor and one-on-one training sessions (Fig. 2).

Economic Indicators

To assess the cost-effectiveness of using the robot, the following financial metrics were applied:

Net present value (NPV): This metric represents the difference between the present value of projected cash flows and the total investment and maintenance costs. A positive NPV indicates that the project generates more value than it costs and is therefore considered profitable. A negative NPV suggests a financially unviable project. The NPV was calculated using the following formula:

$$\text{NPV} = \sum_{1}^{n} \frac{P}{(1+R)^n} - I - \sum_{1}^{n} \frac{C}{(1+R)^n},$$

where P is the cash flow, R is the discount rate, n is the time period, I is the initial investment, and C is the maintenance cost.

Profitability index (PI), also known as the benefit-cost ratio, serves as a supplement to NPV, offering insight into the efficiency of the investment. PI is expressed as a ratio of the present value of future cash flows to the initial investment.

Based on the PI value, the project's feasibility can be interpreted as follows:

- PI > 1: the project is considered profitable and viable for implementation;
- PI = 1: the project requires further evaluation using additional efficiency metrics to determine feasibility;
- PI < 1: the project is deemed unprofitable and should not be pursued.

The PI was calculated using the following formula:

$$\text{PI} = 1 + \frac{\text{NPV}}{\text{IC}},$$

where NPV is the net present value, and IC is the initial investment.

Discount rate (R) was set to match the risk-free rate of Russian government bonds in 2023, which was 15.09%.

Internal rate of return (IRR) is the discount rate at which the NPV of future cash flows equals the initial investment, indicating the breakeven point.

The IRR was calculated using the following formula:

$$\sum_{1}^{n} \frac{P}{(1+\text{IRR})^n} - I = 0, \text{ или } \sum_{1}^{n} \frac{P}{(1+\text{IRR})^n} = I,$$

where P is the cash flow, n is the time period, and I is the initial investment.

The payback period (PP) was calculated using the following formula:

$$\text{PP} = \frac{\text{IC}}{P},$$

where IC is the initial investment, and P is the annual cash flow.

The discounted payback period (DPP) was calculated using the following formula:

$$\text{DPP}=\min(n), \quad \sum_{1}^{n} \frac{P}{(1+R)^n} \geq I,$$

where P is the cash flow, R is the discount rate, and I is the investment.

RESULTS

The economic evaluation of investments in the use of DARs for practice-based training of dental students is presented in Table 1.

Based on the reported economic indicators, the following conclusions can be drawn about the profitability of investing in DARs for practice-based training of dental students:

Fig. 2. Clinical training using a dental anthropomorphic robot.

1) NPV = 54,279,963 rubles;
2) PI = 5.52;
3) IRR = 70.79%;
4) PP = 1 year; DPP = 2 years.

DISCUSSION

Our findings indicate that investments in DARs for practice-based training of dentistry students are highly cost-effective. The project demonstrated a substantial positive NPV, a high PI, and an IRR significantly above typical discount rates, all coupled with a short payback period. These results validate the economic feasibility and attractiveness of the investment.

For the scenario involving one robot per 10 students, the NPV was 54,279,963 rubles. This positive value confirms that the project generates income exceeding both the initial and ongoing costs, underlining its profitability. This outcome can be attributed to efficient time utilization, as the robot ensures continuous training and access to hands-on skill development.

The PI of 5.52 implies that for every ruble invested, the project returns 5.52 rubles of discounted income. A PI > 1 affirms the financial benefit and rationality of the investment, reflecting its strong return, investor appeal, resilience to economic fluctuations, and optimal allocation of educational resources.

An IRR of 70.79% substantially exceeds standard discount rates, underscoring the project's robustness and ability to generate stable cash flow even amid potential economic instability. This also explains the rapid investment recovery (PP≈1 year, DPP=2 years).

Although current sources lack direct data on the economic efficiency of anthropomorphic robots in medical education, trends in the robotics economy suggest significant potential. For example, Arduengo et al. [14] note that robotics adoption enhances productivity and reduces labor costs associated with routine tasks. Similar transitions have been observed in various economic sectors, where automation has minimized labor costs and reallocated human resources to more skilled roles.

These principles can be extrapolated to education, where DARs can lessen instructor workload and improve cost efficiency by optimizing the teaching process.

A systematic review by Turchetti et al. showed that robotic systems such as the da Vinci surgical robot entail high acquisition and maintenance costs, rendering robotic procedures more expensive than traditional methods. However, as users gain experience, procedure times and costs tend to decrease [15]. Therefore, despite high upfront investment, long-term benefits from automation in precision-demanding environments can outweigh the initial costs, a notion applicable to medical education.

Ghani et al. explored various facets of using robots in education, highlighting both advantages and limitations. They concluded that, despite the optimization potential, constraints in social interaction and adaptive response to individual learners may limit the effectiveness of robotic systems. This underscores the need for careful integration of robotics in educational settings, especially in disciplines requiring interpersonal engagement [16].

Hence, the economic potential of using robots in education should be considered alongside their advantages and limitations, particularly in medical education.

Study limitations. This study used data from a single institution, the Russian University of Medicine, which may limit the applicability of the findings to other medical schools with different infrastructures and resources. Further research across multiple institutions is necessary to validate these findings.

Parameters such as robot maintenance costs and service life were estimated, which may impact the long-term economic feasibility. Future studies should consider cost fluctuations and develop scenarios under various economic conditions.

While standard financial indicators (NPV, PI, IRR, PP, DPP) are widely accepted for investment evaluation, they may not fully capture the educational value and long-term benefits, such as improved training quality and enhanced clinical competencies.

This analysis focused on a mid-term horizon (up to 12 years). Future research should also assess the long-term effects of robotic integration on students' professional growth.

Table 1. Economic evaluation of investment in a dental anthropomorphic robot

Indicator	1 robot per 10 students	1 robot per student
Net present value	54,279,963 rubles	59,403,855 rubles
Profitability index	5.52	0.22
Internal rate of return	70.79%	–4.24%
Payback period	1 year	9 years
Discounted payback period	2 years	12 years

CONCLUSION

The study confirms the high economic and educational efficiency of using DARs in the training of dental students. The project demonstrates favorable financial metrics, including a positive NPV and high PI and IRR values, indicating its profitability. Additionally, robotic use enhances practical skills such as procedural accuracy and speed, as reflected in student assessments and instructor feedback.

ADDITIONAL INFORMATION

Funding sources: This study was supported by the Perm Scientific and Educational Center "Rational Subsoil Use" (project "New Materials and Technologies for Medicine", 2024).

Disclosure of interests: The authors declare no explicit or potential conflicts of interests associated with the publication of this article.

Author contributions: All authors confirm that their authorship meets the international ICMJE criteria (all authors made substantial contributions to the conceptualization, investigation, and manuscript preparation, and reviewed and approved the final version prior to publication). The authors made the following contributions: O.A. Tsarevskiy: economic assessment, data collection and analysis, writing; S.A. Arutyunov: economic analysis, editing; D.I. Grachev: review, conceptualization, writing; N.B. Astashina: published data collection and analysis, writing; K.G. Akhmedov: data analysis, writing; A.A. Uzhakov: technical assessment, writing and editing.

REFERENCES

1. Bano S, Atif K, Mehdi SA. Systematic review: Potential effectiveness of educational robotics for 21st century skills development in young learners. *Education and Information Technologies*. 2024;29:11135–11153. doi: 10.1007/s10639-023-12233-2

2. Stasevych M, Zvarych V. Innovative robotic technologies and artificial intelligence in pharmacy and medicine: paving the way for the future of health care — a review. *Big Data and Cognitive Computing*. 2023;7(3):147. doi: 10.3390/bdcc7030147

3. Ahmad P, Alam MK, Aldajani A, et al. Dental robotics: a disruptive technology. *Sensors (Basel)*. 2021;21(10):3308. doi: 10.3390/s21103308

4. Bernauer SA, Zitzmann NU, Joda T. The use and performance of artificial intelligence in prosthodontics: a systematic review. *Sensors (Basel)*. 2021;21(19):6628. doi: 10.3390/s21196628

5. Battista A. An activity theory perspective of how scenario-based simulations support learning: a descriptive analysis. *Adv Simul (Lond)*. 2017;2:23. doi: 10.1186/s41077-017-0055-0

6. Isaksson J, Krabbe J, Ramklint M. Medical students' experiences of working with simulated patients in challenging communication training. *Adv Simul (Lond)*. 2022;7(1):32. doi: 10.1186/s41077-022-00230-3

7. Koolivand H, Shooreshi MM, Safari-Faramani R, et al. Comparison of the effectiveness of virtual reality-based education and conventional teaching methods in dental education: a systematic review. *BMC Med Educ*. 2024;24(1):8. doi: 10.1186/s12909-023-04954-2

8. Thurzo A, Strunga M, Urban R, et al. Impact of artificial intelligence on dental education: a review and guide for curriculum update. *Educ Sci*. 2023;13(2):150. doi: 10.3390/educsci13020150

9. Wang K, Sang GY, Huang LZ, et al. The effectiveness of educational robots in improving learning outcomes: a meta-analysis. *Sustainability*. 2023;15(5):4637. doi: 10.3390/su15054637

10. Astashina NB, Baidarov AA, Arutyunov SD, et al. Development of the "Anthropomorphic dental robot" complex with elements of artificial intelligence to simulate medical manipulations and doctor-patient communication. *Perm Medical Journal*. 2022;39(6):62–70. EDN: CNJATY doi: 10.17816/pmj39662-70

11. Arutyunov SD, Yuzhakov AA, Kharakh YaN, et al. Interactive digital platform and cyberphysical systems of medical education. *Parodontologiya*. 2022;27(4):318–326. EDN: VTOFWY doi: 10.33925/1683-3759-2022-27-4-318-326

12. Arutyunov SD, Yuzhakov AA, Kharakh YaN, et al. Dental simulator based on a robotic complex with an integrated smart jaw. *Russian Journal of Dentistry*. 2023;27(1):63–70. EDN: LMGDRW doi: 10.17816/dent115139

13. Yuzhakov AA, Arutyunov SD, Astashina NB, et al. Development of an anthropomorphic dental simulator based on the Robo-C robot. *Vestnik IZHGTU imeni M.T. Kalashnikova*. 2023;26(4):13–22. EDN: TGHLJC doi: 10.22213/2413-1172-2023-4-13-22

14. Arduengo M, Sentis L. The robot economy: here it comes. *International Journal of Social Robotics*. 2021;13(5):937–994. EDN: YNKDDZ doi: 10.1007/s12369-020-00686-1

15. Turchetti G, Palla I, Pierotti F, Cuschieri A. Economic evaluation of da Vinci-assisted robotic surgery: a systematic review. *Surg Endosc*. 2012;26(3):598–606. doi: 10.1007/s00464-011-1936-2

16. Mahdi QS, Saleh IH, Hashim G, Loganathan GB. Evaluation of robot professor technology in teaching and business. *Information Technology in Industry*. 2021;9(1):1182–1194. doi: 10.17762/itii.v9i1.255

СПИСОК ЛИТЕРАТУРЫ

1. Bano S., Atif K., Mehdi S.A. Systematic review: Potential effectiveness of educational robotics for 21st century skills development in young learners // Education and Information Technologies. 2024. Vol. 29. P. 11135–11153. doi: 10.1007/s10639-023-12233-2

2. Stasevych M., Zvarych V. Innovative robotic technologies and artificial intelligence in pharmacy and medicine: paving the way for the future of health care — a review // Big Data and Cognitive Computing. 2023. Vol. 7, N. 3. P. 147. doi: 10.3390/bdcc7030147

3. Ahmad P., Alam M.K., Aldajani A., et al. Dental robotics: a disruptive technology // Sensors (Basel). 2021. Vol. 21, N. 10. P. 3308. doi: 10.3390/s21103308

4. Bernauer S.A., Zitzmann N.U., Joda T. The use and performance of artificial intelligence in prosthodontics: a systematic review // Sensors (Basel). 2021. Vol. 21, N. 19. P. 6628. doi: 10.3390/s21196628

5. Battista A. An activity theory perspective of how scenario-based simulations support learning: a descriptive analysis // Adv Simul (Lond). 2017. Vol. 2. P. 23. doi: 10.1186/s41077-017-0055-0

6. Isaksson J., Krabbe J., Ramklint M. Medical students' experiences of working with simulated patients in challenging communication training // Adv Simul (Lond). 2022. Vol. 7, N. 1. P. 32. doi: 10.1186/s41077-022-00230-3

7. Koolivand H., Shooreshi M.M., Safari-Faramani R., et al. Comparison of the effectiveness of virtual reality-based education and conventional teaching methods in dental education: a systematic review // BMC Med Educ. 2024. Vol. 24, N. 1. P. 8. doi: 10.1186/s12909-023-04954-2

8. Thurzo A., Strunga M., Urban R., et al. Impact of artificial intelligence on dental education: a review and guide for curriculum update // Educ Sci. 2023. Vol. 13, N. 2. P. 150. doi: 10.3390/educsci13020150

9. Wang K., Sang G.Y., Huang L.Z., et al. The effectiveness of educational robots in improving learning outcomes: a meta-analysis // Sustainability. 2023. Vol. 15, N. 5. P. 4637. doi: 10.3390/su15054637

10. Асташина Н.Б., Байдаров А.А., Арутюнов С.Д., и др. Разработка комплекса «Антропоморфный стоматологический робот» с элементами искусственного интеллекта для имитации врачебных манипуляций и коммуникации «врач – пациент» // Пермский медицинский журнал. 2022. Т. 39, № 6. С. 62–70. EDN: CNJATY doi: 10.17816/pmj39662-70

11. Арутюнов С.Д., Южаков А.А., Харах Я.Н., и др. Интерактивная цифровая платформа и киберфизические системы медицинского образования // Пародонтология. 2022. Т. 27, № 4. С. 318–326. EDN: VTOFWY doi: 10.33925/1683-3759-2022-27-4-318-326

12. Арутюнов С.Д., Южаков А.А., Харах Я.Н., и др. Стоматологический симулятор на базе робототехнического комплекса с интегрированной смарт-челюстью // Российский стоматологический журнал. 2023. Т. 27, № 1. С. 63–70. EDN: LMGDRW doi: 10.17816/dent115139

13. Южаков А.А., Арутюнов С.Д., Асташина Н.Б., и др. Разработка антропоморфного стоматологического симулятора на базе робота Robo-C // Вестник ИжГТУ имени М.Т. Калашникова. 2023. Т. 26, № 4. С. 13–22. EDN: TGHLJC doi: 10.22213/2413-1172-2023-4-13-22

14. Arduengo M., Sentis L. The robot economy: here it comes // International Journal of Social Robotics. 2021. Vol. 13, N. 5. P. 937–994. EDN: YNKDDZ doi: 10.1007/s12369-020-00686-1

15. Turchetti G., Palla I., Pierotti F., Cuschieri A. Economic evaluation of da Vinci-assisted robotic surgery: a systematic review // Surg Endosc. 2012. Vol. 26, N. 3. P. 598–606. doi: 10.1007/s00464-011-1936-2

16. Mahdi Q.S., Saleh I.H., Hashim G., Loganathan G.B. Evaluation of robot professor technology in teaching and business // Information Technology in Industry. 2021. Vol. 9, N 1. P. 1182–1194. doi: 10.17762/itii.v9i1.255

AUTHORS' INFO

*** Oleg A. Tsarevskiy;**
address: 5 2nd Baumanskaya street, 105005 Moscow, Russia;
ORCID: 0009-0000-8602-6305;
eLibrary SPIN: 7244-1376;
e-mail: t1sarevskiy@yandex.ru

Sergey A. Arutyunov;
ORCID: 0009-0005-7605-5715;
eLibrary SPIN: 4682-1730;
e-mail: sa.arutyunov@mail.ru

Dmitriy I. Grachev, MD, Cand. Sci. (Medicine), Associate Professor;
ORCID: 0000-0002-5758-7485;
eLibrary SPIN: 2307-4380;
e-mail: dr.grachev@mail.ru

Nataliya B. Astashina, MD, Dr. Sci. (Medicine), Professor;
ORCID: 0000-0003-1135-7833;
eLibrary SPIN: 6119-8171;
e-mail: astashina.nb@mail.ru

Alexander A. Yuzhakov, Dr. Sci. (Engineering), Professor;
ORCID: 0000-0003-1865-2448;
eLibrary SPIN: 4820-8360;
e-mail: uz@at.pstu.ru

Kamalutdin G. Akhmedov;
ORCID: 0009-0000-5195-3942;
eLibrary SPIN: 8229-7763;
e-mail: kama05doc@gmail.com

ОБ АВТОРАХ

*** Царевский Олег Александрович;**
адрес: Россия, 105005, Москва, ул. 2-я Бауманская, д. 5;
ORCID: 0009-0000-8602-6305;
eLibrary SPIN: 7244-1376;
e-mail: t1sarevskiy@yandex.ru

Арутюнов Сергей Анатольевич;
ORCID: 0009-0005-7605-5715;
eLibrary SPIN: 4682-1730;
e-mail: sa.arutyunov@mail.ru

Грачев Дмитрий Игоревич, канд. мед. наук, доцент;
ORCID: 0000-0002-5758-7485;
eLibrary SPIN: 2307-4380;
e-mail: dr.grachev@mail.ru

Асташина Наталия Борисовна, д-р мед. наук, профессор;
ORCID: 0000-0003-1135-7833;
eLibrary SPIN: 6119-8171;
e-mail: astashina.nb@mail.ru

Южаков Александр Анатольевич, д-р техн. наук, профессор;
ORCID: 0000-0003-1865-2448;
eLibrary SPIN: 4820-8360;
e-mail: uz@at.pstu.ru

Ахмедов Камалутдин Гаджиевич;
ORCID: 0009-0000-5195-3942;
eLibrary SPIN: 8229-7763;
e-mail: kama05doc@gmail.com

* Corresponding author / Автор, ответственный за переписку