Computer Engineering and Applications Vol. 15, No. 1, February 2026

Application of Additive Manufacturing Technology in Custom Surgery and Orthopedic Implants through 3D Bioprinting: Rapid Review

Nunung Siti Sukaesih[1], Della Afrilliani Sutaryo[2], Karmilah[3], Raina Azhari Nariswari[4], Riva Nurizkiah[5], Salma Fajrian Agustin[6], Tanti Intan Nurhayati[7]

NERS Professional Study Program, Indonesia University of Education, Sumedang Campus
* nunungss@upi.edu

ABSTRACT

Musculoskeletal disorders, which are the leading cause of global disability, require better implant reconstruction solutions, given the limitations of conventional implants in terms of anatomical fit, stability, and stress shielding risk. The objective of this rapid review is to summarize the latest evidence on the application of Additive Manufacturing (AM), 3D Printing, and 3D Bioprinting technologies in the manufacture of custom orthopedic implants. The method used was a Rapid Review with the PRISMA framework, which involved searching 3,291 articles in the PubMed and ScienceDirect databases and filtering them down to 14 selected articles. The results show that the integration of 3D imaging, 3D printing, and Artificial Intelligence (AI) significantly improves visual-spatial understanding in orthopedic education, as well as improves implant placement accuracy (e.g., in THA), reduces operating time, blood loss, and radiation exposure through the use of AI-based 3D preoperative planning, custom models, and 3D-printed surgical guides. However, challenges remain in terms of cost, preoperative production time, and lack of long-term follow-up data. In conclusion, 3D and AI technologies have revolutionized orthopedic practice by improving accuracy, efficiency, and personalization of therapy, requiring large-scale research and long-term evaluation for sustainable clinical implementation.

Keywords: Additive Manufacturing, Bioprinting 3D, Implants, Orthopedic

1. INTRODUCTION

Musculoskeletal disorders are one of the leading causes of disability worldwide. WHO data shows that more than 1.7 billion people suffer from musculoskeletal disorders, including osteoarthritis, traumatic fractures, and congenital abnormalities, which significantly affect patients' quality of life and productivity. In cases of complex fractures or large bone loss, orthopedic surgical treatment often requires reconstruction using implants. However, existing reconstruction solutions face major challenges in terms of anatomical fit, long-term stability, and treatment costs (Levesque et al., 2020). Traditional mass-produced orthopedic implants are typically designed based on average population sizes, so they do not always fit the anatomical needs of specific patients. This mismatch can lead to postoperative problems, such as functional impairment, residual pain, and the need for revision surgery. With the increasing rates of traffic trauma, population aging, and bone cancer cases, the need for more personalized reconstruction solutions is becoming increasingly urgent (Ejnisman et al., 2021).

Conventional implants have significant limitations in several critical aspects. First, in terms of anatomical suitability, mass-produced implants do not usually take into account the unique geometric variations of each patient. This can result in micromotion (micro-movement) and failure to achieve optimal integration between the bone and the implant (Prochor & Sajewicz, 2019). Second, regarding intraoperative adaptability, standard implants often require manual modification (e.g., cutting or bending) during surgery, which can prolong the duration of surgery and increase the risk of infection and blood loss (Prochor & Sajewicz, 2019). Third, there are biomechanical complications because traditional implants (especially solid metal) have a much higher stiffness (elastic modulus) than bone, causing stress shielding, where the bone around the implant does not receive normal loads, resulting in bone resorption and loss of bone mass in that area (Safavi et al., 2023).

These limitations have led to the need to develop new implant production methods that can accommodate patient-specific designs and accelerate functional recovery in patients. This innovative approach emphasizes the importance of personalization in orthopedics, where implants are no longer produced to uniform standards but are tailored to the anatomical characteristics, biomechanics, and clinical needs of each individual. The concept of personalization not only aims to improve post-operative comfort and function, but also to reduce the risk of long-term complications, including the need for costly and high-risk revision surgery. With modern technologies such as additive manufacturing and 3D bioprinting, the opportunities to create implants that are precise, biocompatible, and support tissue regeneration are increasingly wide open. Therefore, developing implant production methods based on cutting-edge technology has become an important agenda in addressing current and future orthopedic challenges (Safavi et al., 2023).

The development of additive manufacturing (AM), particularly powder bed fusion (PBF) technology, has opened up great opportunities in the field of modern orthopedics. This technology enables the creation of anatomical models, surgical guides, and custom implants based on medical imaging data such as CT or MRI scans. Through a layer-by-layer process, AM allows for complex designs and internal structures that are difficult to achieve with conventional manufacturing techniques (Lowther et al., 2019). These advantages include the ability to produce implants with high density, porosity control, and the ability to create porous structures to support bone tissue growth and implant integration. Studies show that 3D printing is widely used in cases of orthopedic trauma, bone tumors, and complex reconstruction procedures in the maxillofacial and pelvic areas (Levesque et al., 2020). Additionally, 3D printed models are also used as a means of patient education and doctor training, as they are able to accurately represent anatomical conditions. Beyond metal or

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

polymer printing, the latest innovation is 3D bioprinting, which is a printing technology that uses bioinks containing living cells, biomaterials, and bioactive factors. Bioprinting enables the creation of biological scaffolds that resemble the microarchitecture of native bone, thereby supporting tissue regeneration.

Kang et al. (2022) explain that bioprinting has been successfully used to print various tissues, including bone and blood vessels. Bioprinted scaffolds based on hydrogels and composite materials are capable of accommodating osteogenic cells and accelerating extracellular matrix mineralization. Thus, bioprinting functions not only as a passive tool like metal implants, but also as a regenerative platform. Maresca et al. (2023) add that advances in bone bioprinting open up the possibility of reconstructing large bone defects, which have been difficult to address with conventional bone grafting techniques. This approach has the potential to reduce the need for autologous donors, lower the risk of donor site complications, and accelerate patient rehabilitation.

The application of AM and bioprinting in orthopedics still faces several obstacles. First, the selection of biocompatible metal (titanium, cobalt-chromium), polymer, and hydrogel materials is crucial to clinical success. Second, most evidence is still in the form of case reports or case series, so long-term data on the safety, effectiveness, and durability of implants is still limited (Levesque et al., 2020). Third, aspects of medical device regulation and standardization, quality control, and product certification are challenges in many countries. Fourth, although the cost of 3D printing is decreasing, the implementation of this technology requires infrastructure, trained human resources, and large initial investments (Ejnisman et al., 2021).

With the rapid development of technology and increasing publications related to it, a rapid review is needed to summarize the latest evidence on the application of additive manufacturing and 3D bioprinting technologies in the manufacture of custom orthopedic implants. This review aims to describe the types of technology and materials used, assess clinical evidence related to safety and effectiveness, identify technical, regulatory, and economic barriers, and develop recommendations for future research and clinical implications. Thus, this rapid review is important not only for researchers and medical practitioners but also for policymakers to guide the implementation of this innovative technology in future orthopedic practice.

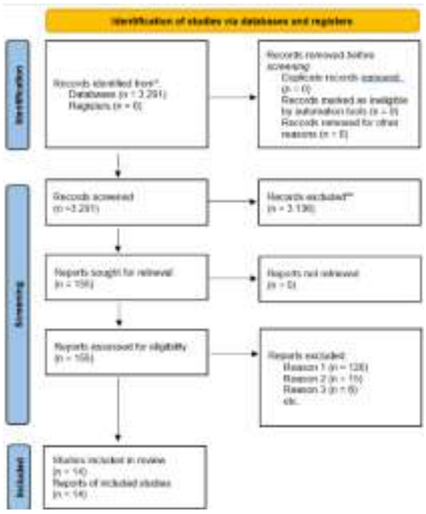
2. MATERIAL AND METHODS

The method used in this study was a Rapid Review using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) method. Rapid reviews summarize knowledge to produce information needed by authors in a short period of time. Although the methods vary, these reviews simplify or eliminate several stages of conventional systematic reviews. This is done by limiting the number and scope of questions, searching for data from fewer databases, reducing manual searches, and simplifying the evidence synthesis process. In line with other published rapid review practices, the research protocol was not published before the review was conducted. The literature sources used were PubMed and ScienceDirect. The literature inclusion criteria were articles on the topic of additive manufacturing in surgery and orthopedics. Articles published in 2020-2025 and written in English. The literature exclusion criteria included articles that were not accessible in full text and research articles that used the literature review method. The keywords used in the PubMed database were "Additive Manufacturing" OR "3D Printing" OR 'Bioprinting' AND "3D Bioprinting" OR "Custom Surgery" OR "Custom Implant" OR "Patient-Specific Implant" AND "Personalized Implant" OR "Orthopedic Implant" OR "Bone Implant" OR "Joint Replacement" OR "Orthopedic Surgery". Meanwhile, the keywords used in ScienceDirect are Additive Manufacturing, Bioprinting 3D in Medicine, Custom Surgery/Implants, Bioprinting 3D in Orthopedic. After that, they were scanned using Mendeley Reference Manager and manually to ensure that there were no duplicate articles. Furthermore, analysis and synthesis were carried out on selected articles related to the topic of discussion in this literature review.

3. RESULTS AND DISCUSSION

3.1 Results

The search results in this rapid review yielded 3,288 articles, using the Pubmed and Sciencedirect databases. A total of 3,124 articles were found in the PubMed database, while a total of 167 articles were found in the ScienceDirect database. These were then filtered again based on the last 5 years, randomized control trials, and clinical trials, and then filtered based on title and abstract, resulting in a total of 14 articles to be used.



GAMBAR 1. Prisma Flow Chart

3.2 Discussion

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

The integration of advanced technologies, particularly 3D imaging, 3D printing, and Artificial Intelligence (AI), has now been proven to provide transformative benefits in various aspects of orthopedics, ranging from education to operative efficiency and planning accuracy. Advances in digital technology, particularly in the fields of medicine and computer-based engineering, have driven various innovations in orthopedic procedures through the integration of 3D modeling, biomechanical analysis, and 3D printing, which improve the accuracy and personalization of therapy. 3D printed models are now an excellent educational tool for learning complex topics such as acetabular fractures. This condition is difficult to understand through conventional methods that rely solely on 2D images, such as X-rays or CT scans. A study by Goyal et al. (2022) shows that the use of 3D models in orthopedic training significantly improves visual-spatial understanding and knowledge retention compared to didactic lectures alone. Participants also rated 3D models as a representative medium worthy of routine use in education and surgical planning.

The greatest benefits of this technology are seen in surgical planning and execution. Preoperative planning is crucial for improving the efficiency, accuracy, and safety of THA surgery. Historically, planning using 2D templates has often been suboptimal due to angle limitations, magnification errors, and patient posture. The AI-assisted 3D planning system in Total Hip Arthroplasty (THA) has been proven to be far more accurate than conventional 2D implant sizing, significantly improving prosthesis matching accuracy and lower limb length discrepancy (LLD) recovery. Furthermore, this advanced planning translates directly into tangible operative efficiency, reducing surgical time and blood loss. This aligns with Yang et al.'s (2024) research on the efficacy of an AI-based 3D planning system (AIHIP) compared to 2D templates in THA Direct Anterior Approach (DAA). AIHIP uses neural network technology (CMG-NET) to reconstruct a 3D model from CT data, identify anatomical structures, and intelligently match prosthesis sizes. The results show that the AIHIP group had significantly higher accuracy in planning acetabular cup and femoral stem prostheses. Clinically, AIHIP shortens surgery time, reduces bleeding and fluoroscopy, and is more effective in restoring lower limb length discrepancy (LLD).

The use of physical 3D printed models for preoperative simulation and the design of personalized custom plates for complex fractures (such as distal radius or trimalleolar ankle fractures) dramatically improves intraoperative efficiency. Custom models and plates allow surgeons to pre-bend implants, plan reduction sequences, and determine optimal screw positions before incisions are made. This significantly reduces operating time, decreases the need for repeated intraoperative fluoroscopy, and minimizes soft tissue trauma (Kong et al., 2020; Liang et al., 2023). In fact, personalized 3D-printed guides, combined with innovative regulators, significantly improve the accuracy and safety of percutaneous pedicle screw fixation (PPSF) in thoracolumbar spine fractures, which in turn reduces radiation dose and accelerates short-term postoperative recovery (Zhang et al., 2020). 3D technology also enables implant customization. Yang et al. (2020) demonstrated the feasibility of customizing titanium implants for skull defects using low-dose three-dimensional CT. CT scans are required to create 3D models prior to CAD/CAM (Computer-Assisted Design/Manufacturing) implant customization.

Although it offers many clinical benefits, this technology also raises a number of considerations. The use of CT for 3D modeling raises concerns about radiation exposure, but recent studies show that low-dose CT protocols can still produce accurate models in accordance with the ALARA principle. Additionally, although 3D planning is capable of restoring anatomical symmetry well, RSA-based findings indicate that improved symmetry does not always directly impact stability or long-term biomechanical outcomes when implants already have adequate intrinsic stability. (M. X. Yang et al., 2020). 3D printing technology has proven to be more efficient and affordable in prosthesis manufacturing compared to manual methods (Sunarto et al., 2023). A prospective multicenter study on sacroiliac joint fusion using 3D porous titanium implants (TTI) showed sustained improvement in pain, function, disability, and quality of life up to five years post-surgery, with high radiographic fusion rates and mild side effects, as well as comparable or better efficiency than conventional implants (Patel et al., 2025). These findings align with medical education studies highlighting the importance of 3D printed models for improving anatomical understanding and surgical planning skills in adolescent idiopathic scoliosis (AIS), where the use of 3D models has been shown to increase cognitive efficiency, confidence, and clinical decision-making speed (Liu R et al., 2025).

Furthermore, a comparison between the traditional McLaughlin procedure and 3D-printed custom humeral head reconstruction showed similar functional outcomes but with shorter operating times and less blood loss, confirming the efficiency advantages of the 3D printing-based approach (Pavlov et al., 2022). Similarly, research on ultra-low-dose CT (ULD-CT) demonstrates the technology's ability to reduce radiation exposure by up to 99% without compromising key diagnostic capabilities, although image quality is reduced in complex bones, making it more suitable for diagnosing simple fractures than for 3D model-based surgical planning (Lei M et al., 2022). In the context of postmenopausal osteoporosis, 3D-based DXA analysis (3D-SHAPER) shows that romosozumab therapy significantly improves the density and microarchitecture quality of the femoral neck compared to comparative therapies, while strengthening evidence of the structural and anti-fracture benefits of combination therapy (Lewieckiet al., 2024). Research on knee reconstruction through Total Knee Replacement (TKR) modeling based on CT Scan data and 3D printing shows the potential for improved implant design accuracy and functional effectiveness in osteoarthritis cases, reinforcing the benefits of applying 3D technology in orthopedics (Salimi, 2023).

On the other hand, the use of percutaneous guide plates with 3D-printed lotus root regulators in thoracolumbar pedicle screw fixation showed the highest accuracy,

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

shortest operating time, and lowest radiation exposure, with faster recovery without an increase in complications (Zhang et al., 2022). In line with these findings, developments in knee deformity correction surgery (OWHTO) through 3D-based Patient -Specific Instrument (PSI) based on 3D technology, particularly with H-point guidance, also showed significant improvements in deformity correction accuracy, mechanical stability, and posterior tibial slope control, accompanied by shorter operating times and lower radiation exposure (Liu G et al., 2022). Despite showing significant benefits, the application of 3D technology faces several challenges, including the fact that the 3D printing process and customization of plates/implants still require more time in preoperative preparation and incur higher costs (especially for custom plates). Furthermore, in many studies, including those investigating distal radius fractures and ankle fractures, 3D printing and plate/implant customization have small sample sizes and lack long-term follow-up data (approximately 3–5 years) to accurately evaluate clinical outcomes and implant durability. Additionally, 3D-based planning generally requires CT scans, which increase patient radiation exposure (although studies indicate low-dose CT can be used).

3D printing technology has revolutionized modern orthopedics in diagnosis, education, and surgical intervention through improved accuracy, efficiency, and procedure safety. Recent evidence shows that 3D printed models facilitate learning for orthopedic trainees and improve understanding of complex fractures. In clinical practice, the application of AI-based 3D planning and 3D-printed surgical guides has been shown to improve prosthesis placement precision and reduce intraoperative morbidity in various orthopedic procedures. This technology offers a more personalized and efficient approach, with the potential to be integrated into routine curricula and clinical practice, although large-scale follow-up studies are needed to confirm its long-term effectiveness.

4. CONCLUSSION

The integration of 3D imaging technology, 3D printing, and artificial intelligence (AI) has brought about major changes in the field of modern orthopedics, covering aspects of education, diagnostics, and surgical intervention. In medical education, 3D printed models have been proven to improve trainees' visual-spatial understanding and analytical skills in complex cases such as acetabular fractures. In clinical practice, the application of 3D and AI-based preoperative planning (e.g., AIHIP) has been shown to improve implant placement accuracy, minimize operating time, blood loss, and radiation exposure, while accelerating patient recovery. Additionally, the use of 3D custom models and plates in complex fractures and 3D surgical guides in thoracolumbar pedicle fixation has demonstrated high efficiency and improved procedural safety. This technology also enables more precise and efficient implant customization, with functional and biomechanical outcomes comparable to or even better than conventional methods. However, challenges remain in terms of cost, production time, the need for CT scans (radiation exposure), and the lack of long-term data on clinical effectiveness. Overall, scientific evidence indicates that 3D technology and AI have revolutionized orthopedic practice by enhancing accuracy, efficiency, safety, and personalization of therapy. Wider adoption in the future, accompanied by large-scale research and long-term evaluation, is expected to ensure the sustainability and effectiveness of this technology in daily clinical practice.

5. ACKNOWLEDGEMENTS

The author would like to thank all those who have provided support in the preparation of this article, especially the supervising lecturer and colleagues who have provided input during the writing process. Thanks are also extended to the institution that has provided access to literature and supporting facilities in the implementation of this rapid review study.

6. REFERENCES

[1] Ejnisman, L., Helito, C. P., De França Camargo, A. F., Rocha, B. A., Baptista, A. M., & De Camargo, O. P. (2021). Three-Dimensional Printing In Orthopedics: Where We Stand And Where We Are Heading. Acta Ortopedica Brasileira, 29(4), 223–227. Https://Doi.Org/10.1590/1413-785220212904245927

[2] Goyal, S., Chua, C., Chen, Y., Murphy, D., & O.'Neill, G. (2022). Utility of 3D printed models as adjunct in acetabular fracture teaching for Orthopaedic trainees. BMC Medical Education, 22(1), 1–10. https://doi.org/10.1186/s12909-022-03621-2

[3] Kiernan, S., Geijer, M., Sundberg, M., & Flivik, G. (2020). Effect of symmetrical restoration for the migration of uncemented total hip arthroplasty: A randomized RSA study with 75 patients and 5-year follow-up. Journal of Orthopaedic Surgery and Research, 15(1), 1–8. https://doi.org/10.1186/s13018-020-01736-0

[4] Kong, L., Yang, G., Yu, J., Zhou, Y., Li, S., Zheng, Q., Zhang, B., & Mayr, J. (2020). Surgical treatment of intra-articular distal radius fractures with the assistance of three-dimensional printing technique. Medicine (United States), 99(8), 1–5. https://doi.org/10.1097/MD.0000000000019259

[5] Lei, M., Zhang, M., Luo, N., Ye, J., Lin, F., Chen, Y., Chen, J., & Xiao, M. (2022). The clinical performance of ultra-low-dose shoulder CT scans: The assessment on image and physical 3D printing models. PloS one, 17(9), e0275297. https://doi.org/10.1371/journal.pone.0275297.

[6] Levesque, J. N., Shah, A., Ekhtiari, S., Yan, J. R., Thornley, P., & Williams, D. S. (2020). Three-Dimensional Printing In Orthopaedic Surgery: A Scoping Review. EFORT Open Reviews, 5(7), 430–441. Https://Doi.Org/10.1302/2058-5241.5.190024

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)

[7] Lewiecki, E. M., Betah, D., Humbert, L., Libanati, C., Oates, M., Shi, Y., Winzenrieth, R., Ferrari, S., & Omura, F. (2024). 3D-modeling from hip DXA shows improved bone structure with romosozumab followed by denosumab or alendronate. Journal of bone and mineral research : the official journal of the American Society for Bone and Mineral Research, 39(4), 473–483. https://doi.org/10.1093/jbmr/zjae028.

[8] Liu, G. B., Liu, S., Zhu, C. H., Li, J., Li, J., Jia, G. X., Dong, W., Zhao, F., & Huang, Y. (2022). A novel 3D-printed patient-specific instrument based on "H-point" for medial opening wedge high tibial osteotomy: a cadaver study. Journal of orthopaedic surgery and research, 17(1), 169. https://doi.org/10.1186/s13018-022-03057-w.

[9] Liu, R., & Ma, H. (2025). Three-dimensional printed models improve orthopedic residents' understanding of adolescent idiopathic scoliosis. BMC medical education, 25(1), 37. https://doi.org/10.1186/s12909-024-06617-2

[10] Lowther, M., Louth, S., Davey, A., Hussain, A., Ginestra, P., Carter, L., Eisenstein, N., Grover, L., & Cox, S. (2019). Clinical, Industrial, And Research Perspectives On Powder Bed Fusion Additively Manufactured Metal Implants. Additive Manufacturing, 28, 565–584. Https://Doi.Org/10.1016/J.Addma.2019.05.033

[11] Maresca, J. A., Demel, D. C., Wagner, G. A., Haase, C., & Geibel, J. P. (2023). Three-Dimensional Bioprinting Applications For Bone Tissue Engineering. Cells, 12(9). Https://Doi.Org/10.3390/Cells12091230

[12] Pavlov, D. V., Korolev, S. B., Kopylov, A. Y., Zykin, A. A., Gorbatov, R. O., Illarionova, T. V., Gorin, V. V., & Alyev, R. V. (2022). Use of Additive Technologies in Surgical Treatment of Chronic Posterior Dislocations of the Shoulder. Sovremennye tekhnologii v meditsine, 14(3), 50–55. https://doi.org/10.17691/stm2022.14.3.06.

[13] Patel, V., Meyer, S. C., Kovalsky, D., Lockstadt, H., Farris, J., Limoni, R., Chowdhary, A., Yuan, P., Langel, C., Kranenburg, A., & Tender, G. (2025). Prospective Trial of Sacroiliac Joint Fusion Using 3D-Printed Triangular Titanium Implants: Five-Year Follow-Up. Spine, 50(9), 620–627. https://doi.org/10.1097/BRS.0000000000005170.

[14] Prochor, P., & Sajewicz, E. (2019). The Influence Of Geometry Of Implants For Direct Skeletal Attachment Of Limb Prosthesis On Rehabilitation Program And Stress-Shielding Intensity. Biomed Research International, 2019. Https://Doi.Org/10.1155/2019/6067952

[15] Safavi, S., Yu, Y., Robinson, D. L., Gray, H. A., Ackland, D. C., & Lee, P. V. S. (2023). Additively Manufactured Controlled Porous Orthopedic Joint Replacement Designs To Reduce Bone Stress Shielding: A Systematic Review. Journal Of Orthopaedic Surgery And Research, 18(1), 1–23. Https://Doi.Org/10.1186/S13018-022-03492-9

[16] Salimi, A. A. (2023). Finite Element Analysis (FEA) Simulation and Implant Fabrication for Performance Comparison of Conventional and Custom Cruciate Retaining (CR) Implants for Osteoarthritis Patients Based on MRI/CT Scan Data Reconstruction of the Knee Bone.

[17] Sunarto, G., Katmini, K., & Eliana, A. D. (2023). Efektifitas Biaya Penggunaan Teknologi Pencetakan 3D (Industri 4.0) pada Alat Bantu Ortotik Prostetik. Jurnal Penelitian Kesehatan" SUARA FORIKES"(Journal of Health Research" Forikes Voice"), 14(1), 17-26.

[18] Yang, M. X., Chen, B., Zhang, Y. P., Zhao, Z. H., & Banerjee, U. (2020). Feasibility of customizing titanium implant with three-dimensional CT imaging of low dose in skull. Medicine (United States), 99(28), E21009. https://doi.org/10.1097/MD.0000000000021009

[19] Yang, W., Gao, T., Liu, X., Shen, K., Lin, F., Weng, Y., Lin, B., Liang, D., Feng, E., & Zhang, Y. (2024). Clinical application of artificial intelligence-assisted three-dimensional planning in direct anterior approach hip arthroplasty. International Orthopaedics, 48(3), 773–783. https://doi.org/10.1007/s00264-023-06029-9

[20] Zhang, M., Li, J., Fang, T., Yan, J., Wu, L., & Zhou, Q. (2022). Application of 3-dimensional printing guide template and pointed lotus-style regulator in percutaneous pedicle screw fixation for thoracolumbar fractures. Scientific reports, 12(1), 2930. https://doi.org/10.1038/s41598-022-06256-x.

[21] Zhang, M., Li, J., Fang, T., Zhao, J., Pan, W., Wang, X., Xu, J., & Zhou, Q. (2020). Evaluation of a Three-dimensional printed guide and a polyoxymethylene thermoplastic regulator for percutaneous pedicle screw fixation in patients with thoracolumbar fracture. Medical Science Monitor, 26, 1–11. https://doi.org/10.12659/MSM.920578.

ISSN: 2252-4274 (Print)
ISSN: 2252-5459 (Online)