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E-BOOK
MEDICAL

Surgical Planning with 3D-Printed Anatomical Models

Evidence, Efficiency, and ROI

Personalized medicine continues to shape the future of healthcare, prompting providers and hospitals to pursue more precise, patient-centered approaches. Among the most transformative tools supporting this shift is 3D printing. As both clinical research and real-world case studies now show, 3D printing is enhancing surgical training, improving presurgical planning, and driving measurable improvements in patient outcomes.

Today, patient-specific 3D models are being integrated into vascular surgery, orthopedics, cardiovascular care, neurosurgery, pediatrics, and beyond, providing a lower-risk, cost-effective environment for simulation, education, and collaborative planning.

This report examines the latest evidence and field-tested applications of 3D medical modeling, highlighting how the technology is being used across a wide range of specialties. From transforming standard 2D imaging into tactile, anatomically accurate models to enabling handson rehearsal of complex procedures, 3D printing is redefining surgical readiness and clinical precision.

[1] Meyer-Szary, J. et al. The role of 3D printing in planning complex medical procedures and training of medical professionals—cross-sectional multispecialty review.

[2] O'Brien, C., Souza, C.A., Sheikh, A. et al. Use of tracheobronchial tree 3-dimensional printed model: does it improve trainees' understanding of segmentation anatomy? A prospective study.

Advancing Realism: The Technology Behind Medical 3D Printing

New studies validate fidelity, realism, and clinical utility

As medical 3D printing becomes more widely adopted, researchers and clinicians have increasingly focused on evaluating the realism, performance, and applicability of different printing technologies. Recent studies have rigorously examined material properties, color accuracy, tactile feedback, and anatomical fidelity, confirming that today's 3D printing solutions can replicate patient-specific anatomy with remarkable precision.

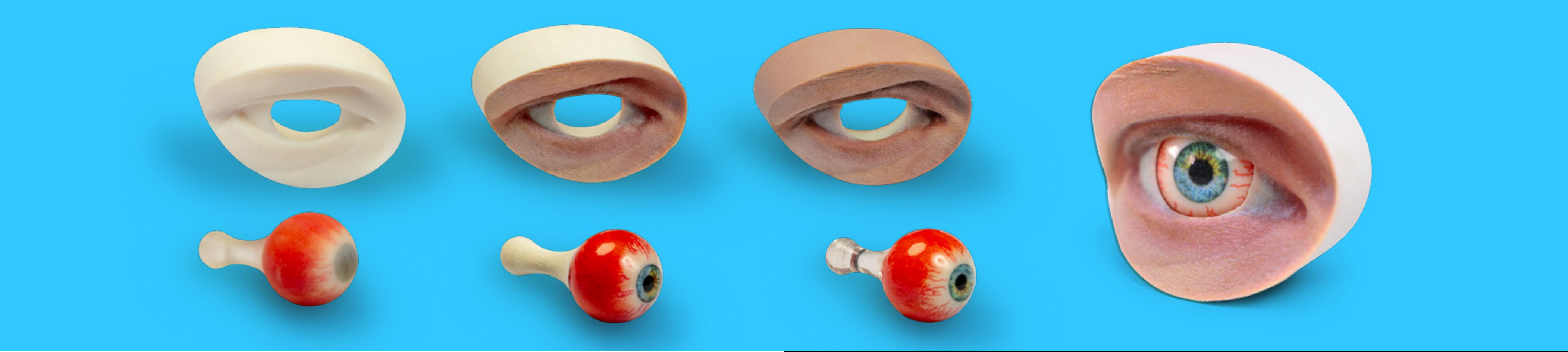
Advancements in material jetting, multi-material printing, and post-processing have enabled the creation of high-fidelity models that not only look anatomically correct but also feel and behave like real human tissue. These capabilities are reshaping how surgeons plan procedures, how students learn anatomy, and how hospitals deliver personalized care.

Evaluating PolyJet printing for point-of-care 3D printing

PolyJet's ability to fabricate smooth, accurate, and complex models makes it well-suited for point-of-care 3D printing in healthcare. Its rapid prototyping capability supports fast-turnaround surgical models, tooling, and patient-specific devices.

- **The study (2022)[1]:** A literature review examined existing research on materials, process optimization, and fatigue behavior of PolyJet-printed parts.
- **The results:** PolyJet technology produced complex geometries with high accuracy, making it valuable for functional prototyping. PolyJet enables over 500,000 material combinations via digital mixing (e.g., Digital ABS, Agilus30, Elastico), and high-temperature-resistant polymers increase dimensional stability and fatigue resistance.

[1] Muthuram N, et al. *Materials Today: Proceedings*, Volume 68, Part 6, Pages 1906–1920 (2022) https://doi.org/10.1016/j.matpr.2022.08.090.



Achieving color accuracy in full-color medical models using the Stratasys Digital Anatomy Printer

Accurate color reproduction in 3D printed anatomical models is critical for realism, especially in surgical training, education, and patient communication. To date, limited research has existed on how color settings and print parameters affect output quality—particularly with material jetting systems like the Stratasys Digital Anatomy Printer™.

- **The study (2024)[2]:** Researchers at The University of Queensland evaluated color fidelity using the Stratasys J750 Digital Anatomy Printer™. They 3D printed 33 color test blocks in CMYK and RGB schemes, using two infill materials (SUP706 support vs. VeroPureWhite). Each model's surfaces were scanned using a Nix Mini 2 handheld color sensor and analyzed using CIEDE2000 color difference metrics.

- **The results:** Using VeroPureWhite as the base infill (instead of SUP706) significantly improved color fidelity and avoiding manual black (K) mixing in CMYK and adding 10–30% white increased opacity and reduced error in color perception. These findings show that it is possible to produce highly realistic, multi-material anatomical models with Stratasys Digital Anatomy Printer technology.

[2] Badar, F, et al. Preliminary Colour Characterisation of a Stratasys J750 Digital Anatomy Printer with Different Fillings and Face Orientations. *Prog Addit Manuf* 9, 1277–1287 (2024). https://doi.org/10.1007/s40964-023-00519-3.

3D Printing Technologies at a Glance

Fused Deposition Modeling (FDM)

A process where melted thermoplastic is layered onto a heated surface, building the part one layer at a time.

Selective Laser Sintering (SLS)

SLS is a type of powder bed fusion technology that uses a laser to fuse polymer powder, layer by layer, into a solid part - no support structures needed.

Material Jetting (Jetted Photopolymer known as PolyJet)

Material Jetting builds parts by jetting thin layers of photopolymer, cured instantly with UV light. Printed parts are ready to use, and support material washes away easily with water.

Stereolithography (SLA)

SLA uses a UV laser to cure liquid resin, building parts layer by layer in a vat of photopolymer. Finished parts require washing and UV curing to fully solidify.

Indirect 3D Printing

Indirect 3D printing uses a 3D-printed mold to cast soft materials that better mimic real tissue. Internal structures are printed separately and placed inside before casting.

The Benefits of 3D Printing Across Specialties

Impacts on quality outcomes

Enable clinically-significant preparation

Humanitas University leverages fast, high-fidelity PolyJet 3D printing for research, surgical planning, and clinical education

At Humanitas University in Milan, Italy, 3D printing has become a cornerstone technology supporting research, clinical training, and surgical preparation. Originally established to support cell biology research through bioprinting of bio scaffolds, the Humanitas 3D Innovation Lab has rapidly expanded its role, especially in medical education and complex case planning. A key enabler of this growth: the adoption of the Stratasys J850 Digital Anatomy™ Printer.

The case study[3]:

A young woman with a malignant tumor of the peripheral nerve sheaths underwent a successful operation made possible by a highly realistic 3D model of her heart and tumor mass. The model enabled the surgical team to assess the exact location, mechanical properties, and vascular interactions of the tumor prior to the procedure - anatomical insights that would be difficult to interpret from 2D imaging alone.

The Stratasys J850 Digital Anatomy Printer's high-speed printing and minimal postprocessing time allowed Humanitas to produce models rapidly - an essential capability for urgent surgical cases and high-volume academic demand. The printer's ability to mix multiple materials enabled models with differentiated tissue textures, further enhancing surgical accuracy and educational value.

[3] https://www.stratasys.com/en/resources/case-studies/humanitas-medical-3d-printing-case-study/

Deliver personalized medicine

Seattle Children's Hospital delivers personalized surgical care with 3D medical modeling

At Seattle Children's Hospital, delivering safe, precise care for children with rare and complex conditions is a top priority. As part of that mission, the hospital's Aerodigestive Program has turned to advanced 3D printing technology from Stratasys to enable highly personalized surgical planning, rehearsal, and patient-family communication.

The case study[4]:

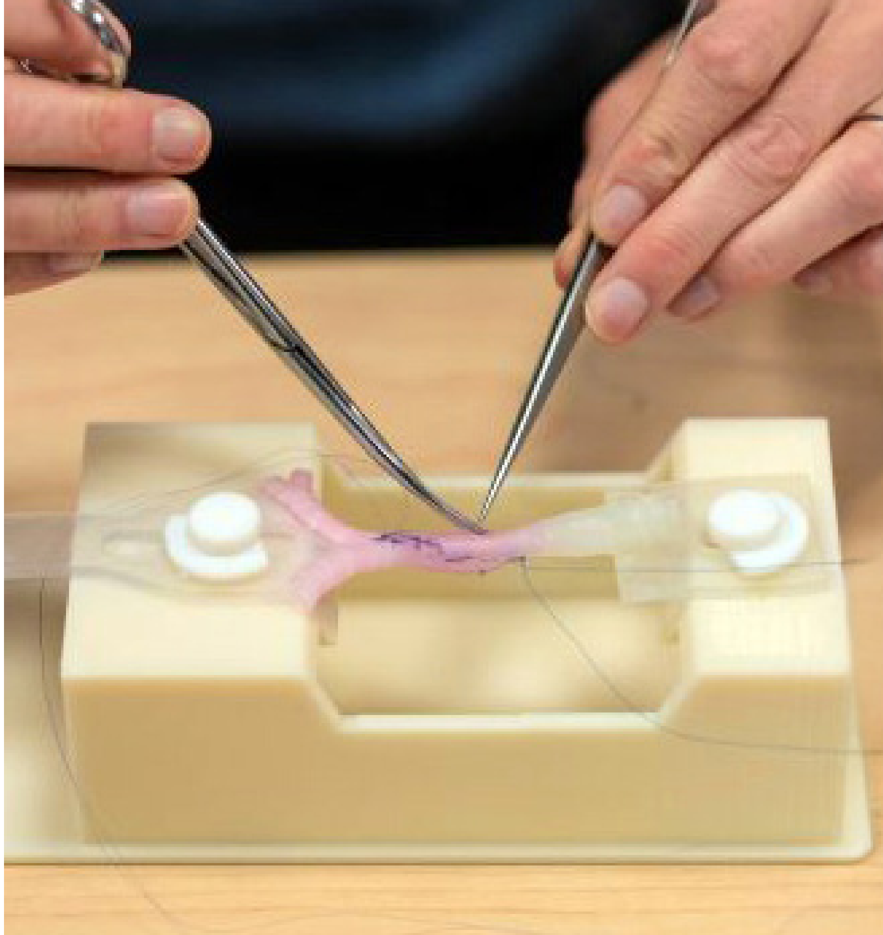
When an infant presented with severe respiratory distress just days after birth, imaging revealed a rare and life-threatening condition: right bronchial stenosis. Her bronchus—essential for breathing—was narrowed to the size of a human hair. Dr. Kaalan Johnson, Director of the Aerodigestive Program, led a multidisciplinary team across otolaryngology, pulmonology, cardiology, and anesthesiology to evaluate treatment options.

Given the severity of the narrowing and the patient's unique anatomy, a slide tracheoplasty was selected. While effective, the procedure is highly complex and not frequently performed. Precision is critical: "That very first step of dividing the windpipe is something you can't walk back from," said Johnson. "You need to know exactly where to cut and at exactly what angle."

To prepare, the team used the Stratasys Digital Anatomy™ 3D Printer to replicate the patient's airway in exact detail, including realistic biomechanical properties. The 3D printed models allowed surgeons to rehearse the full procedure on an accurate, patientspecific replica before entering the operating room.

Personalized, hands-on preparation gave the surgical team confidence and clarity, improving patient safety and surgical outcomes. Just as importantly, the 3D model served as a communication tool. For the patient's family, holding a tangible model of their child's airway helped bridge the gap between complex medical explanations and emotional understanding.

"There is something specifically valuable in our experience in having something you can touch and feel," said Johnson. "When you're dealing with the airway of a tiny baby, being able to hold a model in your hands and perform the actual procedure allows critical discussions and learnings to take place."



By incorporating 3D printed parts into pre-surgical planning, surgeons **reduced operation time by an average of one hour.**

The cost savings were equally significant. Custom surgical guides were produced for a fraction of the cost and turnaround time of traditional methods.

Reduce operating room and imaging time

Prince of Wales Hospital uses 3D printing to reduce surgical time, enhance accuracy, and lower costs

Orthopedic procedures often demand extreme precision— especially when treating bone cancer or repairing complex fractures. At Prince of Wales Hospital, the Department of Orthopedics and Traumatology, in collaboration with The Chinese University of Hong Kong (CUHK), turned to 3D printing to support personalized, pre-surgical planning. Their goal: improve surgical accuracy, reduce time in the operating room, and expand innovative surgical approaches.

The case study[5]:

Using Stratasys FDM Technology™, the team created patient-specific bone models and surgical guides to prepare for complex orthopedic procedures. In cases such as distal femur tumor removal and pelvic fracture repair, 3D printed models helped surgeons plan incisions, trial implant positions, and determine optimal screw angles - critical for preserving joint function and ensuring proper reconstruction.

The hospital also leveraged biocompatible thermoplastics to produce sterilizable, singleuse surgical guides. These were tailored to each patient's unique anatomy and used directly in surgery, streamlining workflows and improving accuracy in real-time.

Incorporating 3D printed parts into the pre-surgical workflow consistently reduced operation time - by an average of one hour per case. The use of patient-specific surgical guides also boosted surgeon confidence and improved communication with patients and surgical teams.

Cost savings were significant: one 3D printed guide was produced for approximately HKD 100, a fraction of the cost and turnaround time associated with traditional manufacturing. The technology's versatility has since led to broader adoption, including custom tools for orthopedic applications and expanded capabilities across departments.

[4] https://www.stratasys.com/it/resources/case-studies/seattle-childrens-hospital/

Drive scientific research

SJD Barcelona Children's Hospital advances cancer research with 3D printing

As a leading pediatric research hospital in Europe, Sant Joan de Déu (SJD) Barcelona Children's Hospital is internationally recognized for its expertise in pediatric cancer treatment and innovation. With cancer as one of the leading causes of death among children and adolescents, the hospital is committed to accelerating research and improving outcomes - especially for brain tumors and other solid tumors that present surgical complexity. To support this mission, SJD Barcelona Children's Hospital has made 3D printing a cornerstone of its translational research strategy.

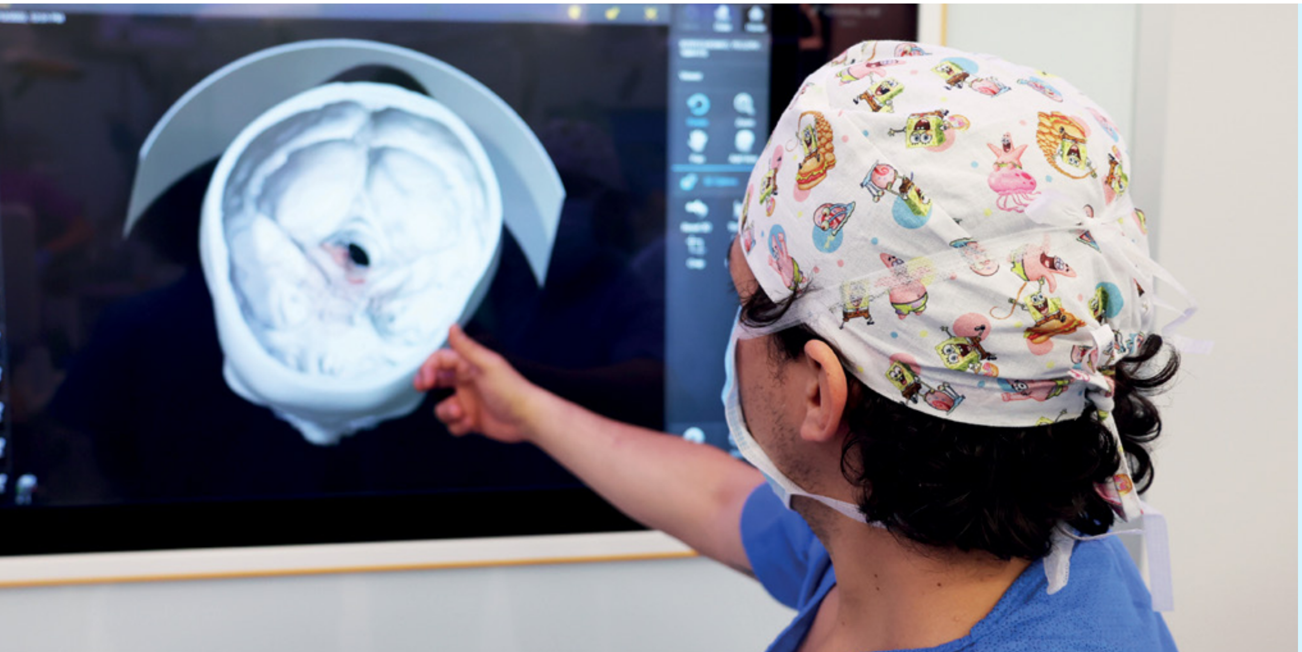
The case study[6]:

Faced with a rising number of complex surgical cases, the hospital integrated 3D printing into its clinical workflow to improve pre-surgical planning. Anatomical models produced from patient imaging helped surgeons understand complex tumor-vessel relationships, strategize surgical approaches, and reduce risk. Building on early success, the hospital founded its in-house 3DForHealth lab to deepen the integration of 3D printing in both clinical and research activities.

Today, the lab supports over 200 pediatric surgeries each year with patient-specific anatomical models, surgical guides, and research tools. The lab added the Stratasys J5 MediJet™ 3D Printer to expand its capabilities and scale production. The printer's ability to deliver multicolor, multi-material models in a single print run has accelerated production and enhanced model realism - key factors for both surgical planning and medical research.

The impact of 3D printing at SJD Barcelona Children's Hospital extends beyond improved clinical performance. The hospital's research teams now use the technology to explore new surgical techniques, validate hypotheses, and collaborate across disciplines with greater efficiency.

"Because we can create models and objects in one print pass, we have significantly reduced costs while increasing productivity," said Martí Valls, Head of 3D Planning at SJD. "The realism of the J5 MediJet models enables researchers and surgeons to work with greater precision—and with patient-specific data at the center."



> "We found that not only could 3D printing reduce surgery time by up to 40%, it could also lead to overall cost reduction."
>
> **Arnau Valls**
>
> R&D Engineer and Technical Manager, 3DForHealth, SJD Barcelona Children's Hospital's 3D printing unit

Improve education and learning outcomes

Deepening learning and improving student recall with 3D printing

Traditional anatomy education - relying on cadavers, textbooks, and atlases—is increasingly limited by rising student populations and declining cadaver availability. In response, educators are turning to 3D printing to offer students tactile, immersive learning experiences that improve spatial understanding and memorization.

The case study[6]**:**

- **The study (2025)**[7]**:** Researchers at the University Center of Maringá in Brazil conducted an integrative review of 15 studies published between 2019 and 2024, examining the use of 3D printed anatomical models in health and anatomy education. The reviewed models represented systems such as circulatory, skeletal, nervous, and reproductive. The team analyzed how 3D printing supports teaching effectiveness, engagement, and academic performance.
- **The results:** 3D printed models improve student understanding through hands-on learning and offer a more personalized educational experience. Studies showed enhanced engagement, stronger retention, and better academic outcomes. As the technology evolves, 3D printing is expected to play an increasingly central role in anatomy education.

[6] https://www.stratasys.com/en/resources/case-studies/sjd-hospital-embrace-3d-printing-medical/

[7] Paim e Silva Cadete Tomás KD, et al. Applications of 3D Printing in the Teaching of Human Anatomy: An Integrative Review. *Ann 3D Print Med*. 2025;19:100213. doi:10.1016/j.stlm.2025.100213.

Indication-Specific Applications

Evidence-based effectiveness data

Orthopedics

In orthopedics, 3D printing can be used to create bone models and guides for surgical preparation and provide an opportunity to increase awareness in young residents and medical students about trauma and fractures. 3D printing is ideal for prototyping bones because the calcium in the human skeleton makes scanned images extremely clear, so surgeons can use the 3D printed bone models for better consultation and assessment ahead of surgeries.

These anatomical models can provide essential information such as initial condition, sizes, directions, positions, and angulations of the bones and surrounding soft tissues. By preparing for orthopedic operations with 3D models, clinicians can shorten the surgical process and increase operation accuracy and success rate.

3D printing reduces operative time and complications in pediatric orthopedics

Personalized surgical planning is essential in pediatric orthopedics, where conditions like limb deformities, tumors, and spinal abnormalities are complex and highly variable. Traditional 2D imaging often falls short, making 3D printing an increasingly valuable tool in improving surgical outcomes.

- **The study (2025)[8]:** Researchers at the Tel Aviv Medical Center conducted a literature review exploring the applications of 3D printing in pediatric orthopedic surgery. The review covered image acquisition, segmentation, model creation, and printing techniques across key clinical areas: limb deformities, orthopedic oncology, and spinal deformities.
- **The results:** The researchers found that 3D printing enhances surgical precision, reduces operative time and complications, and improves patient outcomes. Patientspecific models and instruments enable surgeons to plan and execute complex procedures with greater accuracy. Although large-scale clinical studies are still needed to define standardized protocols, the evidence strongly supports 3D printing as a transformative force in pediatric orthopedic care.

[8] Benady A, et al. Advancements and applications of 3D printing in pediatric orthopedics: A comprehensive review. *J Child Orthop.* 2025;19(2):119-138. doi:10.1177/18632521251318552

Patient-specific surgical guides improve outcomes in novel pediatric ankle fusion cases

Multiplanar ankle deformities in children with arthrogryposis are among the most complex and high-risk challenges in pediatric orthopedics. These patients typically undergo numerous corrective surgeries by adolescence, and in some cases, joint motion becomes so severely limited that arthrodesis, surgical joint fusion, is the only viable option for improving alignment and mobility.

To enhance safety and accuracy in these high-stakes surgeries, a team at The Hospital for Sick Children in Toronto developed a groundbreaking technique that integrates 3D preoperative planning, 3D anatomical modeling, and patient-specific 3D-printed cut guides to perform deformity-correcting ankle fusions.

- **The study (2022)[9]:** Two adolescent patients with arthrogrypotic clubfeet and complex multiplanar ankle deformities were treated using this method.

  In the first case, a 12-year-old boy with bilateral severe deformities and limited mobility underwent staged bilateral ankle fusions. Using CT scans, engineers and surgeons codesigned a virtual correction plan and generated personalized cut guides using the Stratasys J750 Digital Anatomy Printer and Fortus 380mc. These guides enabled precise bone resections that restored plantigrade foot alignment while minimizing the risk of damaging neurovascular structures.

  The second case involved a 12-year-old girl with a severely deformed right ankle. A similar 3D planning and custom-guided fusion approach was used to correct the deformity while preserving surrounding joint structures.

- **The results:**
  - **Improved surgical precision:** 3D digital modeling allowed surgeons to visualize overlapping bony anatomy, simulate surgical cuts, and plan corrections in multiple planes - all before entering the OR.
  - **Customized patient care:** Patient-specific cutting guides enabled safe, exact osteotomies that would be difficult to achieve with traditional freehand methods.
  - **Increased efficiency:** Surgeons selected implant types and incision locations during pre-op planning, whic h reduced intraoperative time and improved surgical flow.
  - **Improved outcomes:**
    - In the first case, the patient regained the ability to walk independently without braces on one side, and functional scores for activities of daily living improved to 90%.
    - In the second case, ankle fusion was achieved with minimal residual deformity and improved emotional and physical function at 1-year followup.
  - **Low-cost, high-impact innovation:** Each anatomical model cost ~$200 CAD, with sterilizable guides produced for ~$50 CAD.

This novel use of 3D printing represents a significant step forward in pediatric foot and ankle surgery—especially for complex deformities that previously carried high risks or limited options.

[9] Bouchard M, et al. Deformity-Correcting Ankle Fusions with Patient-Specific 3D Operative Planning and 3D-Printed Cut Guides: Report of 2 Cases. *JBJS Case Connect*. 2022;12(4):e22.00553. doi:10.2106/JBJS.CC.22.00553.

Neurosurgery

Neurosurgery revolves around minute anatomical structures, and when it comes to performing operations on such vital, complex parts of the human anatomy, preparedness and accuracy are critical. Technology that allows clinicians to practice procedures and understand neurovascular structures can make the difference between a successful or unsuccessful surgery.

Given the delicacy of neurovascular operations, clinicians have found the use of custom, patient-specific 3D models "invaluable" in preoperative planning. 3D printed models give neurovascular surgeons a three-dimensional understanding of their patient's anatomical structure, and the high degree of accuracy of 3D printers allows extremely detailed modeling

> "Neurosurgery is one of the most technically demanding medical professions, warranting a high level of expertise. 3D printing has given medical simulation education a new dimension to acquire and improve surgical skills and knowledge in a controlled environment with no risk to the real patient."
>
> **Prof. Ashish Suri**
> Professor and Unit Head,
> Department of Neurosurgery & Chief Investigator,
> Neuro-engineering Lab, AIIMS, New Delhi, India.

All India Institute of Medical Sciences (AIIMS) advances neurosurgical simulation with Stratasys 3D Printings

Neurosurgery is among the most technically demanding medical disciplines, requiring a high degree of precision, spatial understanding, and tactile skill. Traditional training methods—ranging from textbook learning to cadaver dissection—have long been the norm, but ethical, cost, and accessibility challenges limit their use. To address these limitations, the All India Institute of Medical Sciences (AIIMS) in New Delhi is pioneering new simulation methods using Stratasys FDM® and PolyJet™ 3D printing technologies

- **The study[10]:** Under the leadership of Professor Ashish Suri, AIIMS' Department of Neurosurgery and Neuro-Engineering Lab has developed advanced simulation models for training in craniotomy and neuro-endoscopic surgery. Using the Stratasys J750 Digital Anatomy™ Printer, the team created highly realistic anatomical models replicating bone, soft tissue, and structural complexity.

For craniotomy simulation, the team fabricated burr-hole and bone flap models that mimic the biomechanical properties of the human skull using a combination of BoneMatrix™, TissueMatrix™, and Agilus30™ materials. The outer body and base plate were printed using the Objet350 Connex3™, while the high-fidelity drilling areas requiring precise haptic feedback were produced on the J750 DAP system. These simulators allow trainees to practice complex, high-speed drilling techniques in a risk-free environment while gaining familiarity with real anatomical variability.

- **Improved skill acquisition:** Trainees validated the craniotomy simulator as a highly effective tool for mastering critical neurosurgical techniques.
- **Ethical and cost-effective training:** 3D printed models eliminate the need for cadavers or animal models, reducing logistical, ethical, and financial barriers.

Vascular Surgery

To give surgeons the most realistic training, vascular models must replicate how native tissue expands and contracts as pressure is applied. 3D printing has been shown to help understand vascular anatomy and has been used for medical education and procedural training. 3D printing can be used to plan surgeries for patients with planned vascular intervention, including complex and enlarged dissections. 3D printed models have also been shown to aid understanding of complex anatomy, making them useful for planning procedures and increasing operator confidence.

Jacobs Institute advances vascular innovation and surgical readiness with 3D medical modeling

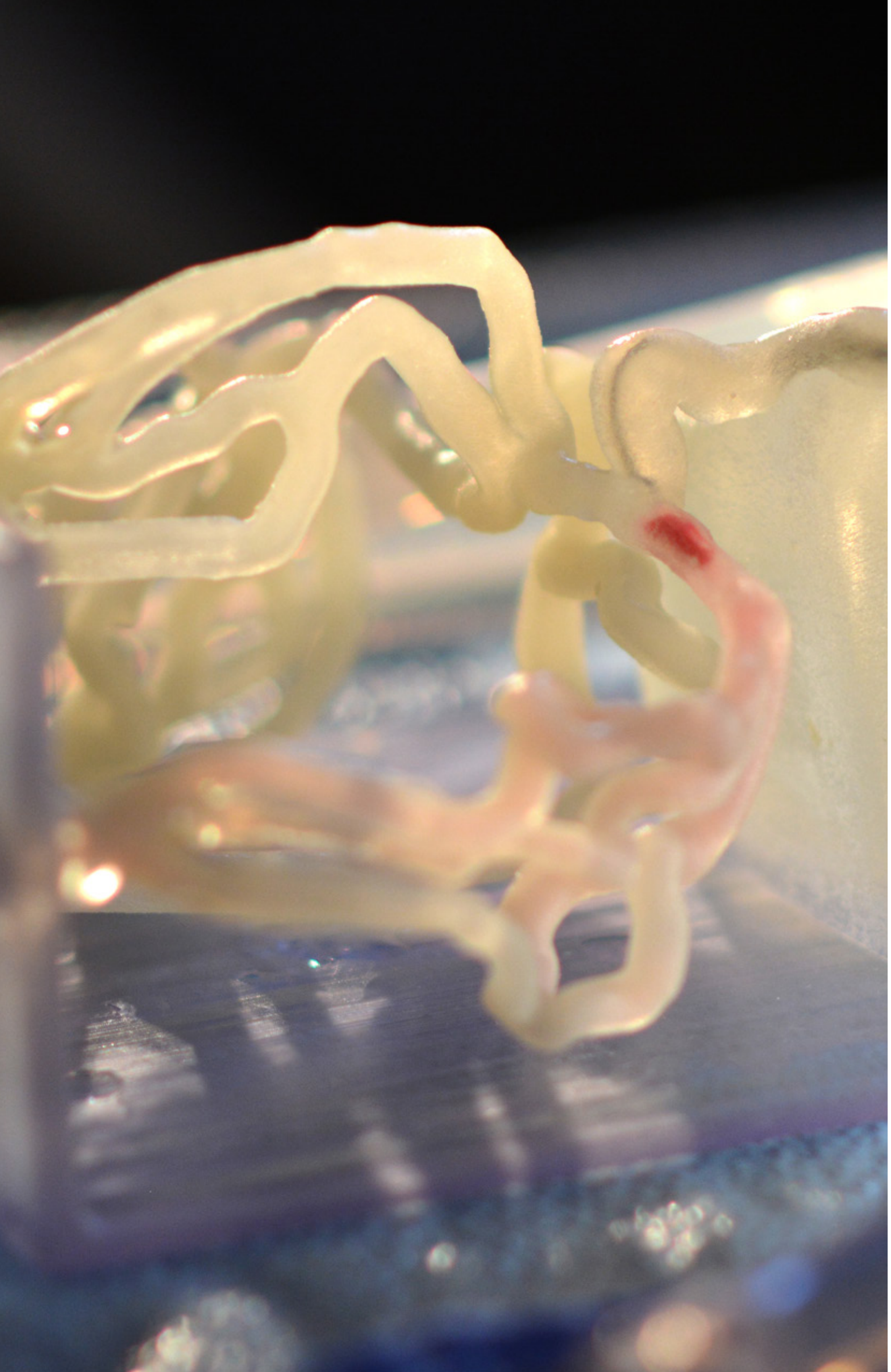
The Jacobs Institute, located in Buffalo, New York, is redefining how vascular diseases are studied, treated, and taught. In partnership with the Gates Vascular Institute and the University at Buffalo's Clinical and Translational Research Center (CTRC), the institute serves as a national leader in training, research, and patient-specific planning—supported by Stratasys 3D printing technology. Historically, surgical training depended on 2D imaging, textbook diagrams, cadavers, and observation-based apprenticeships. Today, 3D medical modeling provides a safer, more efficient alternative for preparing the next generation of vascular specialists.

- **The study[11]:** Jacobs Institute physicians and researchers leverage Stratasys 3D printing to develop highly accurate models of the human vasculature—replicating conditions such as stroke, aneurysms, and thrombosis. These patient-specific models offer risk-free, dynamic environments for surgical simulation, skill assessment, and procedural rehearsals. Instead of relying on theoretical knowledge or rare cadaver specimens, trainees now gain experience on realistic models designed to present the anatomical variation and complexity of actual patients.

  "3D vascular models represent a new paradigm for training the next generation of doctors," says Dr. L. Nelson Hopkins, founder of the Jacobs Institute and the Gates Vascular Institute. "This paradigm includes surgical and endovascular simulation and skills evaluation before they are allowed to treat patients."

> "We use 3D printing technology and materials to create a lifelike vascular environment that isn't achievable any other way."
>
> **Mike Springer**
> Jacobs Institute

[11] https://www.stratasys.com/en/resources/case-studies/jacobs-institute/



The models are customizable, allowing complications to be intentionally designed into the anatomy. Some are fitted with access points, sensors, or simulated blood flow, enabling high-fidelity, interactive experiences for device testing or training. Additionally, the portability and cleanliness of 3D models eliminate the logistical burden of traditional surgical training with animals or cadavers.

Beyond training, the Jacobs Institute integrates 3D modeling directly into the surgical planning process. When confronting the most challenging vascular cases referred to GVI or CTRC, physicians convert CT or MRI scans into physical models that guide decisionmaking, support team communication, and enhance patient education. These models provide both visual and tactile insight—helping teams prepare more comprehensively and mitigate surgical risk.

In one recent case, a 3D model of a patient's brain aneurysm allowed the team to test a web device before surgery. The model revealed that the planned approach would not work. Instead, a revised treatment plan was developed—averting potential complications and improving the patient's outcome.

"

Without the 3D model, we would have gone in expecting the first solution to work. Because of the simulation, we identified the flaw in our original plan and were able to design a much more optimal means of treating the aneurysm."

Dr. Adnan Siddiqui
Jacobs Institute

Cardiovascular Surgery

3D printed models can also be used to improve surgical planning efficiency and operative outcomes for cardiothoracic surgery. Cardiovascular surgeons have reported increased patient safety and clinician confidence when they practice and plan both routine and relatively novel procedures on 3D printed models.

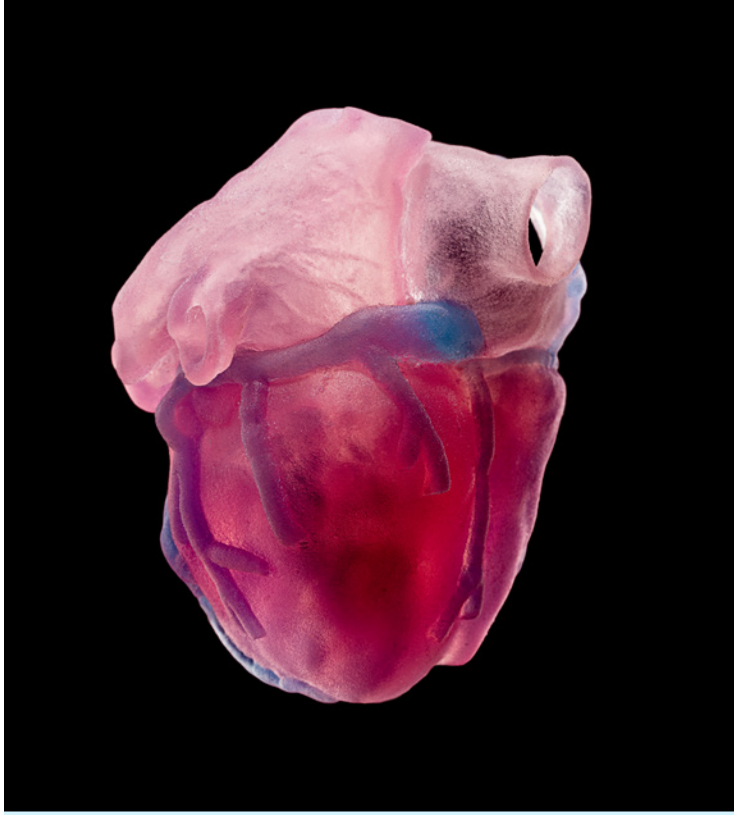
3D printed models can aid surgeons who are treating adult cardiovascular patients and those who are working on pediatric cases. Reports reflect the advantages of planning with 3D printed models for pediatric patients, who often have attendant fine vasculatures and rare congenital defects.

Nicklaus Children's Hospital transforms complex cardiac surgery with Stratasys 3D printing and mixed reality

When 13-year-old Rosemaylee Thelusma was diagnosed with a ruptured sinus of Valsalva aneurysm—an extremely rare and life-threatening heart condition—her doctors faced a daunting challenge. The defect was surrounded by three of the heart's most delicate structures: the coronary arteries, the aortic valve leaflets, and the conduction system. One wrong move could cause permanent damage.

- **The study**[12]**:** To prepare for the high-risk operation, the cardiac team at Nicklaus Children's Hospital turned to advanced visualization tools: the Stratasys Digital Anatomy® printer and mixed-reality holograms. Using Rosemaylee's CT angiogram data, the team produced multiple lifelike, dissectible 3D-printed models of her heart. These allowed the surgical team to simulate the procedure, test multiple approaches, and refine their strategy to avoid damaging critical structures.
- **The results:**
  - Surgical precision: Surgeons could cut and sew an exact replica of Rosemaylee's heart before entering the OR.
  - Optimized planning: Mixed reality revealed critical spatial relationships in real time, changing the surgical approach.
  - Reduced trauma: The refined plan minimized risk to surrounding structures and reduced operative trauma.
  - Better patient understanding: The team used the models and holograms to explain the procedure to Rosemaylee, helping her feel informed and empowered before surgery.

After a successful four-hour operation and a week of monitoring, Rosemaylee was cleared to return home—and to her favorite activity, cheerleading. The technology helped deliver not just a clinical outcome, but a full return to childhood.



“This cutting-edge technology helped us plan a challenging operation and enabled us to reduce the operative trauma for our patient—which is our ultimate goal.”

Dr. Redmond Burke
Chief of Cardiovascular Surgery,
Nicklaus Children's Hospital

[12] https://www.nicklauschildrens.org/news-and-events/patient-stories/rosemaylee-complex-heart-surgerymixed-vr

Surgical Oncology

Similar to other complex diseases, disease state and treatments can vary drastically between patients with cancer. Surgical management may be necessary for symptom relief or in cases where cosmesis is altered.

In surgical oncology, 3D printing can be used to create replicas of tumors and to depict the extent of disease and relationships of sensitive anatomy. Understanding a patient's unique anatomy and disease progression can reduce operating time, enhance utilization of new treatment techniques, and improve patient outcomes.

Creating patient-specific soft liver models for planning and simulation

Complex liver surgeries, particularly in pediatric cases, require precise preoperative planning. Traditional simulation methods using animal models, ex vivo tissue, or virtual reality have limitations. 3D printing now offers a cost-effective, patient-specific alternative that enhances surgical understanding and hands-on training.

- **The study (2023)[13]:** Researchers from Spanish institutions developed and tested a full digital workflow for creating soft, patient-specific liver tumor models. The study involved three pediatric cases (hepatoblastoma, hepatic hamartoma, and biliary tract rhabdomyosarcoma). Each model was created through medical imaging, segmentation, 3D printing, silicone molding, and validation.
- **The results:** The resulting models accurately replicated patient anatomy and enabled detailed surgical planning and dissection simulation. Compared to traditional methods, the 3D printed models were more cost-effective and allowed for improved understanding of complex liver structures. The study also presented a reproducible workflow that could be adapted for other conditions like neuroblastomas or brain tumors.

[13] Valls-Esteve A., et al. Patient-Specific 3D Printed Soft Models for Liver Surgical Planning and Hands-On Training. *Gels*. 2023; 9(4):339. https://doi.org/10.3390/gels9040339.

Enhancing surgical planning and family understanding in pediatric oncology

In pediatric cancer surgery, clear communication and precise planning are vital - both for surgeons and for families facing complex diagnoses. 3D imaging and printing technologies are increasingly being used to support preoperative planning and patient education, offering visual tools that enhance both surgical precision and family understanding.

- **The study (2024)[14]:** Researchers from the University of Michigan reviewed their experience using 3D segmented imaging and printed anatomical models from 2021 to 2023 to plan surgeries for four pediatric patients with extracranial solid tumors (Ewing sarcoma, hepatoblastoma, synovial sarcoma, and osteosarcoma). The models were created from CT and MRI data using in-house imaging and printing workflows.
- **The results:** The 3D models helped guide both tumor resection and reconstruction strategies, with no intraoperative complications or discrepancies compared to the printed models. As of publication, there were no local recurrences in any of the patients. Beyond surgical planning, the models also supported family education, helping clinicians explain anatomy, diagnosis, and surgical plans in a more accessible, visual format.

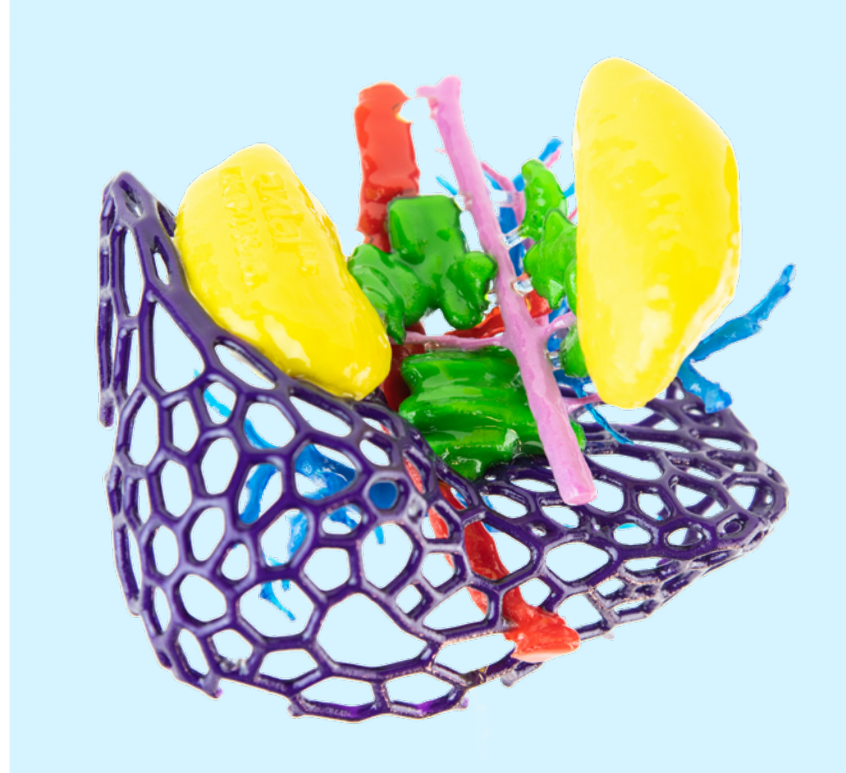
Improving tumor assessment, surgical simulation, and family communication in pediatric cancer cases

Traditional 2D imaging from CT and MRI often falls short when planning complex pediatric oncology surgeries. New technologies, like 3D modeling, cinematic rendering, virtual reality (VR), augmented reality (AR), and 3D printing are redefining what's possible in surgical planning, education, and communication.

- **The study (2023)[15]:** Spanish researchers analyzed three real-world pediatric oncology cases - abdominal neuroblastoma, thoracic inlet neuroblastoma, and bilateral Wilms tumor - to evaluate the clinical impact of emerging 3D technologies in surgical planning. Each case was examined using multiple tools including 3D modeling, VR, AR, and 3D printed anatomical models.
- **The results:** These technologies significantly improved surgeons' ability to assess complex tumor-vascular relationships, simulate procedures, and explain conditions to families and trainees. While VR and AR enhanced visualization, 3D printed models provided tactile, hands-on engagement that aided both surgical planning and communication.

[14] Shah NR, et al. Use of modern three-dimensional imaging models to guide surgical planning for local control of pediatric extracranial solid tumors. *Pediatr Blood Cancer.* 2024;71(5):e30933. doi:10.1002/pbc.30933.

[15] Valls-Esteve A, et al. Exploring the Potential of Three-Dimensional Imaging, Printing, and Modeling in Pediatric Surgical Oncology: A New Era of Precision Surgery. *Children.* 2023; 10(5):832. https://doi.org/10.3390/children10050832.



General Anatomy

3D printed models can be used to create patient-specific models for surgical planning across medical areas. To give surgeons the best preparation for treating patients, 3D replicas must accurately and realistically present anatomical structures. Research reports that 3D printed models meet these criteria.

As the demand for more accurate custom models increases, clinicians are finding that 3D printing offers differentiated, anatomically precise colors and varied textures within a single model, closely approximating individual patients and surgical cases.

Creating head models to improve ventilation for critically ill children

Children with craniofacial abnormalities often struggle to achieve a proper fit with standard noninvasive ventilation (NIV) masks - leading to air leaks and discomfort. By developing accurate pediatric head models, researchers are advancing the design of custom, 3D printed masks that better meet these patients' needs.

- **The study (2024)[16]:** Researchers from Emma Children's Hospital in Amsterdam created three pediatric head models using 3D facial scans of children (ages 3–4) with Down syndrome, cardiofaciocutaneous syndrome, and velocardiofacial syndrome. These scans were merged with standard head shapes to produce full digital head models, which served as the foundation for designing and printing personalized oronasal NIV masks using biocompatible silicone and photopolymer materials.
- **The results:** The study demonstrates that patient-specific head models can be used to rapidly produce functional, custom-fitted masks for critically ill pediatric patients—potentially improving outcomes and comfort in clinical care.

[16] Pigmans RRWP, et al. Development of Personalized Non-Invasive Ventilation Masks for Critically Ill Children: A Bench Study. ICMx. 2024;12:21. doi:10.1186/s40635-024-00607-w.

Creating anatomically accurate hand models for surgical simulation and planning

Surgical procedures for congenital hand malformations are complex and lack standardized protocols. Surgeons often face challenges due to the rarity and variability of these conditions. To support surgical planning and improve outcomes, researchers explored the feasibility of using 3D printing to develop patient-specific anatomical hand models.

- **The study (2024)**[17]**:** Researchers at a French institution acquired MRI scans of a healthy adult hand and segmented them to isolate different anatomical layers. They created a prototype using multi-material 3D printing for bones, muscles, and tendons, and silicone printing for skin and fat layers in a glove-like structure. The model was evaluated through comparative dissections against a cadaveric hand, with surgeons scoring realism, handling, and utility for surgical training.
- **The results:** The 3D printed model successfully replicated patient-specific anatomy and avoided common cadaver limitations like tissue fragility and rigidity. Surgeons noted improved anatomical fidelity and usability. However, the absence of vascular and nervous systems limited full realism. The study concluded that these models could serve as effective training and preoperative planning tools for complex hand surgeries, with ongoing refinements expected to enhance their utility in pediatric cases.

Economic Efficacy, Workflow Efficiency, and Improved Outcomes

The promise of 3D printing

In a healthcare environment shifting towards value and outcome-based care, 3D printed models for surgical planning - with the ability to facilitate procedural efficiency, improve treatment outcomes, and reduce downstream re-intervention costs, offer high potential value

- **The study (2024)**[18]**:** An analysis published in the *Journal of the American College of Radiology* found that 3D printing saved healthcare providers an estimated **41 minutes and approximately $2,500 per case** in operating room costs.

  These findings are based on a national registry established by the American College of Radiology and the Radiological Society of North America, which collected standardized data from over 2,600 cases across 20 healthcare sites over a three-year period. Most cases involved cardiac and neurological applications, with CT and MRI being the primary imaging modalities used to generate the models. The registry aimed to benchmark current practices and better understand the workflows, technology use, and clinical value of 3D printing in routine care.

- **The results:** On average, providers spent around 92 minutes per case, and support staff contributed more than five hours of work including segmentation, design, and postprocessing. While the $606 cost per case reflects the significant investment of time and labor, the fourfold return in operating room time savings highlights 3D printing's potential to optimize clinical workflows and reduce healthcare costs, especially in complex surgical cases. These findings align with prior research and underscore 3D printing's growing role in enhancing efficiency, precision, and value in patient care.

[18] Wang KC et al. Demographics, utilization, workflow, and outcomes based on observational data from the RSNA-ACR 3D Printing Registry. *J Am Coll Radiol.* 2024;21(11):1781–1791. doi:10.1016/j.jacr.2024.06.001

3D printing saved healthcare providers an estimated **41 minutes and approximately $2,500 per case** in operating room costs, according to a 2024 study.

The point-of-care advantage: In-house vs. outsourced workflows

Bringing 3D printing in-house offers a distinct advantage when compared to outsourced production workflows. While outsourcing may be sufficient for low-volume, non-urgent models, in-house production unlocks critical benefits that can enhance clinical outcomes, streamline workflows, and reduce costs.

Faster Turnaround

Hospitals with point-of-care 3D printing can produce anatomical models in a matter of hours—not days or weeks. This speed is crucial for urgent or complex cases that require immediate surgical planning or patient education.

Cost Control

In-house printing eliminates third-party markups, reducing per-case expenses and enabling institutions to allocate resources more effectively. Over time, the investment in a 3D printer can be offset by the cumulative savings of high-volume usage.

Enhanced Collaboration

Real-time, cross-disciplinary collaboration between radiologists, surgeons, and engineers is easier and more efficient with an in-house team. Surgeons can give direct feedback, request adjustments, or iterate on designs without the delays of external communication.

Data Security & Confidentiality

With patient data never leaving the institution, in-house workflows provide better protection of sensitive medical information - an increasingly important consideration in today's regulatory environment.

Clinical Flexibility

From late-stage planning to emergent needs, having in-house capabilities ensures a level of flexibility and responsiveness that outsourced workflows can't match. Clinicians can test, train, and refine techniques without waiting for external delivery or revisions

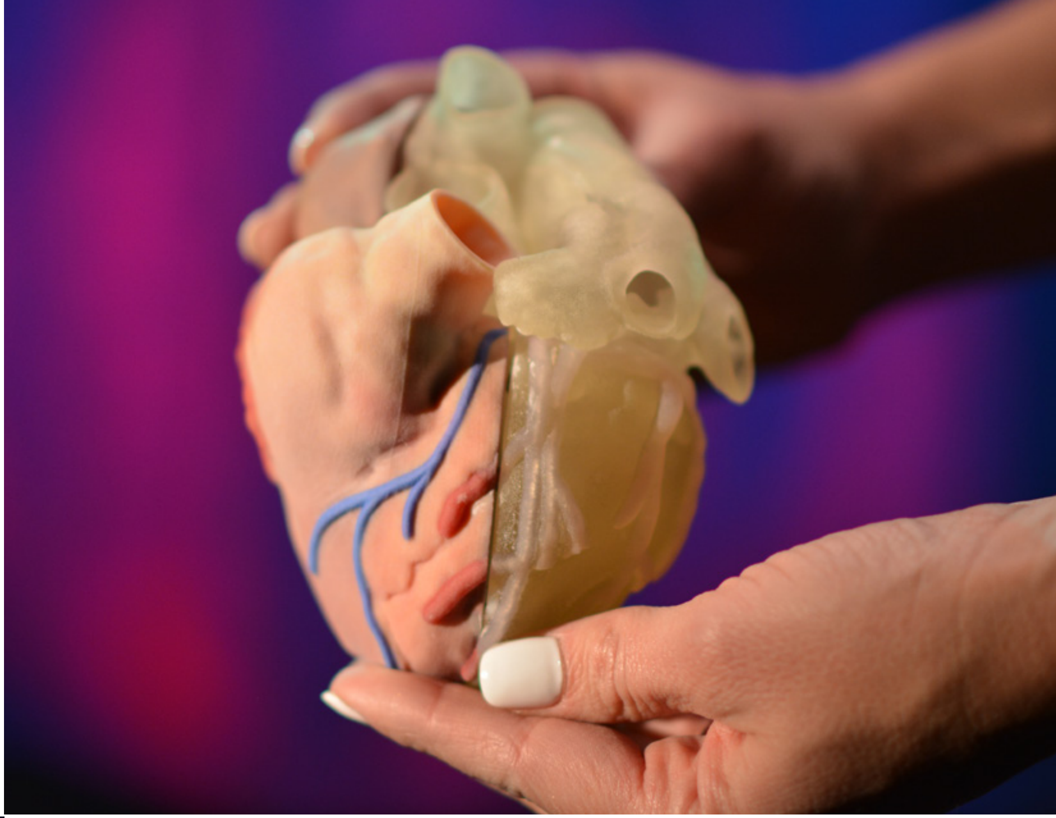
3D Printing

The New Standard for Precision Care

3D printing is no longer a future promise. It's a present-day clinical advantage. As the case studies and data show, additive manufacturing is transforming surgical planning, enhancing patient-specific care, and driving measurable improvements in training, workflow efficiency, and clinical outcomes.

Whether optimizing complex pediatric oncology cases, reducing time in the operating room, or enhancing anatomical education for the next generation of physicians, 3D printed medical models are enabling better decisions - faster. And as hospitals increasingly shift toward valuebased care, the economic and clinical rationale for in-house 3D printing becomes even stronger.

At the intersection of innovation and impact, 3D printing is setting a new standard for what's possible in modern medicine.



Ready to Learn More?

Stratasys is proud to support healthcare providers around the world in delivering safer, smarter, more personalized care. From point-of-care labs to academic institutions and research hospitals, our advanced technologies are helping teams reimagine surgical planning, improve patient outcomes, and accelerate medical innovation.

Let's talk about how your institution can benefit from:

- Faster surgical preparation with patient-specific anatomical models
- Reduced OR time and improved procedural accuracy
- Streamlined in-house production for cost-effective workflows
- Enhanced education and patient engagement

Contact us today to start your journey toward precision, personalization, and better outcomes.

stratasys.com/medical

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