3D Printing Materials Let Medical Designers Work in New Ways

By Victoria Burt

3D printers are used in the medical industry for everything from device design concepts, functional prototypes, and tooling to training and simulation of complicated surgeries. Materials for these projects range from unique multi-material systems that reproduce tissue to design intent to production-grade, high-performance thermoplastics that give designers the freedom to create innovative products.

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The Fortus 450mc from Stratasys can build parts as large as 406 x 355 x 406 mm (16 x 14 x 16 in.)

3D printers take digital designs and make three-dimensional objects. The 3D printing process, also called additive manufacturing, builds parts by depositing small amounts of material, layer by layer. Contrast this to traditional manufacturing methods that remove material by cutting, grinding, milling, and other methods.

There are several technologies used in 3D printers today. Fused Deposition Modeling (FDM®) and printing materials are discussed in this eBook. FDM, introduced in the early 1990s by Stratasys, builds 3D parts by melting and advancing a fine ribbon of plastic through a computer-controlled extrusion head, producing parts that are ready to use.

3D printing has been around for over 30 years but recently has gained a lot of media attention. Wohlers Associates Inc., a consulting firm that tracks developments and trends in rapid product development and additive manufacturing, expects worldwide revenue from the additive manufacturing and 3D printing industry to reach $12.8 billion by 2018. According to *Wohlers Report 2015*, the company's annual publication on the subject, the industry grew to an estimated $4.1 billion in 2014. By 2020, Wohlers Associates forecasts revenues from all products and services in the industry to exceed $21 billion. The company attributes this growth to an increase in finished parts, the wider choice of machines and materials now available, media attention, investment across many groups, and low-cost desktop 3D printers.

HOW FDM WORKS

The process of 3D printing begins with a 3D computer-aided design (CAD) model. After the 3D model is created, it is exported as an .STL file. The .STL file is then imported into one of two Stratasys software programs for FDM, Insight™ or Catalyst™, depending on the intended printer.

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The preprocessing software calculates sections and slices the part design into many layers, ranging from 0.005 in. (0.127 mm) to 0.013 in. (0.3302 mm) in height. Using the sectioning data, the software then generates tool paths, or building instructions, which will drive the extrusion head. The software works like a paper printer's driver, sending data to the 3D printer as a job and telling the print head where to lay down material.

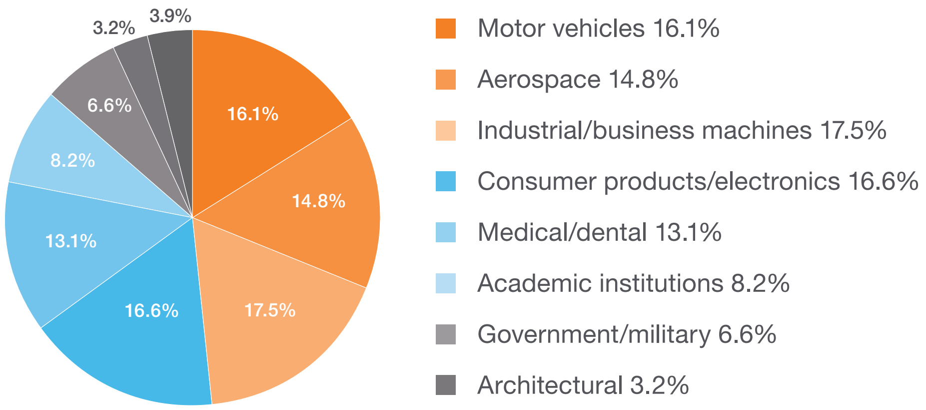
The second step in FDM is production, or the layering process. The 3D printer starts with a few layers of disposable support material to provide a foundation. Support material is also used to shore up features such as overhangs that would otherwise have nothing to rest upon.

The two materials, one to make the part, and one to support it, are heated to a semi-liquid state, forced through an extrusion tip, and precisely deposited in extremely fine layers, roughly the size of a human hair. Alternating between part material and support material, the system deposits layers as thin as 0.005 in. (0.13 mm).

The print head moves in X-Y coordinates, and the modeling base moves down the Z axis as the model and its support material are built from the bottom up. Each layer of molten plastic is deposited on top of the previous one and flattened slightly by the extrusion head. The layers instantly fuse to one another.

3D Printing Market by Segment

Source: *Wohlers Report 2015*



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The key to FDM's accuracy and precision is the coupling of material feed rates and extrusion head motion. Both are constantly changing to produce a flat ribbon of material that measures from 0.008 in. to 0.038 in. wide (0.20 mm to 0.97 mm). On the highest-performance FDM machines, part accuracy, or tolerance, reaches as high as 0.003 in. (0.08 mm), which rivals injection molding.

The soluble support material holds up overhanging portions while the model is being built, allowing for complex models — even nested structures and multipart assemblies with moving parts — to be 3D printed. When the print job is complete, the support material washes away, and the model is ready to be used or, if desired, finished with paint or another process.

HEALTHCARE AND THE 3D PRINTING INDUSTRY

According to the *Wohlers Report 2015*, the medical/dental industry was among the biggest segments for 3D printing in 2014, with 13.1 percent of the market, along with industrial (17.5 percent), electronics (16.6 percent), and motor vehicles (16.1 percent).

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Charlottesville, Va.,-based SmarTech Markets Publishing released a research report titled *3D Printing in Medical Markets 2015: An Opportunity Analysis and Ten-Year Forecast* that looks at where medical-related 3D printing is headed over the next decade. According to SmarTech, in 2014 more than 1,100 3D printers were sold for medical use. The firm predicts that by 2020, that number will double, and approximately 2,200 printers will be shipped annually for medical use. An even larger rate of growth is expected within the materials sector of the market.

In 2014, revenue for materials used for medical 3D printing amounted to around $50 million. By 2020, this number will increase nearly sevenfold, soaring to $345 million, according to SmarTech. This means that the market for materials will be larger than the market for the actual hardware to print these materials. The main driver of this tremendous growth within the materials market is the rapidly expanding need for custom medical implants and models.

Another report from the company Visiongain, a business information provider based in London, England, forecasts the world market for 3D printing in the healthcare industry will be worth over $4 billion in 2018. (The report includes dental products, medical implants, bioprinted tissues, and other medical uses in its definition of the market.) The medical market generated $1.2 billion in 2013, according to Visiongain's *3D Printing for Healthcare: R&D, Industry and Market 2014–2024*, published in January 2014.

Visiongain forecasts the overall market for 3D printing in the healthcare industry will expand rapidly from 2014, stating that "multidimensional printing offers advantages over traditional manufacturing methods as it facilitates the production of highly specific, complex geometries and surfaces. It is suited to the production of high-value, low-volume products. As a result, those printers give methods of synthesis suited to manufacturing products for the healthcare industry, where the demand for high-quality, patient-specific products is increasing, particularly in orthopedics."

BENEFITS OF 3D PRINTING FOR MEDICAL USES

3D printed parts find multiple uses in the medical industry. Designers are using 3D printing to build concept models, functional prototypes, factory tooling (such as molds and robot arm ends), and even finished goods. Doctors, surgeons, and hospitals are also using 3D printing for new medical device designs, training and simulation, and testing

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and gaining in utilization as printers create more realistic simulations of tissue. Surgeons can create models of body parts to be operated on and then practice their surgical skills, such as instrument insertion, knot tying, dissection, and the repair of trauma or congenital defects. In cases where complex, multi-faceted, and multi-disciplinary surgical procedures are required, the ability to predetermine the best possible approaches,

> FDM production printers not only reduce time and cost for manufacturing tools but also can improve the assembly process.

particularly among teams of different specialties (vascular, orthopedic, neurosurgery, potentially all working on the same patient) is key. Anatomical modeling lets surgical teams evaluate several different treatment scenarios before deciding on a plan that ensures these needs are met. These models, in turn, can create reference works for education and training of physicians: kept digitally, they can be reprinted to replace cadaveric specimens, animal testing, or “average” anatomy mannequins.

MEDICAL MATERIALS FOR FDM 3D PRINTING

Since its early days, FDM technology has been identified by industrial thermoplastics and the use of acrylonitrile-butadiene-styrene (ABS). But materials for FDM have advanced and evolved. Today, there are several versions of ABS, each mechanically superior to the original ABS formulation.

To select the proper material for an FDM project, it is essential to understand the capabilities and limitations of FDM technology. Fixtures, tools, and prototypes made with FDM can withstand rigorous testing and constant use on the production floor. Specialized properties such as toughness, electrostatic dissipation, and biocompatibility are easily met with materials used in FDM.

Stratasys offers two materials for FDM machines that are biocompatible (ISO 10993 USP Class VI), ABS-M30i™ and PC-ISO™. Both materials can be

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sterilized using gamma radiation or the ethylene oxide sterilization method.

The best fit for these materials are parts that need good strength and that need to be sterilized. However, neither Stratasys nor the raw material manufacturer can approve resins/plastics for particular applications within FDA compliance. It is the responsibility of the finished device manufacturer to determine the end-use suitability through appropriate testing and analysis of all component parts and materials to be used in the finished products.

For strong tooling, custom fixtures, and production parts, FDM technology works with production-grade materials, including high-performance thermoplastics. For production of finished goods, material stability and long-term performance are paramount. Consideration must be given to the mechanical, thermal, electrical, and chemical properties and any changes that result from aging or environmental exposure.

Stratasys FDM machines use 16 different materials, including three engineering thermoplastics. They are each described below.

ABS-M30 and ABS*plus*

The ABS-M30™ plastic formulation is the plastic commonly used in the FDM process and is specific to the Fortus® line of production 3D printers. This material formulation is also known as ABS*plus*™ for the uPrint™ line of 3D printers.

In raw filament form, these are identical materials with equal mechanical properties. However, there is a difference in finished part material properties between ABS*plus* and ABS-M30. As with molded parts, processing makes a difference. Developed for manufacturing applications, Fortus 3D Printers have advanced hardware and software controls that process the materials differently. By doing so, the material characteristics achievable from ABS-M30 are improved. While ABS*plus* produces tough parts, ABS-M30 parts are generally stronger in all categories.

Both materials will produce parts that are stable, strong, and durable. Both come in a range of colors that include white, black, red, blue, green, fluorescent yellow, and more.

Another common quality that makes these two materials the workhorses of FDM is that they are easy to finish. As with most additive manufacturing processes, FDM machines use a sacrificial

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support structure to build the part, but the ABS materials have something few others do: no-touch support removal. A soluble support material eliminates manual labor. Parts are placed in a tank, and the supports are dissolved away.

The surface finish of ABS*plus* and ABS-M30 parts is more than adequate for concept modeling, functional prototyping, and creating manufacturing tools. If the application is for master patterns, marketing models, or finished goods, and the user wants a surface finish similar to that of injection molding, FDM has an optional hands-free smoothing process in the form of the Finishing Touch Smoothing Station that can smooth parts in under a minute.

This medical nebulizer was 3D printed with ABS-M30i.

Good material properties and simple post-processing are the reasons that ABS*plus* and ABS-M30 are the most-used FDM materials.

ABS-M30i

Medical, pharmaceutical, and food handling equipment have stringent regulations to protect consumers from illness and disease. Regulations include standards such as ISO 10993 and USP Class VI, which classify a material as biocompatible. ABS-M30i meets these criteria, so it can be used for products that come in contact with skin, food, and medications.

ABS-M30i blends strength with sterilization capability. It can be sterilized using either gamma radiation or ethylene oxide sterilization methods. Parts made with ABS-M30i are biocompatible with excellent mechanical properties that are well-suited for conceptual modeling, functional prototyping, manufacturing tools, and end-user parts.

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ABS-ESD7

ABS-ESD7™ is Stratasys' electrostatic dissipative material available for FDM. This material prevents a buildup of static electricity, so it's appropriate for applications where a static charge can damage products, impair performance, or cause an explosion. For these reasons, ABS-ESD7 is well-suited for carriers and organizers for electrical components, fixtures for electronic component assembly, and production line and conveyor parts. Other applications include product design and validation for electronic product enclosures, electronics packaging materials, and powder or mist conveying or dispensing.

ABS-ESD7 also eliminates another common static electricity problem: the attraction and buildup of particulate, such as dust or powders, which can degrade product performance. ABS-ESD7 also avoids attracting atomized liquid, so it's beneficial for medicine inhalers that must deliver the entire drug dose to the patient and not leave mist clinging to inhalers' internal surfaces. All mechanical properties of ABS-ESD7 are within five percent of the ratings for ABS-M30.

ABSi

ABSi™ is an ideal material for conceptual modeling, functional prototyping, and direct digital manufacturing. ABSi's advantage is translucency. Its strength is superior to standard ABS, and the translucent nature of ABSi is beneficial for monitoring material flow and light transmission, most commonly used for medical and automotive applications. Parts made from ABSi are visually unique, dimensionally accurate, durable, and hold their shape over time.

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ASA

A good general-purpose thermoplastic is acrylonitrile styrene acrylate (ASA). It has improved mechanical properties versus ABS, and it boasts one important distinction: UV stability. ASA builds UV-stable parts that won't degrade with prolonged exposure to sunlight, plus it offers some of the best aesthetics of any FDM thermoplastic. ASA's mechanical properties and aesthetics also are good for general-purpose prototyping. It also offers 10 color choices, more than any other FDM material, and colorfastness.

PC

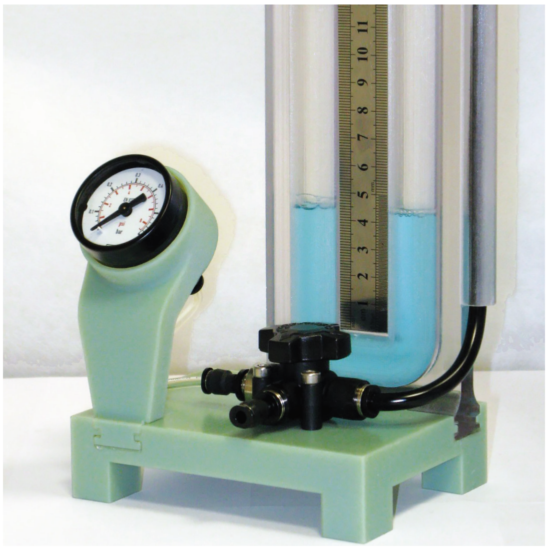
PC is the most widely used industrial thermoplastic, with high tensile and flexural strength and good heat resistance. It has the second highest tensile strength of all FDM materials and a high heat deflection temperature of 280°F (138°C). This is a serious material for tough applications, including functional testing, tooling, or production.

PC-ABS

A blend of polycarbonate and ABS gives the most desirable properties of both PC and ABS materials. It has the superior mechanical properties and heat resistance of PC, including one of the highest impact strength ratings of all the FDM materials. Meanwhile, it has the good flexural strength, feature definition, and surface appeal of ABS. 3D printing in real engineering thermoplastics results in stronger parts, more confident testing, and prototypes that mimic the material properties of the final product.

PC-ISO

Like ABS-M30i, PC-ISO is a biocompatible (ISO 10993 and USP Class VI) material, which makes it another FDM alternative for medical, pharmaceutical, and food packaging industries. PC-ISO is sterilizable using gamma radiation or ethylene oxide methods and is invisible to MRI machines.



Engineers used a Stratasys FDM 3D printer to develop this medical device prototype.

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PC-ISO has high tensile and flexural strength and a high heat deflection temperature. In these categories, its values are 33 percent to 59 percent higher than those of ABS-M30i. PC-ISO is commonly used in food and drug packaging and medical device manufacturing because of the material's strength and medical compatibility.

PLA

PLA is a renewable and biodegradable plastic material offered as a low-cost option for fast-draft part iterations in translucent or opaque. PLA offers good tensile strength, a higher stiffness than ABS and strength comparable to polycarbonate. Its low melting point and HDT mean less heat and power are needed for modeling. PLA works well for quick concept verification and design validation. Ideal applications include early concept modeling, fast prototyping and metal part casting.

ULTEM 9085 Resin

One of three high-performance engineered thermoplastic materials available for FDM, ULTEM™ 9085 resin is found in many aircraft and aerospace products because it meets stringent safety requirements. ULTEM 9085 resin is FST rated, which means it satisfies flame, smoke, and toxicity standards. Even if an application doesn't require FST rating, the strength, durability, and resistance to heat and chemicals make ULTEM 9085 a good choice for fully functional prototypes or end uses.

ULTEM 1010 Resin

ULTEM 1010 resin offers the highest heat resistance, chemical resistance, and tensile strength of any FDM thermoplastic. It is the only FDM material with an NSF 51 food-contact certification and is biocompatible with an ISO 10993/USP Class VI certification. ULTEM 1010 has been used to 3D print medical tools, such as surgical guides that can withstand steam autoclaving. With the lowest coefficient of thermal expansion of any FDM material, ULTEM 1010 resin is perfect for many industrial tooling applications and other parts that require the unique combination of strength and thermal stability.

PPSF/PPSU Polyphenylsulfone

The first high-performance engineered thermoplastic available for FDM was PPSF (also called PPSU). PPSF has good heat resistance

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(372°F/189°C heat deflection temperature) and chemical resistance. It is mechanically superior to other FDM materials outside the high-performance materials. PPSF is resistant to oils, gasoline, chemicals, and acids.

Like ABSi and ABS-M30i, PPSF is sterilizable, but because of its temperature and chemical resistance, it can be sterilized by other methods, including steam autoclave, plasma, chemical, and radiation sterilization.

FDM Nylon 12

FDM Nylon 12 is the first material in Stratasys' family of nylon offerings. Nylon 12 enables new applications requiring repetitive snap fits, high-fatigue resistance, strong chemical resistance, and press (friction) fit inserts. Primarily used in aerospace, automotive, and consumer goods industries, Nylon 12 offers unparalleled toughness and a simple, clean process that's free of powders. Nylon 12 parts exhibit 100 percent to 300 percent better elongation at break and superior fatigue resistance over any other additive manufacturing technology.

Material Suited for Medical Applications

MATERIAL	KEY CHARACTERISTICS
ABS-M30, ABSplus	Versatile, tough
ABS-ESD7	Electrostatic discharge resistant
ABS-M30i	Biocompatible
ABSi	Translucent
ASA	UV stable
PC	Strong (tension)
PC-ABS	Strong (impact)
PC-ISO	Biocompatible
PLA	Fast draft printing, high-resolution parts
ULTEM 9085 resin	Mechanically well-rounded
ULTEM 1010 resin	Biocompatible, highest heat resistance
PPSF	Resistance (thermal/ chemical)
FDM Nylon 12	Strong (high fatigue resistance)
FDM Nylon 12CF	Highest flexural strength. Highest stiffness-to-weight ratio.
FDM Nylon 6	Strong (impact), tough (high fatigue resistance)

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FDM Nylon 12CF

FDM Nylon 12CF™ is a carbon-filled thermoplastic with excellent structural characteristics. The material is comprised of a blend of Nylon 12 resin and chopped carbon fiber, at a loading of 35% by weight. This combination produces one of the strongest thermoplastics in the FDM material portfolio. It has the highest flexural strength of any FDM thermoplastic, resulting in the highest stiffness-to-weight ratio. Appropriate uses include strong but lightweight tooling applications and functional prototypes in the aerospace, automotive, industrial and recreational manufacturing SR-110™ support material.

FDM Nylon 6

FDM Nylon 6™ combines strength and toughness superior to other thermoplastics for applications that require strong, customized parts and tooling that lasts longer and can withstand rigorous functional testing.

Engineered with nylon 6, a popular thermoplastic for manufacturing, this material works with the Fortus 900mc™ to produce durable parts with a clean finish and high break resistance. FDM Nylon 6 is ideal for product manufacturers and development engineers in automotive, aerospace, consumer goods and industrial manufacturing.

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FDM technology lets Acist Medical Systems test prototypes quickly and easily.

A NEW WAY TO THINK ABOUT MEDICAL DESIGN

3D printing is a good alternative to existing manufacturing technologies. But it can be more than a new way to do old things. It can be a new way to design new products, and even new categories of products, that were unthinkable or unmanufacturable with traditional technologies.

3D printing lets designers consolidate parts, reduce assemblies, create negative draft, or build variable wall thicknesses. Designers can add material where it's needed for strength and use less where it's not critical. Options with 3D printing include complex geometries, organic shapes, hollow interiors, and more.

For example, Acist Medical Systems, located in Eden Prairie, Minn., designs and manufactures contrast-injection devices for cardiologists and radiologists. The company uses 3D printed parts in functional testing, fixtures, and production parts. In complex assemblies, Acist uses 3D printing to design plastic parts as efficiently as possible around machined parts, circuit boards, and integrated circuits.

In Acist's EmpowerCTA injection system, a lower-pressure injector, 36 parts went into the display, seven of which were FDM parts. FDM technology enabled Acist to design for manufacturing in a new way by combining parts and building in additional complexity. This approach would have been impossible with traditional manufacturing methods such as injection molding.

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Specifically, if Acist hadn't used FDM's additive manufacturing method, the seven parts that now complete the display would have been 15 — more than double the parts to manufacture and stock. Acist designed the FDM parts around the machined parts, circuit boards, and integrated circuits to optimize design for manufacturing ability. A solid, tested design is important before moving on to mold and machine parts.

The company even tests functional 3D printed units in customer settings. In one instance, operators pointed out the need for multiple types of transducers to be connected to the same machine, along with the ability to switch rapidly from one transducer to another. Acist quickly designed a part in CAD software to solve this problem and printed it with a Dimension™ 3D Printer as a functional part to be shipped and used on machines worldwide. Acist emphasizes that the part, easy to create and print with FDM, would have been very challenging to mold using traditional methods.

Another example of a 3D printed part highlights how the technology allows creating new medical devices that have never been made before. Researchers at Nemours/Alfred I. duPont Hospital for Children in Wilmington, Del., created a scaled-down exoskeleton for a young girl using an FDM 3D

An FDM 3D printer allows Emma to wear a custom lightweight exoskeleton, which enables her to fully use her arms.

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Printer. The custom device is durable for everyday use and can be redesigned as the child grows. The parts for this device would otherwise be too small and detailed for traditional CNC systems.

3D printing for medical applications will continue to grow as new materials and new ideas are realized. The technology provides many benefits, including the customization and personalization of medical products and equipment, cost-effectiveness, increased productivity, and enhanced collaboration. It also is helping to create new designs and products — and categories of products — that had previously been impossible or were inconceivable. The day is not far off when an operating room contains surgical instruments that are prototyped and redesigned using 3D printing, the fixtures that hold instruments and keep the room organized are 3D printed, the cases on the monitoring equipment are 3D printed, the implant going into the patient has been customized and built by 3D printing, and the surgeons practice the procedure using 3D printed anatomical models. Free from the constraints of conventional manufacturing, designers, engineers, doctors, surgeons, and other entrepreneurs can think differently about design, creating parts solely for desired form, fit, and function.

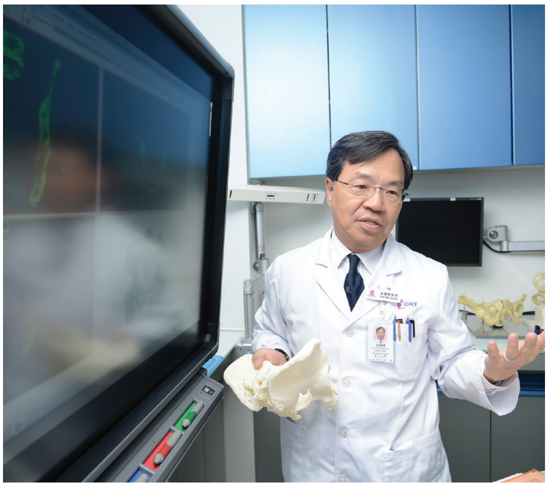
3D printed products are produced faster and for a lower cost than traditionally manufactured parts.

3D Models Improve Hospital's Orthopedic Surgeries

Pre-surgery planning and rehearsal using 3D printed models has reduced complex surgery time by an hour and improved success rates.

Professor Kwok-sui Leung is expanding his department of Orthopaedics and Traumatology, Faculty of Medicine of the Chinese University of Hong Kong (CUHK) beyond its traditional role as an academic clinical department. At the department's Prince of Wales Hospital, Leung is improving the success and accuracy of surgeries, boosting patient confidence, and exploring new innovative surgical methods all at once. How?

By using 3D printing to create bone models and surgical guides for orthopedic surgery preparation.



3D printing is ideal for prototyping bones because the calcium in the human skeleton makes the scanned images very clear. A Computed Tomography (CT) scan generates the required files for 3D printing. Surgeons use the 3D printed bone models for consultation, assessment, and surgical planning for conditions including bone cancer surgeries, degenerative arthritis, realignment of deformed limbs, and reconstruction of fractured bones.

Reduced Costs and Time for Surgeries

The Prince of Wales Hospital adopted a Fortus 3D Printer from Stratasys that uses FDM technology to print both surgical guides and surgical tools. Before using 3D models to prepare for surgical procedures, most surgeons at the Prince of Wales Hospital relied on their experience and CT scans to visualize and plan the operation. Validating their planned approach took place in the operating room. Preparing for an operation using 3D printed models shortens the surgical process and increases operation accuracy and success rate.

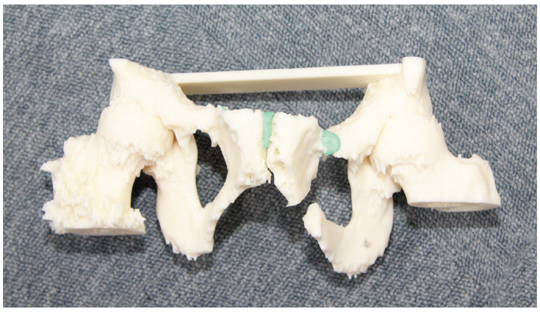
"Patients' 3D printed bone models are used to test different positions of stabilizing plates or screws. 3D printing allows in-depth assessment and pre-surgical rehearsal, resulting in a smooth operation process in which implants are more accurately fitted to the curvature of the patient's bone," Leung said. "The risk of bleeding and subsequent infection is also reduced."

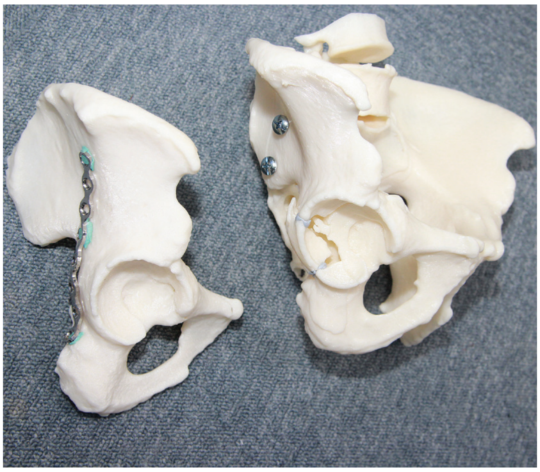
One of the most common incision sites in bone cancer surgeries is at the end of the femur, close to the knee joint. To completely remove the tumor and reconstruct a functioning extremity, accuracy of an incision site is critical. Correcting pelvic fractures from car accidents — another routine hospital procedure — also requires extreme precision. For complex procedures, such as determining the angle of screw placement and location of metal implants, 3D models provide
the trial space necessary to gain the accuracy desired.

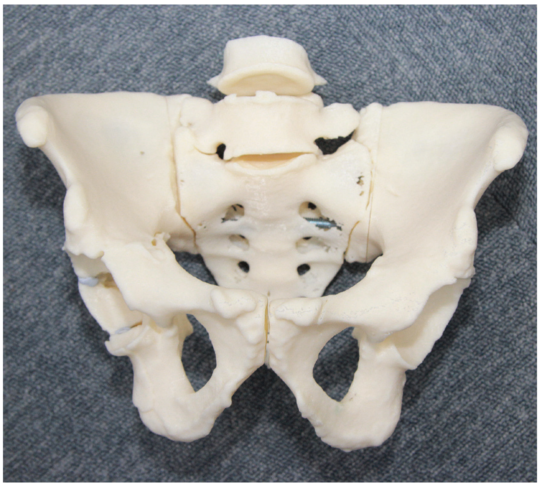
Prince of Wales Hospital uses 3D printing in cases ranging from corrective osteotomy (re-alignment of bone from deformity) to complex bone fractures from car accidents. On average, operation time has been reduced by an hour when incorporating 3D printed parts in the pre-surgical process.

Creating Innovative Approaches

Elvis Chun-sing Chui, biomedical engineer at the Orthopaedic Learning Centre of CUHK, said, "The adoption of 3D printing provides a platform to experiment with innovative surgical approaches. Moreover, it enhances the communication between medical practitioners and patients. Patients better understand the diagnosis and treatments with the aid of the 3D printed parts."



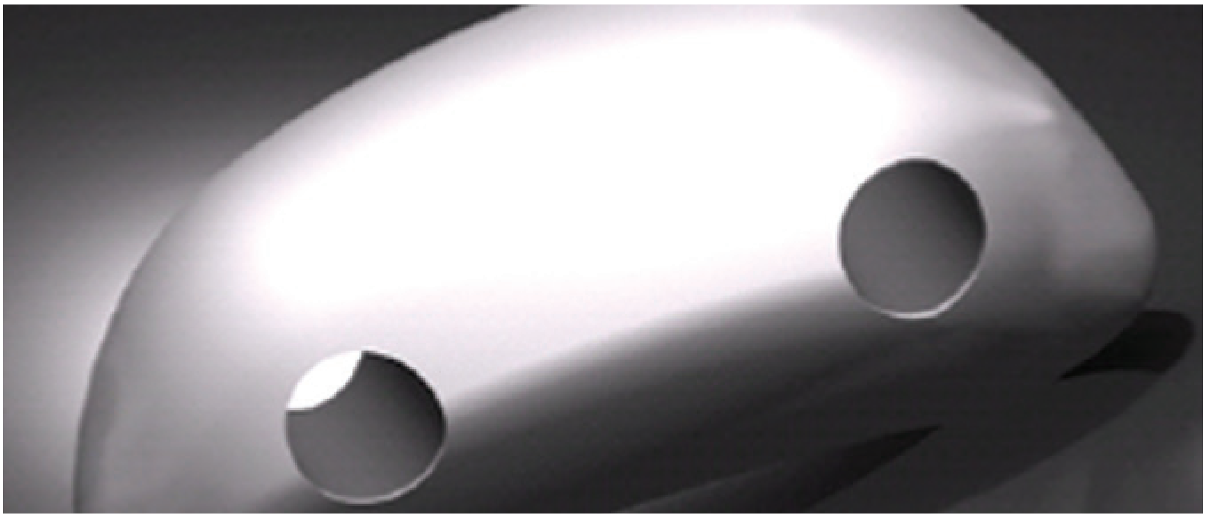




In addition to printing surgical guides, CUHK and Prince of Wales Hospital have further extended their applications to printing small, single-use surgical tools.

For example, frequently it's helpful for orthopedic surgeons to use a guide to ensure accurate screw placement before inserting them into the bone. These small, plastic guides are custom made for each individual patient, based on their unique anatomy and surgical procedure. And because the Fortus 3D Printer can build with PC-ISO, a biocompatible thermoplastic that is sterilizable, the clinician can use the guides on patients directly from the 3D Printer. In one case, the 3D printed guide only cost approximately HKD100 — several times less than traditional manufacturing costs, and production was much quicker as well.

"3D printing helps us advance medical research and development," said Leung. "[3D printing] offers ample potential in both the surgical guides and surgical tools areas. And, the cost saved from using 3D printing can now be used for research and development, ultimately benefiting patients, surgeons, and researchers."



CAD model of patella.

FDM Implant Puts the Spring Back into Oreo's Step

In 2011, a six-year-old mixed breed dog named Oreo suffered a dislocated left hind patella. The patella was removed to relieve the pain, but the dog became lame after the surgery. The veterinary practitioner then consulted the Orthopaedic Innovation Centre (OIC), a Canadian research and testing facility that serves the medical device market, about the possibility of creating an artificial implant for Oreo. The OIC, which regularly uses 3D printing to shorten the design and production cycles for its clients and create low-volume or customized products, saw this as an excellent solution for Oreo.

To help Oreo, OIC obtained a donated patella that was used to generate a scaled digitized copy. A biomedical engineer then converted the file into a computer-aided design (CAD) model. X-ray radiographs of Oreo's other patella were then used to modify the CAD design to match his femur.

"In Oreo's case, we were able to produce a custom-tailored implant in only four days, including design, analysis, physical testing, and manufacturing. As we move down the learning curve, it will probably be possible to produce similar implants in only a day or two."

3D Printed Implant

OIC built an artificial patella using FDM technology on its Stratasys 3D Printer with PC-ISO bio-compatible polycarbonate (ISO 10993 USP Class VI). Physical testing was performed on the implant to validate its ability to provide the necessary mechanical strength. The implant was sterilized using ethylene oxide at

54°C (130°F) for one hour. During Oreo's surgery, the implant was attached to the tendon and quadriceps using polypropylene sutures.

Oreo recovered without incident, and eight weeks after his surgery he had regained complete function of his leg, with a full range of motion and weight-bearing capacity. His owner reported that he could once again go on long walks and jump using both hind legs. Now, more than three years later, Oreo continues to enjoy an active lifestyle without complications, thanks to his 3D printed implant.

"FDM is an ideal technology for implant manufacturing because it is capable of producing strong, durable, biocompatible parts with the right physical properties," said Martin Petrak, president of Orthopedic Innovation Centre.

"With FDM, we can tailor the implant to perfectly match the recipient's anatomy, which has the potential to provide dramatic improvements in functionality and recovery time."

Oreo

ABOUT STRATASYS

Every day, our customers find simpler, smarter approaches to stubborn design problems — and greater confidence to confront towering human and technological challenges. By providing the shortest possible path from idea to solid object, Stratasys empowers them to untangle complexity, tackle tough problems, uncover new solutions — and to do it all with the urgency our accelerating world demands.

We've been at the forefront of 3D printing innovation for more than 25 years. We are fueling the next generation of innovation through our work in aerospace, automotive and education. We're trusted worldwide by leading manufacturers and groundbreaking designers, makers, thinkers and doers.

For more information, visit www.stratasys.com.

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