PRODUCT DESIGN & DEVELOPMENT®

The Anatomy of Modeling Humans

Trade in your clay, wax and plaster for software designed to rapidly create complex, organic shapes.

By Jon Green, VP Manufacturing, GPI Anatomicals

Educating patients is serious business.

That's why anatomical models that show the inside of a knee or heart, used by doctors to help explain a patient's condition, are meticulously accurate – and far more complex to design and manufacture than even savvy design engineers would suspect.

GPI Anatomicals, in Lake Bluff, IL, has made over 4 million medical models since 1990 for pharmaceutical, orthopedic, and medical device companies worldwide. While GPI Anatomicals offers over 75 stock models of various body parts – healthy and in various stages of degeneration or disease – many of its customers must explain disease conditions relative to their products, which requires a custom illustrative model — therein lies the design challenge.

Ostensibly the task of designing an organically shaped model seems doable with computer aided design (CAD), today's equivalent of power tools for the design process. At GPI, the staff can both understand medical language and translate anatomical feedback from physicians. Rough design concepts are initially sketched in 2D then refined in 3D modeling software, cross-checked against Grey's Anatomy (the book, not the TV show), reviewed multiple times by doctors, and manufactured in molded plastic using the latest cost-effective rapid technologies.

With the human body being irregularly shaped; criss-crossed with arteries and veins, nerves, ligaments, tendons and muscles, an anatomical model is relatively complex to define digitally. Add to that the challenge of designing a single solid object from multiple interlocking pieces that a doctor or patient can take apart, while also having the models elegantly displayed on a base — and these shapes can take on many layers of complexity.

As recently as last fall, GPI's team relied on processes as old as the Hippocratic Oath – developing their models by hand in clay, wax or plaster. These models undergo multiple iterations, as changes directed by clients or medical experts are endemic to the model-making business.

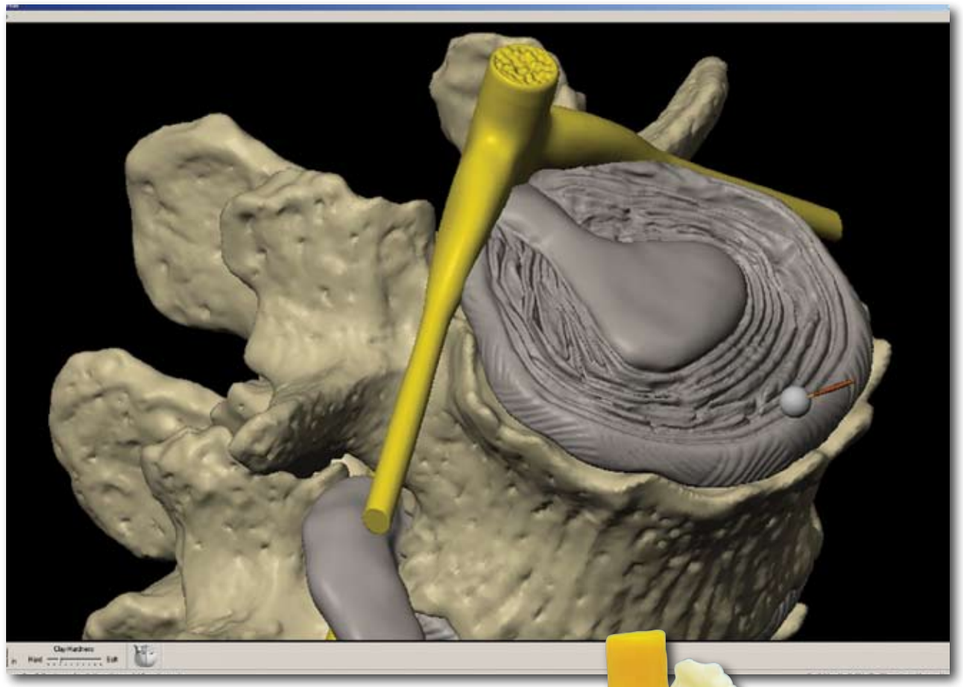
Reverting back to a clay model for each design revision can add days or weeks to a project's development. The team has also struggled to

integrate pieces of models made by various team members having different styles into a homogenous finished model. Due to these challenges in the design and development process, company CEO and founder Scott Galloway felt it was time to find a better way.

Complex, Organic Shapes Welcome

In July 2008, GPI purchased their first FreeForm 3D modeling system from SensAble Technologies (Woburn, MA). Designed for the rapid creation of complex, organic shapes, FreeForm is useful for many stages of the product lifecycle – from concept and product design, to scan cleanup and product development.

The FreeForm system allows users to model with virtual clay – quickly and intuitively inflating, tugging, smoothing, and carving to create the often asymmetrical, dysmorphic shapes of a diseased or damaged body part.



A custom spinal model project presented the first opportunity to take advantage of the new technology -- the FreeForm 3D modeling system from SensAble Technologies.

With FreeForm, designers use a force feedback haptic device instead of a computer mouse, allowing them to actually 'feel' the on-screen model as they sculpt and carve in a manner akin to creating a model out of physical clay, foam or wood. The FreeForm haptic device (known as the PHANTOM) makes the 3D modeling process more direct and natural, while also delivering time savings in the initial modeling and development.

Vertebrae Model Is Easily Modified

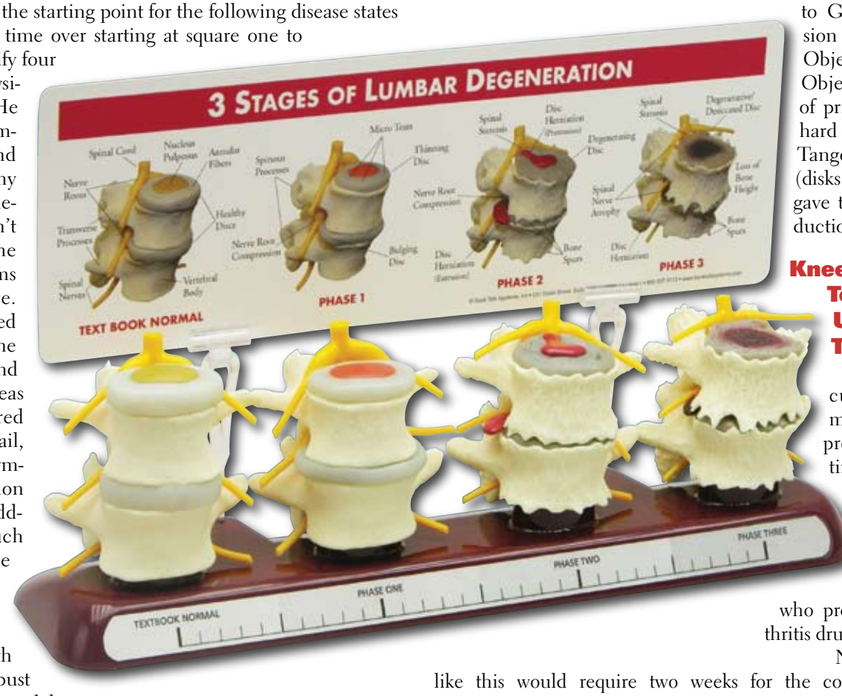
A custom spinal model project presented the first opportunity to take advantage of the new technology. A professional chiropractic company, BT Systems Inc., came to GPI requesting four larger-than-life-size models of the L4 and L5 human vertebrae showing stages of osteoarthritis – a normal state along with three stages of progressive spinal degeneration. The client needed specifically detailed views not found in GPI's extensive stock model lineup, so a custom design was in order.

Two medical designers were assigned to the project – one with years of experience in parametric modeling programs, the other a senior designer with expertise in translating customer visions into 3D models by hand. Neither had ever worked with FreeForm before.

Knowing how long it can take to master traditional CAD programs, both designers were pleased and surprised that within just a few days they were actively using FreeForm and progressing with the project. The project began with CAT Scans of the L4 and L5 vertebrae taken from multiple sources, and imported as STL files into FreeForm for use as template information.

The senior designer began by creating a 'normal' vertebrae from the CT scan data, using FreeForm for smoothing and fixing 'holes' in the scan data, and then modifying and detailing the bone model to be anatomically accurate and unique to GPI.

The second designer then used the digital model of the healthy 'normal' vertebrae as the starting point for the following disease states — saving significant time over starting at square one to create and then modify four different sets of physical clay models. He found he could comfortably design and model the anatomy with FreeForm, something that wouldn't be possible with the parametric programs he'd used before.



FreeForm was used to enlarge and refine the source files and redefine certain areas with slightly altered shapes or greater detail, for example deforming a certain portion of the bone or adding pathologies such as osteophytes (bone spurs) or degenerated disks. Running on an HP XW 8400 machine with 8GB of RAM – robust enough for fast 3D modeling – FreeForm had the tools needed to quickly and easily make these changes, including the tug and smooth tools for overall form making, and texturing tools such as emboss and carve tools to add details. Using the PHANTOM haptic device and 'feeling' the model as he sculpted the virtual clay helped streamline the process.

Throughout development, BT Systems Inc., required multiple revisions and reviews of the evolving models. FreeForm allowed the designers to create QuickTime VR movies of the model that were then emailed to the client for quick review and comment. The Quicktime VR files allowed viewing and spinning the model in real time. This ability to view models virtually was extremely helpful to the client and model development. It eliminated the several days that would have been required if using traditional techniques, including packing and overnight-shipping the physical clay models, and then waiting for the chiropractor to send back the changes.

Once the models were approved, GPI used a combination of FreeForm's autosurfacing tool and SolidWorks to prepare the final models for manufacturing. IGES files of the Freeform models were output to SolidWorks, where they were used to help create a custom base for the models.

Items such as holes for assembly and mounts for the base were also added to the models in SolidWorks. The ability to integrate the two CAD packages was essential in reducing the product development process by weeks. The final files were output in STL format and sent to GPI's Prototype division for print out on an Objet 3D printer. The Objet printer was capable of printing in both Vero hard material (bone) and Tango flexible material (disks and nerves) which gave the customer a production-quality prototype.

Knee Model, Team Effort Under Tight Timeframe

Not long after the custom vertebrae model project was in production, a long-time pharmaceutical client asked for a custom prototype of a human knee model to be provided to doctors who prescribed an osteoarthritis drug – in just one week. Normally, a project like this would require two weeks for the concept phase alone.

Internal debate ensued on whether sculpting an initial model by hand would be faster than digital design, since the team had existing knee bone models on hand that could easily be used as a starting point.

Time pressures drove the decision to design digitally, but in order to meet the deadline, the project had to be parsed out among four designers. To make sure all components were integrated smoothly, the group selected the same FreeForm-using designer from the vertebrae project to design the knee itself and assemble the finished project.

FreeForm allowed GPI's design team to shave weeks from the design time cycle – and deliver a production-ready model in just four days.

Since GPI Anatomicals had designed numerous knee bone models in the past, many digital source files existed. What was miss-

ing was the skin, muscle and other tissue around the bones. Using the Poser software program, a digital leg was positioned in different angles of flexion in order to find the one that best provided a clear anatomical view.

The files were exported as OBJ files and imported into FreeForm, where they were scaled to size, sectioned down the middle and sculpted to conform to the underlying bone anatomy. Screen shots of the top and side views of the knee were taken, brought into Photoshop, and used to create alpha maps for the model textures. Using FreeForm's emboss tool feature, the alpha maps were projected onto the surface of the digital knee – effectively embossing and debossing the surface texture details. This step alone saved several days of design time over traditional sculpting methods.

Those in the design team who had voted for a clay model as a starting point had an eye-opening moment. The product development team was amazed that the unrealistic deadline that GPI's design team had been given – produce an approved final design in a week – was actually realized.

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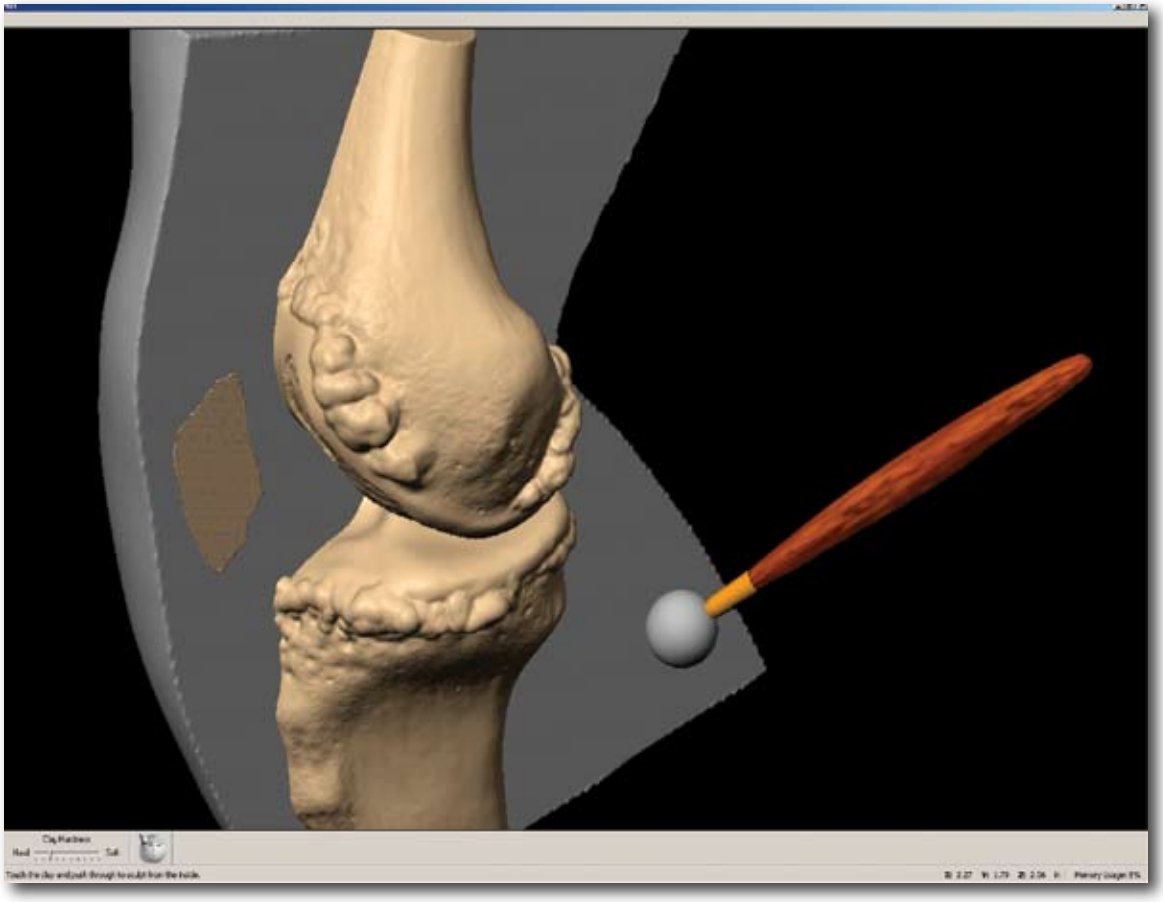

Toward a Complete Body Part Library

Over time, GPI's goal is to create its own library of digitally defined body parts that the company can customize when clients call.

FreeForm's speed and flexibility with organic design is propelling this effort at a far faster pace than when designs began in clay. As the digital library grows, the design team has also begun using FreeForm to sketch out sample ideas for concept presentations – ideas that take less time to generate, are more accurate and realistic; and, if approved, save time when they are refined into final concepts.

In a business where designing complex, organic shapes is its livelihood, GPI Anatomicals found FreeForm to be the perfect fit.

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For more information visit www.gpianatomicals.com. PDD

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