Medical Case Study: Saving Cyrano- How Additive Manufacturing Helped Create a one-of-a-kind knee joint for a cat- EOS

Cyrano escaped a leg amputation thanks to laser sintered prosthesis

For quite some time, Mr. Cyrano L. Catte II, an orange-and-white cat, had the perfect life. He had a nice home in Upperville, Va., U.S.A., more than adequate food, and owners who loved him very much. Then, at the age of nine, he got bone cancer in his left hind leg. Cyrano's owners spared no expense or effort. They took him to the University of Colorado, where he made instant veterinary history by being the first cat to receive stereotactic radiation (focused beams aimed at the tumor) therapy. Two sets of radiation cured his cancer – full remission – but one of the side effects was bone deterioration of his distal femur and some on the upper end of the tibia as well. The normal procedure for such a condition would be to amputate the leg. In Cyrano's case, that was not recom- mended: he weighed 26 pounds, and movement on three legs would be difficult.

Cyrano the cat (above) is the first feline in the U.S to receive a Total Knee Arthroplasty (TKA). Femoral and tibial components were created with a Direct Metal Laser Sintering (DMLS) system from EOS (Source: NC State University).

Challenge

One potential alternative would be a complete replacement of the cat's knee (stifle) with an artificial one – a first in the U.S. for felines. Cyrano's intrepid owners took him to the veterinary facility at North Carolina State University in Raleigh to met with Dr. Denis Marcellin-Little, a veterinary surgeon and a professor of orthopedic, and Professor Ola Harrysson of the Industrial and Systems Engi- neering (ISE) department. Right away they recognized the challenges: The implants have to be very small and because of the poor quality of the joint's bone structure stems were needed to anchor the implant components with the bones.

Just as quick, they decided using Direct Metal Laser Sintering (DMLS) from EOS to make the two main components of the artificial knee. The addition of the stems and the incorporation of features to match up with custom drilling and cutting guides gave the metal components shapes that were not readily manufacturable by traditional molding or subtractive cuttingProcess.

There was also the issue of the varied surface textures of the final device. "From an orthopedic standpoint, we wanted to include different types of surfaces," Marcellin-Little says. The two stems that extended inside the hollowed-out femur and tibia were slightly textured to promote bone ingrowth. Further up on the femoral and tibial components was an area of porous mesh to facilitate strong osseointegration. While the stems provided short-term stability for the implant, the textured and meshed surfaces would promote long-term stability. Finally, the bearing surface at the end of each cobalt chrome piece had to be extremely polished to enable smooth motion against the polyethylene tibial mobile bearing surface, which would rotate during leg movement.

Solution

Design started with 3D data from CT scans of Cyrano's good and bad hind legs. 3D design models of the implant components were made using MIMICS software from Materialise. "We started from one of BioMedtrix's knee implants for dogs and miniaturized it," Marcellin-Little says. "We added the stems, the bolts that hold the stems in place, and other features unique to this design." The result was very sophisticated compared to other feline implants currently in use. "We incorporated features from human devices," Harrysson says. "The trick was in making them small enough for a cat – think

Of a finger joint prosthesis, which would be about the right size.

The metal component models were manufactured at EOS' global headquarter in Krailling, Germany, sent to BioMedtrix for finishing and then the DMLS parts were ready for handing off to the surgical team.

Results

DMLS can work with a number of different metals. Titanium is great for bone ingrowth but it is much softer than cobalt chromium. "The loads on a titanium femoral head would wear the metal down eventually. Because the implant components would already be thin in some places, they might be subject to breaking or cracking if they eroded still further. Cobalt chromium was our best choice," Marcellin-Little points out.

All these textures were possible, and fairly easy to create, by using Additive Manufacturing. "The EOS technology not only gives us design freedom for orthopedic implants," Harrysson says. "It also offers the means to build osseointegrated surfaces directly into the part." Traditionally manufactured implants often have surfaces added in post-processing, such as multiple layers of beads sintered on manually. Plasma spraying and other surfacing techniques are not as accurate as DMLS, which allows designers to specify the pore size, density, and the layout of the porous section.

Key to the project was assembling a multi-talented design and manu- facturing team, which consisted of 16 experts and spanned five states and two continents. "This kind of implant had never been made before, and this surgery never attempted," Marcellin-Little says.

The surgery, which took six hours, went smoothly. "As we suspected, Cyrano's distal femur had very poor bone quality," Marcellin- Little notes. "Without the stems that we had designed in, the femoral component would not have been stable at all, even if we had used polymethylmethacrylate bone cement."

Afterwards Cyrano began the long road of rehabilitation and therapy that would lead to his recovery. He did well. Besides his observable limp, he is able to use the leg and joint. "Cyrano was a perfect patient, very cool and very calm," Marcellin-Little says. "He is much more comfortable than he had been since the cancer developed, and he's pleased, and his owners are pleased"

"The main change this techno- logy has brought is that the manufacturing process is no longer a barrier to the imagination of an orthopaedic clinician who needs to create something very specific."
Dr. Denis Marcellin-Little, Veterinary Surgeon and Professor of Orthopaedic Surgery in the College of Veterinary Medicine at NC State

"What we learned from the Cyrano project is transferable to other animals and even to human medicine. Now that we know how to miniaturize a joint this sophisticated there are a number of potential applications, in hands or jaws, for example."
Ola Harrysson, Professor of the Industrial and Systems Engineering (ISE) department at NC State