Paper Reference
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Edexcel GCE Chemistry (Nuffield)

Advanced Subsidiary

Unit Test 2: Passage for Section B

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BONE MAKERS

Injuries to the skull and face can leave the bones damaged beyond repair. In the past, surgeons have resorted to metals, such as titanium, to pin bones together. More recently, they have used polymer composites as implants, which come close to bone in strength and mechanical properties. But for facial surgery to be really successful, the implant needs to be made to a precise three-dimensional structure so that it complements the person's skull, and gives them back their own unique features.

For about ten years surgeons have been using 'artificial bone' as their implant material. This was originally a composite of poly(ethene), which is well tolerated in the body, together with hydroxyapatite ($Ca_5(PO_4)_3(OH)$), a brittle inorganic mineral that makes up most of our bones. The composite behaves like bone in the body because it is chemically similar to natural bone. Thus some of the calcium phosphate which is present in hydroxyapatite forms ions and dissolves. This encourages bone to grow up to the surface of the artificial material unlike metals, which cause loss of bone tissue at the metal-bone junction.

Research chemists have used supercritical carbon dioxide ($scCO_2$) to process polymers. Under supercritical conditions – at temperatures above 31 °C and pressures 70 times above atmospheric pressure – carbon dioxide is neither liquid nor gas, but has the properties of both. Like a liquid, $scCO_2$ can dissolve a range of solutes, and like a gas it has low viscosity. Adding $scCO_2$ to a polymer lowers its "melting" point. Normally, high temperatures are required to turn a polymer to a viscous liquid. It is difficult to mix a solid such as hydroxyapatite into the polymer, but with added $scCO_2$ this process becomes easier.

Surgeons need implants with very precise shapes for facial implants. To reproduce these shapes the face is scanned, information is captured on a computer and sent to a laser machine. The computer-controlled laser plays on the surface of a bath of liquid monomer, hydroxyapatite and $scCO_2$, and the monomer is converted into solid polymer where the laser hits. The base in the bath then moves down a step and the laser draws the next layer and so on until there is a three-dimensional model of the image. The model is then removed from the bath and cleaned with $scCO_2$, the latter now acting as a solvent to remove toxic residual monomers.

This method can only be used with acrylic monomers (i.e. derivatives of propenoic acid, CH_2=CHCOOH) because these absorb laser light and convert to the solid polymer. However, acrylic polymers are not the ideal implant material. They are intrinsically toxic, which can lead to inflammation in the body. Despite these drawbacks, precision-shaped implants have been made with composites of poly(methyl methacrylate), common name Perspex, mixed with hydroxyapatite.

When one of these implants is used to repair a bone, the piece of plastic, like a metal plate or pin, will be there for the rest of the patient's life. These implants would not be suitable for a younger child who is still growing. The composite would not grow with the child.

Chemists are now making implants out of biodegradable polymers. They have used poly(lactic acid), and mixed it with growth hormone. They hope this will stimulate the growth of bone cells, and eventually bone, on and around the implant, so that as the polymer degrades it would be replaced by real bone. However biodegradable polymers do not absorb laser light so the chemists add a surface coating of carbon. This absorbs enough energy from the computer-controlled laser to melt the surface of the polymer, fusing the particles together and making a three-dimensional model.

The next step will be to make real implants to transfer into patients. Eventually, such biodegradable implants with specific shapes could be used in patients who are still growing, and who will end up with natural bone in their bodies rather than plastic.

[644 words]

Adapted from "Bone Makers" by Kathryn Roberts, Education in Chemistry, March 2005