Traditional surgical management for cancer affecting skeletal structures has involved amputation. This loss of skeletal support will usually have a structural and a functional impact on the patient. Although amputation is considered the gold standard when cancer disrupts the appendicular skeleton, the presence of orthopaedic or neurological deficits affecting other limbs may prevent the patient adapting to acceptable mobility. In these cases, limb-sparing techniques have been developed to provide a viable curative intent treatment. Reported techniques include autografting (after pasteurisation or irradiation of the tumour), allograft, distraction osteogenesis, manus translation, ulna rollover, vascularised fibular grafts or the use of metal endoprosthetics. Stereotactic radiosurgery has also been reported to provide good clinical results in selected cases.

The earliest method for limb-sparing involved replacement of the cancerous segment of bone with a similar sized and shaped length of bone harvested from a cadaver (cortical allograft). Whilst allograft replacement of the distal radius provided good clinical function, it was limited by the immunogeneity of the implant, which lead to rejection in more than 50% of cases. This high complication rate, and the difficult logistics of sourcing sterile cadaveric bone, stimulated the interest for a wholly synthetic implant that is available 'off-the-shelf' and suited for a range of patient sizes. The use of synthetic prostheses is well-developed in human oncologic surgery, with a variety of implants available for limb salvage of various bones. Complications of prosthetic replacement include mechanical failure of the prosthesis (8-29%), and soft tissue infection (26%). In general, excellent clinical results are reported. The advantage of a metal prosthesis is a bone bank is not necessary, and the surgical planning and performance are much easier. A veterinary-specific stainless steel endoprosthetic is available in the US. Dogs tolerate this technique very well, but complication rates are high with significant infection or implant failure developing in more than 50% of patients. Given that 50% of dogs with bone cancer will succumb to metastatic disease within a year of treatment, this high complication rate erodes the enormous benefits that limb-sparing surgery can otherwise provide these patients for their remaining lifetime.

Stainless steel is a poor choice for managing large skeletal defects due to its relative rigidity, its poor integration with host tissues, and its propensity to retain a large bacterial biofilm burden on its surface. To overcome these complications, future success with endoprosthetics will likely involve the use of osteophilic materials that allow for bony ingrowth and soft tissue attachment. These properties allow integration of the implant with local tissues and greatly improve the strength, longevity and durability of the endoprosthetic construct.

Titanium and its alloys are rapidly becoming materials of choice for biomedical implants due to many favourable properties. The advent of computer aided design and 3D printing technologies using titanium powder allows creation of an implant that is uniquely designed to fit a specific patient. A crucial design element of the titanium implant is a porous scaffold that enables vascular and cellular ingrowth into the implant, such that new bone tissue will ultimately form on the implant surface. This potential for complete integration of the implant into the host tissues (a process known as osseointegration) is a ‘holy grail’ for human biomedical implants; integration mimimises the potential for infection and implant failure, which can be devastating for the patient. However, the precise geometry and architecture of the scaffold structure to support osseointegration along a length of a large defect remains unknown.

Computer-Aided Design (CAD) allows complex and patient-specific three-dimensional geometries to be designed that are optimally configured to the needs of an individual patient. Additive Manufacturing (AM) – otherwise known as 3-D printing – allows realization of the computer-designed implant. CAD and
AM provides a freedom from the design constraints of conventional manufacturing processes,\textsuperscript{13-15} whilst keeping build time and costs to a realistic level.

In human surgery, custom designed implants\textsuperscript{22,23} are rapidly gaining acceptance and have been utilised in a variety of situations, particularly for craniofacial reconstruction and joint reconstruction.\textsuperscript{15,23-25} Due to the precise geometric fit of the custom implant, surgical complexity and operating times are reduced, with improved cosmetic outcomes.\textsuperscript{15}

Veterinary experiences with CAD/AM of orthopaedic implants will be described in this lecture.\textsuperscript{14,29} It is likely that patient-specific porous titanium implants will provide an effective solution for functional sparing surgery of bone cancer at multiple sites in the skeleton, with a lower risk of infection-related complications. As with any novel procedure, several technical challenges remain to be overcome to ensure these implants can achieve their promised potential for all patients.

Selected references: