Orthopaedic Surgery

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Introduction

Over the past fifty years orthopaedic surgery made giant strides forward. It developed from a discipline that dealt primarily with the treatment of fractures, bone infections and tendon transfers and that treated degenerate joints by fusing them to one of such sophistication as to be able to treat fractures by internal fixation and early mobilisation. It is now possible to replace most joints in the body and to benefit from the results of stem cell research that hold promise of yet further exciting developments, the more important but by no means exclusive advances in orthopaedic surgery are presented.

Total hip replacement

Total hip replacement as a treatment of degenerative arthritis of the hip in patients with pain and curtailed physical activity has been widely acclaimed as being a success with some prosthesis claiming as high as a 3-decade long-term survival. Refined acetabular and femoral prosthetic designs, improved cementing techniques and the use of bio-integradable materials, such as hydroxyapatite have contributed in no small way to such long-term survival of both cemented and uncemented implants. Similarly the use of highly cross-linked polyethylenes for acetabular and tibial implants holds promise of improved wear rates and decreased prevalence of osteolysis.

In order to address the needs of young arthritic patients (below 50 years of age) with a high level of physical activity and a strong determination not to give up their sporting commitments there has been a revival of surface replacement of the hip. A hybrid hip made up of a cementless hydroxyapatite coated acetabular metal cup and a femoral metal prosthesis that is cemented to the existing femoral neck is gaining support. This metal-on-metal resurfacing of the hip has good short-term results with a cumulative five year survival rate of 98%.[1]

The Birmingham hip resurfacing arthroplasty (Midland Medical Technologies Ltd., Birmingham, UK) became available in July 1997. It is a high-carbon cast chrome-cobalt device and has the advantage of preserving femoral bone stock.

Although complications such as avascular necrosis and fracture of the neck of the femur have been reported, there is no doubt that metal-on-metal hip resurfacing arthroplasty has a part to play in modern orthopaedic surgery.

Minimally invasive total hip arthroplasty has created great controversy with regard to clinical efficacy, financial concerns and social issues The operation is performed through one or two small incisions. Clinical data suggests that the approach is associated with more complications when used by general orthopaedic surgeons.

The accuracy in positioning the components in a total hip arthroplasty may however be improved with the use of image-guided surgical navigation, thus overcoming the difficulties created by limited direct visualization.

Knee replacement

In Malta for every hip replacement that is performed, six knees are replaced. The prevalence of knee degeneration may be due to the fact that obese patients carry an extra load that has to be carried by a more peripheral joint, the number of stairs in most households, the considerable number of hills, and the fact that a number of Maltese patients have a tibia vara with consequent overloading of the medial compartment of the knee.

The clinical results of total knee arthroplasty are excellent but debate still continues about the differing fixation techniques and the use of different designs. Implant-survival rates of 91%, 84% and 78% at ten, fifteen and twenty years respectively have been reported by Rand *et al.*[2]

An all-polyethylene tibial component or a modular metal-backed tibial component are used. To address the issue of backside wear a mobile bearing total knee replacement was designed, using a rotating platform. However they are not suitable for severely deformed knees because of an associated increase in complication rate in such knees.

The use of a small incision and special jig instrumentation

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make a minimally invasive approach possible with decreased blood loss, early recovery of function and shorter hospital stays. The accuracy of implantation can be helped by the use of computer-assisted surgery. Perlick *et al* in a randomized study of eighty patients, compared computer-navigated computed tomography-based implantation with conventional implantation and noted significantly better mechanical femorotibial alignment in the study group; specifically the implant was positioned within ±2 degrees of the intended positon in 73% of the patients in the study group compared with 59% of those in the control group.

When the degenerative disease process involves only one compartment of the knee a unicompartmental knee replacement is sufficient to restore knee function and abolish pain. The medial compartment is predominantly replaced, the prosthesis can have a fixed or mobile bearing and ten-year survival rates range from 91 to 98%. In some centres where the minimally invasive technique is used, the operated patient is sent home that same day or the following day and is supported by a very efficient community care group that includes physiotherapists.

Stem cells and growth factors in orthopeadic surgery

Great progress has been reported on the results of orthopaedic research on the understanding of the genetic-basis of degenerative joint disease and the biologic response to injury. Studies on stem cells, growth factors and tissue engineering lead to the development of novel therapies and implants.

Tissue engineering aims at regenerating tissues and restoring organ function by implanting cells or tissues grown outside the body. Cells can be harvested from a donor site, grown on to a scaffold and stimulated to divide and differentiate into the required phenotype and finally transplanted as living tissue into the patient. These cells can be sourced from mature cells from the patient, from bone marrow (stromal or mesenchymal cells) and from embryonic stem or germ cells.

Stem cells are undifferentiated cells that can produce identical cells. The mesenchymal stem cell can be stimulated to generate osteoblasts, chondrocytes and adipocytes by manipulating the conditions of culture and by biochemical supplements to which they are exposed to produce bone, cartilage, muscle and adipose tissue. Tissues generated in this way can be used directly to repair large bone defects. Similarly vascularised bone flaps can be generated into a desired shape *in vivo* and then transplanted.

Children suffering from osteogenesis imperfecta had ablation of their own marrow before receiving allogeneic bone marrow transplants.[3] Within a few weeks there was an improvement in the amount and quality of the bone formed. The mesenchymal cells in the graft generated osteoblasts that in turn synthesised a normal bone matrix.

Adult stem cells are able to migrate towards damaged tissue and reside there to contribute to its repair and regeneration. Another possible application is the local transplantation of mesenchymal stem cells to the site of a fracture to promote healing by generating osteoblasts. At present insufficient knowledge on the long-term stability of the repair tissue and on the tendency of mesenchymal stem cells to differentiate towards other lineage restricts their use.

Growth factors are secreted proteins that act on cells to carry out functions such as cell division, cell differentiation, and matrix synthesis. The growth factor is carried to the target cell by both viral and non-viral vectors. The binding of the growth factor to its receptor cell results in the transmission of a signal which ultimately effects gene expression.

Examples of approved bone growth factors include osteogenic protein-1 (OP-1 or BMP-7), and recombinant human bone morphogenetic protein-2 (rhBMP-2). Both can be used to promote bone healing in fractures of the tibia complicated by non-union.[4]

BMP are the only factors known to induce bone formation heterotopically by inducing undifferentiated msenchymal cells to differentiate into osteoblasts. The growth factor is applied locally in the form of an 'implant' but a parenteral form of administration is currently under investigation.

Autologous chondrocyte implantation and osteochondral grafting

Articular cartilage has a limited potential to heal so that mechanical damage to the joint surface can lead to early onset osteoarthritis. Abrasion chondroplasty and subchondral drilling have been used to stimulate cartilage-healing by recruiting pluripotent mesenchymal cells from the bone marrow leading to a fibrous tissue substitute filling the defect in the articular cartilage. Current methods used to fill cartilage defects include osteochondral cylinder transplantation and implantation of autologous chondrocytes.

Osteochondral grafts in the form of cylinders are harvested from the periphery of the articular cartilage of the femur and then press-fit into the articular defects that have been drilled to accept the osteochondral cylinders. The patient is kept non-weight bearing for two weeks and then allowed to partially weight bear until the twelfth week when full weight bearing is allowed.

In autologous chondrocyte implantation a shaving of articular cartilage is obtained arthroscopically, chondrocytes are expanded *in vitro* and then reinjected into the defects three to four weeks later. Dedifferentiation to a fibroblastic morphology and phenotype occurs in the expansion phase but this is reversed by the presence of defined growth factors so that the cells regain their chondrocytic phenotype. Success rates for autologous chondrocyte implantation range from 60% to 90% depending on the site and size of the cartilage defect.[5]

Although it has been shown that the biomechanical properties of the neocartilage are inferior to those of normal articular cartilage, the chondrocytes may continue to proliferate and mature one year after initial implantation.[6] A prospective

clinical study by Horas *et al*, to investigate the two year outcome of osteochondral grafting and autologous chondrocyte implantation of articular cartilage defects in the femoral condyle concluded that both treatments decreased the patients' symptoms.[7] However the improvement provided by the osteochondral grafting was better than that provided by autologous chondrocyte implantation. The latter treated defects were primarily filled with fibrocartilage, whereas the osteochondral cylinders retained their hyaline character.

Spinal disc replacement

Total disc replacements for the spine aim at relieving the pain originating from a pathological disc and at restoring movement to the affected spinal segment. Metal-on-polyethylene implants completely replace the disc. Prospective randomised studies comparing the performance of two total disc-replacement designs with that of spine fusion were reported.[8] While both disc-replacement designs were associated with minimal complications at the time of early follow-up, long-term follow-up will be required.

In Europe total disc replacements have been used for more than twenty years. In an extensive study of complications following metal-on-polyethylene total disc replacement, van Ooij *et al* reported complications including degeneration adjacent level and implant subsidence, at a mean of fifty-three months after implantation.[9]

Orthopaedic trauma

The philosophy of open reduction and internal fixation of fractures has been accepted world-wide thanks to the AO group (Arbeitsgemeinschaft fur Osteosynthesefragen) and the Association for the Study of Internal Fixation (ASIF), a Swiss Group and formed in 1958.

At that time, the treatment of fractures often included prolonged bed rest in traction and subsequent application of a cast or splint, often resulting in poor functional results and lifelong disability. This group of Swiss surgeons established the principles of complete functional restoration of the injured limb through anatomical reduction and stable fixation, with use of atraumatic surgical techniques, and early mobilisation. To do this they developed a system of implants, instruments, and surgical techniques that allow the reliable treatment of fractures by adhering to the above principles.

Debate still exists as to the type of fixation required for a particular type of fracture as new techniques are developed and as multicenter trials publish their results. Unstable compression fractures of the spine are fixed at operation to regain stability and early mobilization of the patient. Techniques are in use for cervical, thoracic, lumbar and sacral segment fixation.

Similarly fractures of the pelvis, acetabulum, femur, tibia, os calcis and their articulating weight bearing joints can be fixed to restore the anatomy and function of the articular surface and allow early mobilization of the patient.

In an attempt to reduce the mortality of the more serious pelvic fractures a new technique of pelvic packing and external fixation has improved survival rates by controlling bleeding. Iliosacral screw fixation for fractures and fracture dislocations of the sacral and sacroiliac joints has become standard treatment.

Techniques such as intramedullary nailing of fractures of the shafts of the humerus, femur and tibia including the use of interlocking screws to fix the ends of the bone to the intramedullary nail and prevent rotation have mostly replaced the use of plates for the fixation of diaphyseal fractures. Closed nailing techniques have replaced open techniques allowing a faster rehabilitation and less soft tissue damage.

A new generation of locking plates (LISS plating system – Synthes) allow fixation of selected periarticular, metaphyseal, periprosthetic, and osteoporotic fractures and non-unions. These plates can be inserted percutaneously. They dramatically increase fracture stability and allow early mobilisation of the affected or nearby joint.

The use of external fixation in compound fractures allows mobilisation of the patient with such fractures and provides a stable fixation for those requiring repair of associated neurovascular injuries. This consists of a metal frame to which pins are attached to connect to the bone fragments by a threaded distal end.

Bone defects can be managed by the use of allograft or bone segment transportation. The bone segments are fixed to an external fixator with a mobile frame. An osteotomy in the main fragment of bone with a healthy blood supply allows the middle fragment to be transported to the distal fragment to slowly bridge the bone defect as new bone is formed between the proximal two fragments: a slow process that takes months to complete. Similarly large and deep soft tissue defects can be covered by a musculocutaneous flap or a vascularised graft.

Advances in molecular biology and tissue-engineering have introduced the use of recombinant human bone morphogenetic protein-2 (rhBMP-2) in the form of an absorbable collagen sponge implanted at the site of the fracture to improve the rate of bone and soft tissue healing.

Major ligament injuries are repaired and where this is not possible, eg. cruciate ligament injuries, formal reconstruction using tendons or a combination of tendon and bone restores the mechanical stability of the affected joint. Major reconstructive trauma surgery may be complicated by deep venous thrombosis and pulmonary embolism and the use of duplex ultrasonography as a screening tool, as well as the use of low dose heparin or low molecular weight heparin as prophylaxis, help to reduce the incidence of thromboembolism.

Osteoporotic spine fractures

Compression vertebral body fractures cause pain, loss of height of the affected vertebra, kyphotic deformity of the spine and a shorter patient. Most of these fractures were and are still treated conservatively but new techniques are being developed to

reduce such fractures, decrease the pain and regain vertebral height.

Pedicle screw fixation is a well known and tried method to reduce and stabilize such fractures. However osteoporotic bone does not lend itself well to pedicle screw fixation so that newer methods of treatment such as vertebroplasty and kyphoplasty are gaining recognition. The spine is put in extension to reduce the vertebral fracture and regain vertebral body height and viscous cement (methylmethacrylate) is injected percutaneously under x-ray control via an 11-gauge trocar with a cannula inserted through or adjacent to the pedicle into the posterior aspect of the vertebral body to fill the defect created (vertebroplasty). Alternatively, the compressed vertebral body may be reduced by inflating a bone balloon that displaces the vertebral trabeculae and elevates the superior end plate allowing some restoration of height of the vertebral body (kyphoplasty). Viscous methylmethacrylate cement is then injected to fill the gap in the reduced vertebral body. Methylmethacrylate cement may leak causing neurologic injury in both vertebroplasty and kyphoplasty. In a study of 274 vertebroplasties, Chiras *et al* reported post-vertebroplasty radicular pain in 3.7% of patients and spinal cord injury in one.[10]

Arthroscopy

The interior of the knee was first examined endoscopically in 1918 by Takagi in Tokyo. In 1926, the first account of arthroscopic surgical procedure of a synovial biopsy was published by Geist. The purpose and use of arthroscopy has extended from diagnostic to therapeutic, and from the knee to the shoulder, ankle, hip, elbow and wrist.

Arthroscopic partial meniscectomies, meniscal repairs and cruciate ligament reconstructions form the order of the day in soft tissue knee surgery.

Similarly arthroscopically assisted techniques of rotator cuff repair and subacromial decompression in the shoulder are well established and are associated with similar and even superior results compared with those achieved with open repair[11]. Arthroscopic repair offers several advantages,including preservation of the anterior deltoid origin, inspection of the entire glenohumeral joint, less post-operative pain, and more rapid rehabilitation. Hip arthroscopy is useful for diagnosing and excising labral tears – a source of hip pain that can otherwise be difficult to diagnose. Arthroscopy of the ankle is a useful diagnostic tool and is ideal for removing small loose osteochondral fragments.

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