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ORIGINAL ARTICLE

Surgery of joints

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Abstract
Crude forms of musculoskeletal surgery have been performed through history for the treatment of deformity, pain and the horrors of battle. In more modern times Muller is credited with the first synovectomy in rheumatoid arthritis in 1884, and a Synovectomy was first performed by Richard von Volkmann (1830–1889) for joint tuberculosis. Chemical synovectomy consisting of the intra-articular injection of various agents was popular for a while but is now largely discarded. Joint resection for sepsis and tuberculosis has been documented since the early 1800s, and also joint arthrodesis, and osteotomy. Modern arthroscopic techniques have added the utility of faster intra-joint inspection and treatment while reduced surgical time exposure and often applied with the use of limb regional anaesthetic nerve blocks, to avoid general anaesthetic. Joint arthroplasty has been developed since1800s, with the use of many artificial joint components. There have been many notable pioneers of this work who are documented in this text, among them Austin T. Moore (1899–1963), George McKee (1906–1991) and Sir John Charnley (1911–1982). The success of joint arthroplasty to the hip, knee, shoulder and other joints has resulted in life-changing benefit for hundreds of arthritis and injury sufferers.

Keywords Surgery · Arthritis · Synovectomy · Joint prosthesis · Arthroscopy

Surgery of joints

A Synovectomy was first performed by Richard von Volkmann (1830–1889) for joint tuberculosis (Allison and Coonse 1929). Muller is credited with the first synovectomy in rheumatoid arthritis in 1884 (Schüller 1887; Muller 1894) and followed in the early nineteenth century with further reports on the procedure (Goldthwait 1900; Murphy 1916). However, it was the paper by Swett in 1923, which popularised the operation (Swett 1923). Although some benefit was claimed for synovectomy of the knee, no benefit was claimed for the metacarpal-phalangeal joints (Arthritis and Rheumatism Council and British Orthopaedic Association 1976). A multicentre evaluation of synovectomy in the treatment of rheumatoid arthritis over a three-year period provided no evidence of benefit (Arthritis Foundation Committee on the Evaluation of Synovectomy 1977). Downie and colleagues (Downie et al 1973) showed in a study on 145 patients with rheumatoid arthritis that synovectomy did not influence the rheumatoid disease process, and that the results of synovectomy merely reflected the activity of the disease process at the time of follow-up assessment. Arthroscopy and synovial biopsy in a small number of patients who showed progression of disease showed histological changes in the synovium identical to those prior to the operation.

Chemical synovectomy consisting of the intra-articular injection of various agents, including alkylating agents (nitrogen mustard and thiopeta) sodium morrhuate, osmic acid, and radionuclides (gold 198, erbium 169, and yttrium 99) was popular for a while but has since been largely discarded. Resection of joints for septic and tuberculous joints was popularised by James Syme (1799–1870) of Edinburgh (Syme 1829).

Resection of the elbow joint was performed by J.C. Warren for rheumatoid arthritis in 1834 (Bick 1968). Henry Jacob Bigelow (1818–1890) performed the first excision of the head of the femur in the United States (Bigelow 1852).

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Excision of the femoral head and neck with a rim of acetabulum and formation of a pseudoarthrosis, first described by Gathorne Robert Girdlestone (1881–1950) (Girdlestone 1943), is only rarely performed today.

It was Eduard Albert (1841–1900) of Vienna who coined the term arthrodesis, and thus earned the title of "father" of the procedure (Albert 1888). A variety of methods were introduced to fuse the knee joint, including the simple procedure described by Russell A. Hibbs (1869–1932) in 1911 (Hibbs 1911) to the more elaborate compression method of John Charnley (1911–1982) and Lowe described in 1958 (Charnley and Lowe 1958). Although Charnley's name is associated with compression arthrodesis it is of interest that the American orthopaedic surgeon, J.A. Key described the same procedure in 1932 (Key 1932). Arthrodesis of the hip was originally performed to arrest tuberculosis and usually involved some form of bone grafting. Hugh Compson Trumble (1814–1962) of Australia employed an ischiofemoral graft in arthrodesis of the hip in osteoarthritis and rheumatoid arthritis (Trumble 1932) to which H. A. Brittain of Norwich, England, added a subtrochanteric osteotomy (Brittain 1942). Today arthrodesis is limited to severe destructive disease affecting a single joint. The most successful arthrodesis is that of the wrist (Ritt et al. 1994).

Osteotomy was first performed by Joseph Anton Mayer (1798–1860) of Würzburg, Germany (20 (Mayer 1851). Bernhard Heine (1800–1846) is credited with the invention of the first osteotome in 1830, which was a somewhat elaborate and complex instrument (Seffert 1985). Sir William MacEwen (1848–1924) of Glasgow, Scotland, produced a simpler and more effective osteotome, which remained the instrument of choice for many years (Beaton et al 1998). MacEwen reported 1880 successful results of osteotomies of the knee in 1800 patients, without one case of postoperative infection or death (MacEwen 1880). Alexander Ogston (1844–1929) of Aberdeen, Scotland, also reported successful outcomes of oblique osteotomy of the medial femoral condyle in patients with knock-knee (Ogston1877). It was Thomas Porter McMurray (1888–1949), an Ulsterman, and Professor of Orthopaedics in Liverpool, England, who described the operation of hip osteotomy McMurray 1990 cited by le Vay 1990). McMurray is also remembered for his description of the clinical test for internal derangement of the knee joint (McMurray 1942).

Early interpositional arthroplasty

The development of interposition arthroplasty heralded the era of joint replacement. A variety of implants have been tried including wood, muscle, pigs bladder, celluloid, guttapercha and glass (Hey Groves1927; Le Vay 1990). Fascial and para-articular fat implants were popularised by John B. Murphy (1857–1916) (Murphy 1913) and Willis C. Campbell (1880–1941) (Campbell 1939) and met with some success. Silver, magnesium, and zinc proved unsuccessful in the hands of Albert Hoffa (1859–1907) (Hoffa 1925) and F. Konig Konig 1913) as did gold foil inserted on the femoral head by Robert Jones (1859—1924) and colleague R W Lovett (Jones and Lovett 1924). Perhaps the most successful of these implants was ivory, a known choice of Thermistocles Gluck (1853–1942) (Gluck 1890, 1891) and Ernest William Hey Groves (1827–1944) (Hey Groves 1983, cited by Ratcliff A H C 1983).

During the second and third decades of the twentieth century Marius Smith-Petersen (1886–1953) of Boston, Massachusetts, USA introduced a mould arthroplasty of the arthritic hip joint using vitallium (65% cobalt, 30% chromium, 5% molybdenum, and other substances.) (Smith-Petersen 1939) having previously tried glass, viscaloid, pyrex glass and bakelite Smith-Petersen 1948). At special centres and in the hands of skilled orthopaedic surgeons good results were able to be obtained in young patients (Campbell 1939). A detailed account of the early use of interpositional arthroplasty has been described by Ritt and colleagues (Ritt et al1994), and Bota and Colleagues (Bota et al 2021).

Interpositional arthroplasty – further developments

Philip Wiles (1899–1967) in London, England, performed six total hip replacements in patients with juvenile arthritis, using all-metal components, consisting of a femoral head with a stem and a cup screwed into the acetabulum (Wiles 1958). Wiles reported good long-term results (Wiles 1958). In 1946 Robert and Jean Judet in Paris, France replaced the femoral head with polymethylmethacrylate with an acrylic stem with a metal core that passed down the neck of the femur Judet et al 1947). The immediate results were excellent, after a few months the plastic surface fissured and the stem broke (Judet et al 1947). Nevertheless, it was a milestone in the history of hip arthroplasty Judet 1962). The reason for the failure was the lack of understanding of the relevant biomechanics. The plastic had only been used for dental implants and was totally unable to meet the stresses in the hip. In addition, heat sterilization and cooling and treatment with formaldehyde weakened the plastic, making it more liable to fracture.

A variety of femoral head prostheses were tried by various workers, mostly consisting of vitallium and various steels. The metals behaved in the tissues, but the plastics including acrylic, polyethylene, nylon and polyamide proved unsatisfactory (Judet 1962). Austin T. Moore (1899–1963) had, however, greater success with a vitallium prosthesis for

the femoral head (Moore and Bohlman 1943; Moore 1952) as did F. R. Thompson with a similar device (Thompson 1954). However, this type of prosthesis lacked congruity between the head and the socket.

George McKee (1906–1991) of Norwich, England, introduced a metal-on-metal prosthesis that worked well (McKee 1951; McKee and Watson-Farrar 1966). Difficulties in the manufacture and poor fixation led to a fall-off in its popularity, although a comeback occurred in the 1990s (Walker and Gold 1971; Anstutz and Grigoris 1996). A detailed account of the development of joint arthroplasty over 70 years to 1960 has been described by Fischer and Colleagues (Fischer et al 2000).

Interpositional arthroplasty—modern era

It was another Englishman, Sir John Charnley (1911–1982) whose engineering interests enabled him to study the biomechanics of hip replacement, and made the greatest impact on modern arthroplasty. Charnley's prosthesis consisted of a small-diameter polished femoral head, which reduced friction, torque, and wear, and a metal stem which was fixed by acrylic cement Charnley J. (1961). The head is articulated with an ultra-high molecular weight polyethylene acetabular cup (Charnley 1961). Charnley's initial clinical results were excellent in the first ten years (Charnley 1972; Charnley and Cupic 1973). Charnley's prosthesis is now standard for the hip (Wroblewski 1986; Callaghan et al 1998; Older 2002). Reduction in the size of the femoral head has been reported to reduce wear (Livermore et al 1990) and fracture of the stem due to fatigue had required improved metal alloys and changes in cement technique design (Charnley 1975). Bone resorption continues to remain a problem due to reaction to the acrylic bone cement (Charnley et al 1968) and polyethylene wear particles (Fisher et al (2001). Late infection of the prosthesis prompted Charnley to attempt prevention by operating in an ultrasterile "theatre within a theatre" Charnley and Eftekhar 1969). In an attempt to reduce infection risk, surgeons began to add antibiotics to the cement (Hughes et al 1979).

Evolution of the knee joint replacement followed the principles of hip replacement, and a knee joint prosthesis eventually consisted of a metallic femoral component with an ultra-high molecular weight polyethylene tibial bearing component Ranawat et al 1993). Early knee joint replacements consisting of metal hinges (Walldius 1961) and metal replacements of the tibial plateau (Macintosh 1958; Bruni et al 2013) proved unsuccessful. Schwartsmann and colleagues have discussed that for younger patients requiring hip replacement which will last many years, new bearing materials and joint designs have been developed (Schwartsmann et al 2012).

Total replacement of the shoulder (Neer 1977) elbow (Morrey and Bryan 1987) ankle (Newton 1975) and finger joints Swanson 1973; Flatt 1974) have been developed. Resection of the metatarsal heads (Fowler's operation) (Fowler 1959) and Keller's operation for hallux valgus (Keller 1904) may not have the glamour of joint replacement but nevertheless are very rewarding to the patient. In 2019–2020 in Canada, the Canadian Joint Replacement Registry (CJRR) recorded over 60,000 hip replacements and over 75,000 knee replacements performed. It was observed that 8.1% of hip and 6.9% of knee replacements were revision surgeries, with infection, aseptic loosening and instability as the top reasons for revision (Canadian Institute for Health Information 2023).

As foreseen by Professor Buchanan in his writings prior to 2006, these now modern arthroplasty successes in Canada and all developed nations are largely due to the initial efforts of Sir John Charnley, but also his peers and other experts listed above. Professor Buchanan also had stated “that the Nobel Prize was originally awarded to the person who provided the greatest good to the greatest number, and, therefore, in this regard it is surprising that Sir John Charnley was not awarded the Nobel Prize for his research and development of hip joint replacement.”

Comments by the editors and co-writers – Michael G Hogan orthopaedic surgeon, and Colin Kean, W F Kean, and KD Rainsford

In the last 16 years to 2023 the approach to orthopaedic surgical care has changed considerably since the original writings by Professor Buchanan which were completed in 2006. The initial treatment of joint disease and injury damage follows established parameters of patient and caregiver education, physical therapy, and topical, oral and injectable pharmacological treatments. The ultimate treatment of a joint that can no longer provide pain-free articulation and ambulation is to proceed to surgical intervention.

Surgical joint treatment covers many approaches and might include removal of impinging bony osteophytes: opening confined spaces (e.g. subacromial decompression); soft tissue coverage e.g. patellar resurfacing; joint resurfacing; and joint replacement. The techniques of soft tissue and space-making interventions have limited application and a limited life span in controlling pain.

Joint replacement surgery has continually improved since the initial prosthesis developed, produced and inserted by Sir John Charnley and others, as discussed in the document above. Biologic compatible beading has been applied to bony interfaces, hydroxyapatite added for bone integration, and design modifications to improve longevity and stabilization have been developed.

Over the past 10 years, orthopaedic surgical intervention has moved to include individual custom-made prosthesis (CMP). Custom joint development is now being developed for the hip, knee, ankle, shoulder and other joints. These joint resurfacing components are manufactured from a 3-D computed tomography (CT) scan. The CT scan can be used to better evaluate the topography and alignment of any joint. This allows the custom made components to be biomechanically fashioned as an exact replication of the original host joint. Multiple components may be produced to replace the damaged joint and they need to replicate the host patient's physiologic motion in all planes. The 3-D CT scan is processed by biomedical engineers to re-establish the perfect components that will reproduce the individual patient's prosthesis. As an example, for knee joint reproduction, all aspects of the host bone such as the femoral curve, tibial slope and lower extremity alignment are devised, while preserving as much natural bone as possible. Patient-specific frontal plane lower extremity alignment is significantly improved (Ivie et al 2014; Mannan and Smith 2016). Compared with off-the-shelf (OTS) prostheses, vs Custom Made prostheses (CMP), a 2017 retrospective study of 248 patients resulted in lower adverse events, and less patients discharged to rehabilitation centres (Culler et al 2017). A further study showed improved in vivo kinematics for (CMP) VS (OTC) prostheses (Zeller et al 2017), and custom-made components and custom cutting jigs will likely continue to be considered more favourable than (OTC) components by both patients and surgeons. Further study is required to determine the long-term efficacy of the (CMP) total knee favourable than (OTC) components by both patients and surgeons.

As an example of custom joint replacement surgical outcome, we quote the results of Schroeder and colleagues in their retrospective review on 540 knee surgeries in 433 patients who underwent custom total knee arthroplasty (Schroeder et al 2021). The mean patient age was 71.8 years and the mean body mass index was 29.1 kg/m2. It was stated that patient satisfaction was high at 89% after a mean of 2.8 year follow-up and knee injury and osteoarthritis outcome score for joint replacement was 82. There were 8 revisions (1.5%) at an average of 0.7 years post joint replacement and thus a 98.5% implant survivorship at that time frame.

We believe that Professor WW Buchanan would have been very satisfied with these results and developments of modern arthroplasty.

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Declarations

Conflict of interest The authors have not disclosed any competing interests.

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