ORIGINAL ARTICLE

Charles O. Townley: Design By Reason

James W. Pritchett MD
Seattle, WA

Abstract

The career of Charles O. Townley tells a nearly complete story of the development of joint replacement surgery. The basic concepts for all his procedures were to replicate normal anatomy and his designs were calculated to transmit stress to supporting bone in a physiologic fashion. Townley envisioned the ideal replaced joint as "pseudobiological," with implanted material serving only as an articular barrier to allow joint movement and pain relief. He developed the Townley Anatomic Total Knee, which was widely used in the 1970's and 80's. The TARA (Total Articular Replacement Arthroplasty) with its characteristic curved stem has been the most enduring of the surface replacement hip prostheses.

Townley's 60-year career is a study in the development of modern materials, instruments and implants. He did not wait for the development of either polyethylene or methylmethacrylate to perform total joint replacement surgery. While maintaining a busy private practice in Port Huron, Michigan, he was an original thinker who spent much of his career defining the anatomy, physiology, and healing of fibrous tissues in the shoulder and knee. Starting in the 1940's Townley designed implants for the toe, hand, shoulder, ankle, and elbow, in addition to hip and knee implants.

Address for Correspondence:

James W. Pritchett M.D.
901 Boren Ave #800.
Seattle, WA 98104 USA
Tel: 206 779 2590
Fax: 206 726 6166
E-mail: Bonerecon@aol.com

The author certifies that he has no commercial associations that might pose a conflict of interest in connection with the submitted article.

Early Life

Orleff Charles Townley was born in Minneapolis, Minnesota on December 30, 1916. He was raised mostly by his paternal grandparents under humble circumstances as his father tried to find steady employment. His mother left the home because of alcoholism. As an adult Townley once reconnected with his mother but they did not stay in contact. He had one sibling, a brother named Elvin who was 2 years older. During the depression of the 1930's, Townley and his brother, father and stepmother relocated to Ohio where they worked a pig farm.

The name Charles came from his uncle AC Townley. Townley did not like the nickname "Orly" and at age 12 changed his name to Charles O. Townley during a school enrollment, afterwards going by the nickname Chuck. Some called him Charlie O later in life.

Townley attended high school in Grove City, Ohio, where he excelled in his studies and on the football team. He entered Capital University in Columbus, Ohio on a football scholarship but also worked as a busboy and night hotel clerk. After graduating with a BA in physical education Townley considered a career as a coach, but chose instead to stay an additional year taking courses in mechanical engineering and the life sciences.

Townley had a close friend, Fred Minch, who had lost his father. Mrs. McKee of McKee Holding Co. in Columbus, OH was a Minch family friend who wanted to send Fred to medical school. Fred Minch was not academically inclined and convinced Mrs. McKee to send Townley to Ohio State University instead. He finished medical school in only 3 years.

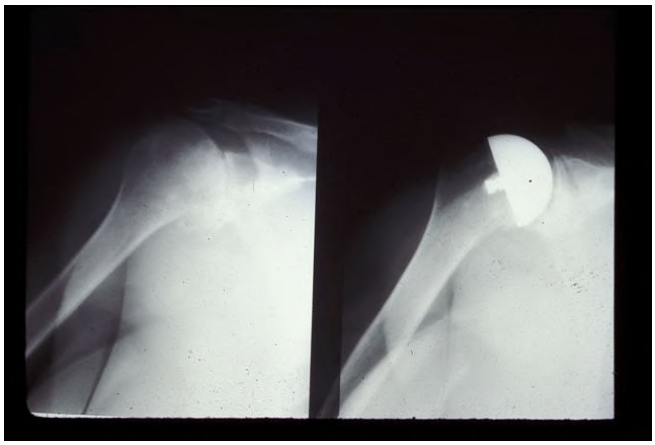

Fig 1. An AP radiograph of the right shoulder demonstrating the humeral head resurfacing prosthesis used to treat osteoarthritis.

In 1944 he chose Henry Ford Hospital in Detroit for his residency because they were willing to pay him $225 a month which he needed to support his wife and two children.

After a year and half at Ford Hospital, Townley was enrolled as a captain in the uniformed services and sent to Tilton Army Hospital in Fort Dix, New Jersey in 1946. The operative experience on a variety of trauma conditions was extensive.

In 1948 Townley returned to Ford Hospital, where he was appointed an associate surgeon due to his extensive experience. Townley quickly developed his skills as a researcher, performing anatomic dissections and embryologic studies and using histology to study tissue healing and pathology. In addition, Townley began designing instruments and surgical techniques.

John Charnley from London had not yet started his work on his low-friction arthroplasty (Charnley hip prosthesis) when he visited Ford Hospital in 1948. Townley picked him up at the airport, gave him a tour of the town and introduced him to the orthopedic department. Charnley spoke to the orthopedic staff about positive pressure arthrodesis and fracture management. Townley described his first designs for a total knee prosthesis, which interested and impressed Charnley.

Townley was also interested in vascular repairs of disrupted arteries while at Ford Hospital. In 1947 he published his first article in the Journal of Bone and Joint Surgery, emphasizing the principles of prompt and accurate diagnosis, intimal injury from blunt force trauma, and the use of heparin. [2] Townley described the use of tantalum stents for immediate restoration of vascular perfusion and for protection of vein graft repairs.

In 1948 Claude Townley, father of Charles, was repairing a washing machine at the Townley Motel, "A Tourist's Home by the Sea", in Kill Devil Hills, North Carolina. He received a severe electrical shock that injured his dominant right shoulder and left him unable to lift or rotate his arm. A local orthopedic surgeon examined him and took a radiograph but was unable to suggest any effective treatment. Claude Townley drove to Detroit so that his son could examine him.

Townley found that his father had a posterior dislocation. Through a posterior approach, Townley and Leslie Mitchell (Chairman at Ford Hospital) performed an open reduction and capsular repair. Postoperatively, a lumbar corset with an outrigger secured the arm in external rotation to avoid redislocation. A complete recovery followed and Claude Townley returned to manage his rooms, apartments and cottages until his death at age 87. In 1950 Townley used his father's case to illustrate the correct radiographs (axillary view) needed to assess a shoulder dislocation.[7]

Recurrent dislocation of the shoulder was one of the common surgical problems treated at Tilton Army Hospital, and anatomical repair seemed to be the most valid approach for treatment.[7] In 1957 Townley designed a resurfacing implant for the humeral head for rheumatoid and degenerative arthritis (Fig 1). The humeral head prosthesis looked like a femoral head resurfacing prosthesis.

In 1950 Townley moved his family to Port Huron, MI from Detroit to enter private practice. Port Hu-

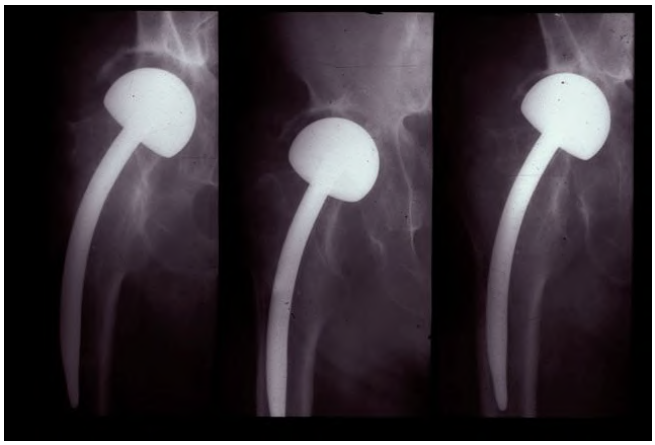

Fig 2. This AP radiograph of the right hip demonstrates a Total Articular Resurfacing Arthroplasty (TARA). The acetabular prosthesis in this radiograph is made from polyurethane. After two years the center radiograph demonstrates narrowing of the joint space. On the right radiograph the polyurethane has entirely disappeared. The result remains satisfactory and no revision was required.

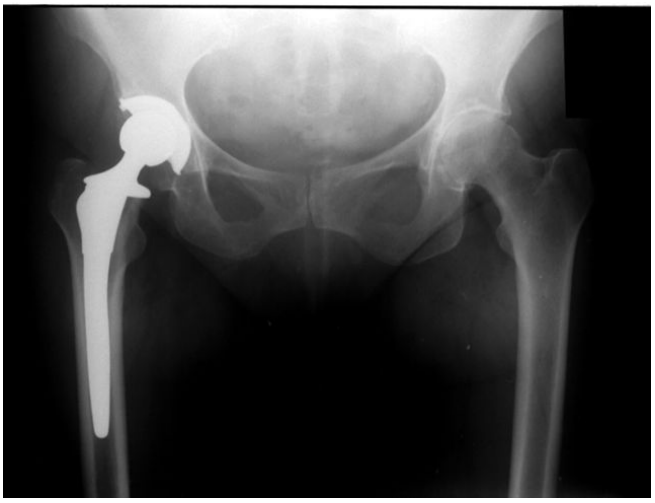

Fig 3. An AP radiograph of the pelvis shows a Physiologic Stress Loading prosthesis (HPS).

ron was the boyhood home of another innovator, Thomas Edison.

Hip Replacement

As a resident with Dr. Leslie Mitchell, Townley saw that cup arthoplasties often failed. He felt that earlier cup prostheses did not allow sufficient excision of "at risk" bone and designed his own prosthesis in 1951, adding a stem for additional fixation and making the length and width of the stem greater in cases where less bone was available. Townley began implanting the "fixed cup" in 1952 and used the fixed femoral cup as a hemiarthroplasty from 1952 to 1960. The Zimmer Co. listed the Townley fixed femoral cup in its catalogue for 20 years starting in 1952 and these prostheses sold steadily. At the same time Zimmer offered Townley's great toe hemiarthroplasty implant.[18] This implant was metal and similar prostheses for metacarpal-phalangeal and thumb basal joint arthritis were also offered.

In 1960 Townley used the fixed femoral cup as a total hip prosthesis replacement with a variety of acetabular options (Fig 2).[13] In the first 500 cases in which the fixed femoral cup was used as either a hemi- or total hip replacement, there were no femoral failures in properly performed cases. The fixed femoral cup remained a successful alternative for the treatment of osteonecrosis and osteoarthritis. He did not prefer metal on metal articulation after using them in 122 patients but he never said why and there no failures recorded.[6]

At the same time Townley was developing the fixed femoral cup, he also designed the Horizontal Platform Supported (HPS) prosthesis (later called the Physiologic Stress Loading prosthesis (PSL)) (Fig 3).[10] These implants stress the proximal femur in compression rather than shear. The complete proximal femoral cortical arc is in contact with the "collar" of the prosthesis, causing a physiological load on the medial trabecular system and making the supporting "platform" of the prosthesis perpendicular to the resultant forces rather than to the neck of the implant.[5]

A significant difference between the HPS implant and other implants is that the platform of a Townley design loads the cortical bone. The fixation point for other implants is on the inside (medullary) surface of the femur; but unlike a crustacean, man is not designed to walk on the inside of his bones.

When cement was needed, Townley used it only to assist implant fixation in the trochanteric and subtrochanteric area. He strongly opposed endosteal fixation of femoral implants, arguing that supporting a femoral prosthesis by a pressurized column of cement contributes to bone loss. Laboratory testing and later clinical work both indicate that the HPS implant loads bone more physiologically than other implants.[4,5,14]

Townley's Search for the Perfect Total Hip Replacement

Soft tissue interpositional arthroplasty and mold arthroplasty were in common use for hip surgery at Ford Hospital from 1944-1950, although with unpredictable results. Townley identified three main causes of failure:

- Inability to replace or maintain an "articular barrier" between the femoral head and the acetabular surface meant that erosion and protrusion of the femoral head into the pelvis often occurred.
- Failure to obtain absolute immobility between the subchondral bone and the prosthetic device resulted in painful erosion of the femoral head.
- Failure to obtain even and physiologic distribution of weight on the implant and supporting bone caused subsidence of the implant.

Townley continued to pursue his vision of a "pseudobiological" joint, one that would place a porous articular barrier between the femoral head and acetabulum and allow fibrous tissue to grow through the pores of the articular barrier, providing a self-lubricating soft tissue membrane. An articular barrier was necessary to allow movement and pain relief while protecting the maturing fibrous tissue. Townley turned his attention to biomaterials hoping to find a porous and durable material for the articular surface.

Biomaterials

At Tilton Army Hospital, Townley had befriended Mike Mandarino, MD, with whom he shared an interest in football: Townley had been a collegiate player and Mandarino had played professionally for the Philadelphia Eagles. Townley and Mandarino remained friends, and Townley was interested to learn that Mandarino had begun using polyurethane to assist fracture fixation.[3] In 1958 Townley began working with the W.S. Merrell Co. (Cincinnati, OH) to investigate the use of polyurethane as a bearing surface for joint resurfacing. Also in 1958 Silas Braley offered Townley the chance to use silastic as in interpositional material. Townley declined, feeling that it would fragment.

Working with W.O. Brinker DVM, head of Veterinary Medicine at Michigan State University, in 1959 Townley used polyurethane in total surface replacements of the hip in dogs. Although the dogs did well for the first few months they reached a plateau by the end of the first year and then gradually deteriorated. Necropsy results showed that the polyurethane had fragmented but had caused no adverse reaction in the tissues. Townley also used polyurethane to supplement bone grafts for spinal fusion.

Michael Freeman cited John Charnley's Teflon double cup as the first attempt to perform a total resurfacing hip replacement and Townley's work with the stemmed fixed femoral cup as the second attempt.[1] In 1960 and 1961 Townley performed total hip resurfacings using the stemmed fixed femoral cup and polyurethane for the "articular barrier".[12] The acrylic was molded to the smooth femoral head prosthesis to assure congruity. The same batch of acrylic, which was kept cooled, was used as a cement to anchor the prepared acetabular prosthesis and femoral implant. Holes were drilled through the hardened acrylic to allow ingrowth of fibrous tissue for the pseudobiological joint. Townley continued drilling through the acetabular prosthesis even when polyethylene became available.

The polyurethane acrylic resorbed over time without any noticeable reaction in the body, and the hip prosthesis then functioned as a hemiarthroplasty.[12] Radiographs could be used to follow the resorption process. Unfortunately, the gross misuse of polyurethane by many surgeons across the country led to disastrous complications in fracture care, and these celebrated failures led to the abandonment of the general principle of cementing throughout the USA for the next decade.

Townley and his wife, Naomi, had their first of seven children (Jeff, Mickey, Jon, Sue, Jill, Julie and Kim) in 1945. They raised their family in Port Huron and the family led an active life. The Townley's had a horse ranch and a waterfront home with tennis courts. Townley was active as a coach in little league but he also played golf and tennis. Jill grew up to be a nurse, Julie is a child psychologist, Sue writes children's books and Kim had a variety of occupations and continues to live in Port Huron. Jeff sold orthopedic implants and later entered the computer field, Jon is an artistic director for movies and other projects, and Mickey is a golf professional.

Total Knee Replacement

Townley's work on the anatomic knee was done entirely alone starting in 1948. Most of the work was done in addition to his busy, full-time private practice performing much of the work in his basement shop. Townley sketched his first designs for an anatomic knee replacement while a resident at Ford Hospital; basing the original drawings on anatomic dissections he had performed on the cadavers used by medical students at Wayne State University.

The original drawings included the joint surfaces of both the femur and tibia. Townley observed three distinct radii of curvature in the saggital plane of the femoral condyles, and he recognized that multiple sizes would be necessary with an asymmetric patellar flange.

At first only the tibial surface was replaced because of concerns about a metal-on-metal articulation. In 1951 Townley made his first tibial hemiarthroplasty plate. From 1953 to 1972 he implanted 170 hemiarthroplasty prostheses, placing grafts under the tibial plate to correct deformity. Seventy-five percent of patients enjoyed excellent or good results.[8]

Sometimes Townley used a metal, anatomically-shaped patellar prosthesis. Townley had also designed a femoral resurfacing implant but rarely used it as a hemiarthroplasty prosthesis. Companies were not interested in marketing Townley's implants; they thought that his designs required too much metal and considered them too radical to sell. Consequently, Townley arranged to have the tibial plate manufactured by Zimmer (Warsaw, IN) and then sold it himself to patients for $75, the manufacturing cost of the implant.

In 1968 Townley returned to the concept of a total condylar resurfacing. It was clear that an acrylic interposition surface would be possible and a metal-on-metal articulation could be avoided. Plaster molds of the femur and tibia were made to capture the anatomy. The natural surface of the tibia was used to make nonconforming prosthesis. To broaden the contact area the radius of curvature for the femur was larger in the medio-lateral plane than in the anterior-posterior plane.

In the sagittal plane the femur had a smaller radius of curvature to permit normal anterior-posterior displacement and nonconstrained rotation. Townley relied on the cruciates to provide joint stability and appropriate roll back. He had his first implants manufactured in Michigan by Chrysler and also published his own technical guide through Acorn Press in Port Huron. He made his own instruments and took a finished product to Howmedica (Manhattan, New York) in 1970.

Townley's project stalled at Howmedica because they were working on the Geomedic Knee with Mark Coventry. Townley went to Zimmer but

Fig 4. An AP radiograph of the right knee demonstrates the Anatomic Total Knee replacement in 1992. In the center of the film the preserved tibial eminence for ACL and PCL retention is seen.

Fig 5. Charles O. Townley with his operating nurse at Port Huron Hospital in the 1970's.

Depuy (Warsaw, IN) showed the most interest. Because of manufacturing and inventory considerations Depuy initially provided just three of the seven sizes Townley desired. The first implants did not provide for the patella or the asymmetric trochlea. The patella was added after a year, making that implant the first total knee with a patellar button and the first cemented anatomic total condylar knee.

Townley introduced the Anatomic Total Knee (ATK) at the 1972 AAOS meeting in Dallas. Not only was it the first, but it quickly became the most commonly used unconstrained total condylar knee in the world. The first literature reference to the ATK was in 1973 Clinical Orthopedics, volume 94, containing the proceedings of the first symposium on knee replacement surgery.[11] In this volume several authors contributed a wide range of papers on the predecessors to modern designs. Townley's extended article on the ATK followed in 1974.[17] He continued to use his ATK implant and published his results for the next 25 years (Fig 4).[13] Townley believed that all ligaments must be preserved and balance and that sacrifice of either the anterior or posterior cruciate ligament was a concession to improper joint synchronization.

In 1962 Townley was under consideration for the Nicolas Andre award of the Association of Bone and Joint Surgeons (ABJS), and Dr. DePalma, Editor of Clinical Orthopaedics and Related Research, asked Townley to submit his work on recurrent dislocation of the shoulder in competition for that award. The basis of his paper consisted of research results from work begun in 1946, including microscopic sections of the "labrum" taken from 292 surgical specimens; histologic sections of 154 cadaver dissections, including experimental dislocations, histological studies of embryonic and fetal shoulders, surgical observations of treated cases.[9]

Townley found that there is a great deal of developmental variation in the fibrocartilagenous glenoid labrum. Some patients dislocate more easily than others due to a less well-developed upper portion of the capsule and a less firm attachment of the capsule to the glenoid rim. The essential lesion in recurrent dislocation is an unhealed separation of the capsule from the glenoid anteriorly and disruption of the capsulo-humeral triangle posteriorly, but correction of either will prevent recurrent dislocation. The Nicolas Andre Award went to Dr. Depalma's resident Dick Rothman.

In 1972 Dr. Townley began teaching osteopathic orthopedic residents from Ohio and Michigan at Port Huron Hospital and at the Townley Orthopedic Clinic (Fig 5). He also began giving lectures

Fig 6. Photograph of Charles O. Townley at the founding of the Knee Society.

Fig 7. An AP radiograph of the right knee with a full resurfacing unicompartmental prosthesis. The lateral radiograph demonstrates the anterior flange.

about hip and knee replacement surgery. During the 1970's and 1980's he made more than 100 presentations around the world. In 1981 he was made a member of the Australian Orthopaedic Association. In 1972 Townley's wife left him to marry a car dealer. He never remarried.

In 1974 Townley entered into royalty arrangements with the DePuy Co. They would make and distribute his designs for the hip, knee and shoulder. This was a very successful relationship for both parties. In the late 1970's the Townley Orthopedic Clinic grew to several surgeons and a large waterfront building was constructed. Townley was always interested in environmental issues, lobbied the city of Port Huron unsuccessfully to allow him to build a windmill to power the Townley Orthopedic Clinic.

In 1984 Depuy ended their relationship with Townley and in 1987 Townley founded BioPro, Inc. (Biologically Oriented Prostheses) which began manufacturing his and other implant designs. In 1983 Townley and others founded the Knee Society (Fig. 6). He became its president in 1988. Townley was also very interested in ligament reconstruction and in 1983 developed the Townley Synthetic Ligament for reconstruction of the Anterior Cruciate and Collateral Ligaments.[16] Townley demonstrated his technique in 1988 and 1991 in Barcelona and Madrid and afterwards the synthetic ligaments were used in Spain with excellent clinical results.

In the 1990's Townley performed nearly as many unicompartmental replacements as tricompartmental replacements. The Townley unicompartmental implant has an anterior trochlear flange and looks like half of a half-total knee (Fig 7). He reported 94% good results in 667 patients at 9 years.

Working in conjunction with Alfred University in New York, Townley developed a durable powder in 1990 to form ceramic prostheses, and Townley's company (BioPro) became the first US manufacturer to produce ceramic prostheses. Large ceramic heads were used for hemiarthroplasty, smaller ceramic heads were used for conventional total hip designs, and a ceramic, stemmed fixed femoral head was designed for both hemiarthroplasties and total articular replacement arthroplasty.

In the 1990's BioPro released Townley's great toe prosthesis.[18] This was designed to treat Hallux Rigidus and this implant became the companies' largest selling implant worldwide. A similar prosthesis for the basal thumb joint was also released and had performed quite well. Except for modularity and porous coating these implants were identical to the original Zimmer prostheses (Fig 8).

Fig 8. An AP radiograph of the great toe implant.

In 1996 Townley approached Aisa Sendijarevic, Ph.D. at Troy Polymers about pursuing a better version of polyurethane. The bone resorption caused by wear debris from ultra-high molecular weight polyethylene (UHMW-PE) under the complex stresses in replaced joints provided the impetus to develop a better material. After three years of experimentation, a very durable form of polyurethane (PU-elastoplastic) was created by using a new formulation.[15] A US patent was granted to Townley in 2001. Testing is ongoing but the results are very promising as polyurethane has superior wear characteristics, better lubrication properties and less osteolysis than polyethylene.[15]

In 2002 Townley sold the BioPro Company to Pat Pringle and John Ange for a nominal sum after securing their commitment to continue to operate the company after he was gone. Pat Pringle had run the BioPro plant and John Ange was an attorney and the son of Marjorie Ange, who managed Townley's medical practice and many other affairs for more than 50 years. Townley proved to be a difficult man to practice with and by the year 2000 he no longer had any partners. He resisted the pressure from the hospital to give up surgery and the last 3 years of his practice were his most difficult. He retired in 2003 (at age 86), closed the Townley Orthopedic Clinic and sold the property. Despite encouragement from his friends, he lost interest in life and he died at his home in Port Huron on December 22, 2006.

Townley was honored in 2009 as a "Pioneer in Medicine" by the St. Claire Co. Historical Society. He was quite a philanthropist in Port Huron donating extensively to found a child care center, senior center and support the hospital, Red Cross and other charities. He had a remarkable memory for his patients who came up to him frequently in town. He drove an electric car.

Townley lived a sometimes difficult but simple life. His language was colorful and his meaning was clear. He was generous with his time, thoughts and energy, and he was fun to be around. He was famously stubborn when he thought he was right. Everyone who knew him had an amusing story about him. Dr. Townley was not always the sole of discretion or blessed with diplomatic skills. He had simple tastes, was quite a storyteller and original thinker.

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