Chapter

# Introductory Chapter: Past, Present, and Future of Joint Reconstructive Surgery

*Alessandro Rozim Zorzi and João B. Miranda*

## 1. Introduction

By 2030, the demand for primary total hip arthroplasty in the United States of America is estimated to grow by 174% and the demand for primary total knee arthroplasty is projected to grow by 673%. Overall, total hip and total knee revisions are projected to grow by 137% and 601%, respectively, between 2005 and 2030 [1]. This estimate demonstrates that joint problems, especially those correlated with population aging, are an important public health problem. The queues for performing arthroplasties in developing countries are among the longest in the health systems of countries such as Brazil. Governments around the world will need to take steps to ensure assistance with public policies aimed at increasing patients' access to treatment with surgery for joint reconstruction.

On the other hand, it is important to emphasize that arthroplasty is a very effective surgery, which resolves pain in most cases and restores mobility, functional independence, and quality of life for the patient. No wonder hip arthroplasty was elected the most important surgery of the twentieth century [2].

## 2. Definition

Arthroplasty is an orthopedic surgical procedure, where the articular surfaces of a synovial joint are removed, remodeled, or replaced, to restore function and relief pain. It is indicated in cases of advanced joint destruction caused by different etiologies (osteoarthritis, inflammatory arthritis, trauma, tumors, sequelae of osteoarticular infections, neurological injuries, among others), where three factors combine: severe and refractory pain, functional limitation, and poor quality of life.

## 3. Types of arthroplasty

Although nowadays the term "arthroplasty" is strongly associated with the placement of a "prosthesis", there are other forms of arthroplasty that are still practiced and need to be recognized by the specialist in joint reconstructions. Many of them have only historical value for the hip and knee joints, where the development and success of metallic prostheses, which follow Charnley's "low friction" concept, have made it the gold standard

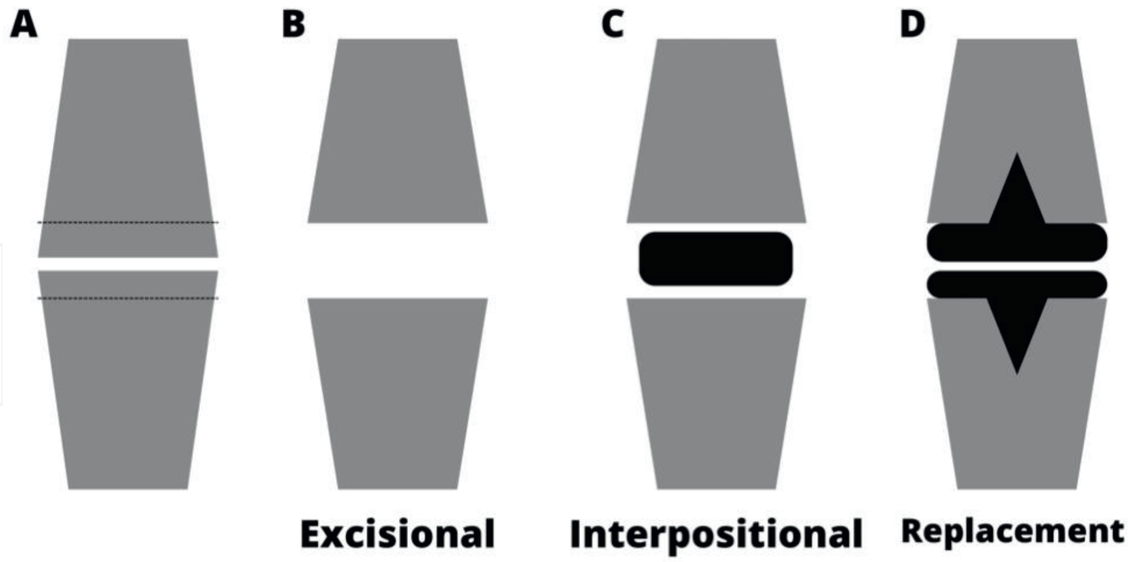


**Figure 1.**
*Types of arthroplasty: A) severely damaged joint, with significant reduction of joint space. The dashed line shows the original joint space width; B) excisional, which consists of simple resection of joint surfaces; C) Interpositional, when, in addition to the resection, some biological tissue or synthetic material is interposed between the joint surfaces; D) replacement, when a prosthesis is implanted to restore joint geometry.*

in the treatment of the vast majority of cases. But other joints, especially small joints and upper limbs can still benefit greatly from other forms of arthroplasty. **Figure 1** shows a schematic of the types of arthroplasty.

### 3.1 Excisional arthroplasties

Also known as resection arthroplasty, it consists of removing part of the joint. The space that is left fills in with scar tissue over time. Nowadays, its use is indicated most often for correction of deformities in the toes (hallux rigid, hammer toe, mallet toe), for the treatment of rhizarthrosis in the trapezio metacarpal joint of the hand, and for some elbow problems. In hemophiliac patients, for example, hypertrophy of the radial head causes pain and limitation of pronation-supination. Radial head resection promotes good results in these patients.

It can also be used as a salvage procedure in difficult cases of the shoulder (Jones surgery) or hip (Girdlestone surgery). The functional result in the knee is very poor and should be avoided. It may be rarely indicated in cases of refractory infection of the prosthesis, in elderly patients, or in patients with no gait prognosis, in which comorbidities would make the performance of an arthrodesis risky.

The problem with resection arthroplasty is that it generates instability, often so severe as to render the limb virtually nonfunctional. Therefore, its purpose is to relieve pain in patients with low functional demand and without surgical conditions for other forms of arthroplasty.

### 3.2 Interpositional arthroplasties

Interpositional arthroplasty consists of the resection of damaged joint surfaces, with the interposition of biological tissue or synthetic materials. Although it has presented poor results in the past, mainly in load-bearing joints of the lower limbs, it currently plays a role in the treatment of some specific pathologies.

In the small joints, an interposition arthroplasty is an option for surgical treatment of hallux rigidus, for elderly patients with low functional capacity. Also could be used to manage rizarthrosis, the so-called Eaton's arthroplasty with ligament interposition. Interpositional arthroplasty with temporalis fascia flap has been one of the most frequently performed procedures to treat temporomandibular joint ankylosis.

In large joints, it has been used frequently for elbow problems. It is considered a salvation option in young patients where conservative treatment has failed and total elbow arthroplasty is relatively contraindicated [3].

### 3.3 Replacement arthroplasties

The articular surface is partially or completely replaced by a prosthesis. The prosthesis protects the subchondral bone and restores joint geometry, returning normal tension to the ligaments and joint capsule. This is the most successful type of arthroplasty, the result of a long historical development, which led to the development of the prostheses currently in use. In joints such as the hip and knee, the superiority of replacement arthroplasty is indisputable, being considered the gold standard treatment in severe destruction. In the shoulder and ankle, promising results are beginning to be achieved.

## 4. The past: a brief history of replacement arthroplasties

Knowledge of the past is important to understand how we arrived at the present way of performing arthroplasty, in addition to making it possible to understand the directions of this surgery in the future. Although today, it is strongly linked to the activity of the implants and medical equipment industry, in the early days the first arthroplasties emerged thanks to the creativity and perseverance of important names in orthopedic surgery.

Modern days of replacement arthroplasty date back to the 1960s, with the development of "low friction arthroplasty," which reduced the wear sustained by artificial hip joints over time and provided more predictable outcomes. From the first femoral head attachments fashioned from ivory to current technologies, we can take this point in history as a milestone for the emergence of current models manufactured by the modern prosthetic industry (**Figure 2**).

However, without the first steps in any scientific endeavor, future steps are impossible. The nineteenth century brought three major technical advances that revolutionized surgery: Joseph Lister's aseptic technique, the discovery of anesthesia, and the discovery of X-Ray. Before the nineteenth century, people with severe joint problems and walking difficulties were called "cripples." There was not much to do, just the use of herbs to relieve pain and walking aids such as canes and crutches. In the eighteenth century, some surgeons dared to perform joint surgery to try to relieve the pain of these patients, but with poor results. Henry Park (1744–1831) in Liverpool, United Kingdom, was the first surgeon to report an operation with excision of the femoral head, basically performing an excisional arthroplasty. Later, in the 1940s, femoral head excision was popularized by Gathorne Robert Girdlestone (1881–1950) from Oxford in patients suffering from tuberculosis [4].

Later, surgeons began to consider using different types of materials or biological interposition tissues, developing the interposition arthroplasty without success.

It was only in the nineteenth century, with the use of aseptic surgery, anesthesia, and x-rays that the first attempts at joint reconstruction with prostheses began to become

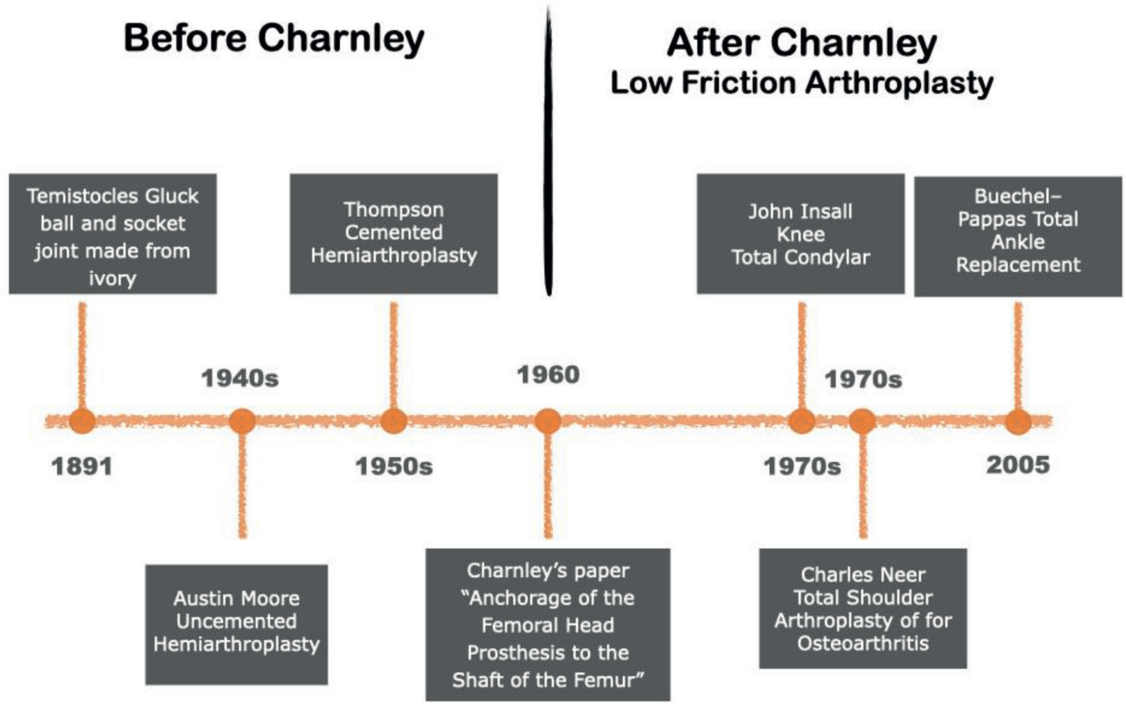


**Figure 2.**
*Timeline of the evolution of arthroplasties.*

viable. In 1891, Themistocles Gluck from Berlin developed a ball and socket joint made from ivory that was fixed to the bone with nickel-plated screws. French surgeon Pierre Delbet (1861–925) used a rubber prosthesis for replacing the femoral head in 1919. In 1927, the British surgeon Ernest W. Hey-Groves (1872–1944) used ivory. In 1948, the Judet brothers, Robert (1901–1980) and Jean (1905–1995) used an acrylic prosthesis.

In 1940, Austin Moore implanted the first Vitallium prosthesis to replace the proximal femur. Modifications were made to preserve the proper neck angle and the stem was fenestrated in subsequent years. In the 1950s, Thompson developed his hemiarthroplasty for femoral neck fractures. Initially, it was operated without cement fixation, but with practice, it changed to a cemented procedure. This phase was marked by the pioneering spirit of great names in orthopedics at the time, who sought a solution to the problem of joint reconstruction. However, the results were still unsatisfactory. These were abandoned when Sir John Charnley defined modern hip arthroplasty [4, 5].

John Charnley developed the concept of "low friction arthroplasty" based on three principles: the idea of low friction torque arthroplasty, the use of acrylic cement and the introduction of high-density polyethylene as a bearing material. Low friction arthroplasty is the principle used until today, although with evolutions and small modifications, in all current prostheses. So we can say that Charnley's paper "Anchorage of the femoral head Prosthesis to the Shaft of the Femur", from 1960, was the birth of the current era of arthroplasties [4–7].

After Charnley, the realization of hip arthroplasties began to have promising clinical results, which led this surgery to become a routine practice and led to production on an industrial scale, contributing to the birth of the current implant industry. The success obtained in the hip encouraged other surgeons to seek similar solutions for other joints in the human body.

The evolution of knee arthroplasties follows a sequence very similar to that of the hip, with the first attempts to perform resection or interposition arthroplasties most of the time unsuccessful. The history of total knee arthroplasties made great progress with the application of the "low friction arthroplasty" principle and the launch of the "total Condylar" model created by John Insall in the 1970s. From then on, there were successful and replicable results, which made possible the flourishing of the modern knee implant industry [8].

In a similar way and practically at the same time, Charles Neer improved his model of hemiarthroplasty created in the 50s for the treatment of fractures of the proximal humerus and launched in the 70s a model of total prosthesis with a component for the glenoid, indicated for cases of shoulder osteoarthritis [9].

The ankle was the last joint in the lower limb where total joint replacement was attempted, and therefore, it is the least developed. The mobile bearing system for the ankle first used by Pappas and Buechel appears to have become widely accepted by orthopedic manufacturers as an accurate solution for replicating the biomechanics of the ankle.

## 5. The present: current results

Arthroplasties are currently among the most practiced surgeries in the world. Routinely, thousands of patients undergo this type of intervention daily in almost every country around the world. This is possible thanks to the effective and safe results obtained with the technique and the great impact on the recovery of people's quality of life.

The safety and effectiveness of the technique can be verified through data collected in large cohorts, called registries, available in many countries around the world. There are local, regional, and national registries. Four registries stand out as the main forces behind the effort to popularize the concept of evidence-based medicine: the Mayo Registry and the Harris registry are important institutional registries in the United States; while among national registries, both the Swedish Knee Registry and Hip Registry [10].

A total estimated 630,000 hip replacement procedures were performed in the United States in 2017. For total knee replacement, the increasing incidence of TKA is a universal phenomenon. In 2017, the United States had 911,000 total knee procedures performed [11].

## 6. Future perspectives

The arthroplasty surgery practiced today was developed about 50 years ago. It was created in the "analogical era." The rapid transformations that occurred with the fourth industrial revolution, accelerated by the COVID-19 pandemic, led us to live in the "digital age." In this scenario of intensive use of technology and computing in all sectors of human life, it is predictable that arthroplasty will undergo transformations. Some of them are already present, although still timidly, in clinical practice. We list below five technologies that are already available, although still timidly used, and that could lead to significant advances in the near future:

- Computer-assisted surgical navigation

Although there is still no consensus on what would be the ideal alignment of a limb with knee prosthesis, the traditional concept of neutral alignment have being questioned by concepts such as kinematic alignment, the quest for reliable and reproducible achievement of the intra-operative alignment goal has been the primary motivator for the development of Computer assisted surgical navigation (CASN). There are already a significant number of clinical studies showing that the use of CASN increases the accuracy of the planned alignment [12]. However, there is still a lack of clinical studies demonstrating that the long-term clinical outcome of using CASN is better than traditional alignment without the use of technology. Although the cost of using the equipment has been progressively decreasing over time and with greater use, it will be necessary for the future to improve the system to further reduce the cost of use and enable its use on a large scale. The reader is invited to explore the chapter in this book called “advanced, imageless navigation in contemporary THA: optimizing acetabular component placement” written by Prof Andrew Kurmis.

- Robotic-assisted surgery

As a natural evolution of the use of CASN, robotic systems with mechanical arms associated with the navigation system emerged. Companies such as Zimmer Biomet (Rosa), Stryker (Mako), Smith & Nephew (Cori), for example, already offer orthopedic surgeons the clinical use of robot-assisted prostheses. Current systems include robotic arms, robotic-guided cutting jigs, or robotic milling systems, with different navigation strategies using active, semiactive, or passive control systems [13–15]. One problem is that the robots used in arthroplasties are not very versatile. There are specific systems for hip or knee, some more recent systems already allow using the same robot for both hip and knee, but not for other joints. This greatly increases the cost for the hospital, making the technology even restricted to places with higher purchasing power. For a deeper understanding of the use of robots in arthroplasties, the reader is invited to read the chapter entitled “active robotic total knee arthroplasty” written by Prof. Andrei Gritsyuk.

- Augmented reality

However, in parallel with the development of navigation and robots, the recent digital technological advance (fourth industrial revolution caused by the emergence of the internet) already presents another type of innovative solution to assist the surgeon in the implantation of the prosthesis: the use of the augmented reality (AR). It is stated that AR could provide a more efficient and cost-effective solution than robotic surgery [16].

- Patient-specific implants

The development of new 3D printing technologies made it possible to design patient-specific implants and single-use instruments, which have also been proposed as an alternative technology to improve accuracy, while also improving efficiency and limiting the associated cost of arthroplasties. This technology has the potential of reducing operating room times over reusable sets, and benefit theater personnel ergonomically while presenting potential cost-saving benefits in terms of reduced sterilization costs and surgical times [17].

- Nanotechnology

The future also promises advances not only in systems to aid prosthesis implantation but also in the manufacture and composition of implants. The

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reader is invited to visit this book the chapters written by Mr. James Broderick on "Biomaterials in arthroplasty" and Prof. Jörg Lützner on "Modern Coatings in Knee arthroplasty."

## Author details

Alessandro Rozim Zorzi[1,2]* and João B. Miranda[2]

1 São Leopoldo Mandic Medical School, Campinas, SP, Brazil

2 Department of Orthopedics, Rheumatology an Traumatology, University of Campinas (UNICAMP), Campinas, SP, Brazil

*Address all correspondence to: arzorzi@hc.unicamp.br

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