Knee History: From Early Developments to the Total Knee Replacement

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Abstract

The knee is often cited as an anatomical weakness in the human body, consisting of two large bone levers. Pathology and trauma of the knee represents the troubles of the human condition and can elucidate hidden features of our past. Recorded knee injuries and treatment date back to primitive times. The Egyptians later began to use splints, and the Greeks subsequently studied knee anatomy. While the Middle Ages were characterized by a lack of development, the Renaissance saw progress in surgery and industrialization stimulated construction of specialty hospitals with a focus on the knee. Modern knee care is symbolized by the advent and evolution of the total knee arthroplasty (TKA) and a doubling of knee arthritis cases in the past 50 years. Therefore, there is great utility in studying the history of knee care, which will allow surgeons and scholars to progress their research and ultimately improve patient care for a burgeoning issue. This paper will for the first time provide a brief overview of the history of orthopaedic care of the knee, with particular emphasis on the TKA.

Ancient Roots (8000 BC – 1100 AD)

Fractures of the knee and early orthopaedic care undoubtedly date back to the earliest part of human history. There is fossil evidence of knee pathology such as fractures, as well as attempts at bone healing in the Neolithic era (8000 BC). Most of the time, physiologic healing resulted in successful union at functioning positions. Nonoperative management of knee injuries predates surgical intervention and continues to be a mainstay of treatment.

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1 Leslie M. Knee arthritis in Americans has doubled since 1940. Science. August 2017. doi:10.1126/science.aan7238
The first evidence of leg splints for fracture healing came from the Shoshone Native Americans (1500 BC). Fashioned out of wet untanned hides, these splints were able to create a rigid structure to stabilize bone reduction. On the other hemisphere, there is evidence that Aboriginal Australians created clay leg splints as well.

Although the Native Americans and Australians first used splints for the purposes of knee injuries, a fascination with embalming and mummification positioned the Ancient Egyptians to develop splinting for cultural reasons. The Egyptians documented a splinting process for injuries in Imhotep’s *Edwin Smith Papyrus* (3000 BC).

The written word allowed the Egyptians to document the stories and artifacts of knee pathology. Most notable are the knees of the Queen Neferetari, wife of Ramses II, which contain marked evidence of painful knee osteoarthritis. Scribes that would stand on knees and sit cross-legged for hours in the pharaoh’s palace were also victim to rheumatic knee pain. Ointments composed of fat, oil, and animal marrow were invented as a result of these conditions.

The next major text that guided knee therapy came in Greece during the time of Hippocrates (400 BC). The *Corpus Hippocraticum*, which contained the Oath physicians still recite today, had a remarkable description of the musculoskeletal system. The concept of traction, malunion, and reduction of the knee are discussed in the chapter *On Fractures* in Volume III.

> “The bones at the knee are indeed frequently dislocated, but they are easily reduced, for no great inflammation follows, nor any constriction of the joint.”

Subsequently, Galen of Pergamon, a product of the Hippocratic school himself, began his systematic study of animal and human anatomy (circa 150 AD). The results of Galen’s study were considered infallible in Europe until the 16th century. Galen’s contributions to musculoskeletal anatomy in *De Motu Muscularum* improved the treatment of knee fractures, especially in the identification of muscles and sensorimotor nerves. Simultaneously, the Romans increased the rate of leg amputations, creating a demand for prostheses, such as the Capua Leg.

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At the Eastern Roman capital of Constantinople, the Arab physician Al-Razi added padding to splints and also emphasized the use of alcohol for wound sterilization (900 AD). Al-Razi was also the first to practice the patellectomy for the treatment of severely comminuted knee fractures, which he describes at length in his book *Al-Hawi*.  

A century later, the Persian scholar Ibn Sina published his compendium *Kitab al-Qanun fi al-tibb* (1000 AD). Upon translation into Latin, the book became as influential as Galen’s work in Europe until the 17th century. Of particular interest is the *Al-Jabr* orthopaedics chapter, which for the first time formally categorized fractures of the knee.

"The patella is rarely fractured, but it is sprained frequently. The fracture is diagnosed by the presence of crepitation, which can be palpated or heard. In respect to treatment, the leg should be extended, then the patella be reduced. But if the fracture was comminuted, the fragments should be gathered first then reduced."

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10 The Wellcome Trust Image Gallery. https://wellcomecollection.org/works?query=M0012307&wellcomeImagesUrl=GET%20/indexplus/image/M0012307.htm%20HTTP/1.1
Middle Ages & Renaissance (1100 AD – 1800 AD)

Although the Middle Ages had less scientific advancement, there remained a few enclaves in Europe with active surgical programs that encouraged experimentation. The University of Bologna in Italy is noted as one of the first institutions with a hands-on surgical program. The French surgeon Guy de Chauliac, who trained at Bologna, invented a traction device for distal femur and tibial plateau fractures around the knee, based on the works of Al-Zahrawi centuries prior.

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Most of the surgeons at the time were barbers untrained in anatomy and pathology. However there were exceptions, such as the Flemish barber Jan Yperman, whose intellectual spirit produced the *Cyrurgia of Jan Yperman*, which provided rare information on hematoma and edema during fractures of the knee.

"The master (surgeon) shall visit the patient every day to inspect the fracture and if necessary to loosen or tighten the strings. He will apply ointment of poplar buds from the knee ... if swelling occurs. A rag soaked in vinegar will cool the legs." 

Medicine and orthopaedics made significant advancements after the secularization of Europe. The renaissance was a visual period, with authors of medical texts often having dual backgrounds in artistry and science, which is reflected in the great works of the era.

The illustrations in *De Humani Corporis Fabrica* published by Vesalius fundamentally changed anatomy into a visual discipline (1543).

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FIG 4: Illustration of leg anatomy from *De Humani Corporis Fabrica*, which depicts Vesalius' detailed dissection of the human musculature around the leg and knee. (1568 AD)

The Frenchman Nicolas Andry for the first time focused on the nonoperative treatment of bones and joints of children. In his seminal book *Orthopédie*, Andry described the knee as a focal point for identifying problems with leg alignment in children, as well as the use of an iron plate for the correction of deformities (1741).

"The sooner that you hinder a Child to walk, when you observe his Knees begin, the least in the world, to incline inwards, it will be so much the better; and if from neglecting these precautions, the Leg is already crooked, you must apply, as soon as possible, a small Plate of Iron upon the hollow side of the Leg, and fasten it about the Leg with a Linnen Roller."

However, the mainstay of operative management of knee conditions in the pre-industrial era was amputation. Henry Park in his letter to fellow surgeon Percival Pott declared the use of total limb amputation as "indispensably necessary" for the treatment of intermittent hydrarthrosis of the knee (1733), which today is rarely treated operatively. The practice of extensive amputations emboldened many surgeons, but had low success and a propensity for infection.

**Industrialization (1800 – 1900 AD)**

Industrialization increased standards of living and advancements in sterilization made surgery safer. The first documented knee resection arthroplasty by Ferguson reflected the new confidence of surgeons (1861). In Europe, Verneuil subsequently described arthroplasty of the knee using the joint capsule for interposition (1863).

Knee arthroplasty was brought to the United States by John Murphy at the Rush Medical College of Chicago, where he treated ankylosed knees using fat and fascia to generate an articular surface. However, it quickly became clear that the knee was more recalcitrant than initially thought, as Murphy later declared in 1905:

"The knee is the most difficult joint in which to secure perfect restoration of function."

The first concept of a total knee arthroplasty (TKA) did not arise until 1880 by Themistocles Gluck, who proposed an ivory implant in the knee. Unfortunately, ivory was prone to

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16 Vesalius Andreas, *De Humani Corporis Fabrica*, Italy, University of Padua, School of Medicine, Padua, 1543.
infection and rapid wear. Nevertheless, Gluck’s idea cemented the notion of knee replacement surgery and this became a topic of serious research.

At the turn of the century, the invention of the x-ray by Wilhelm Röntgen in 1895 gave orthopaedists a new lens by which to diagnose and treat a range of conditions, including knee fractures, avascular necrosis, and osteoarthritis.

**Modern (1900 – present)**

The most dramatic changes in modern knee care can be tracked with the development of the Total Knee Arthroplasty (TKA), which is the focus for the remainder of this paper. Advancements in surgical approach, implant design, biomechanics, and antisepsis characterize the Modern Era and culminate with the current TKA.\(^{20}\)

Gluck’s ivory implant was refined into a metallic interposition in the 1930s, which was superior mechanically and abiotic.\(^{21}\) Smith-Peterson developed a metal femoral mold arthroplasty\(^{22}\), and MacIntosh proposed a metal tibia hemiarthroplasty.\(^{23}\) These operations, however, did not significantly reduce knee pain and were plagued by a high failure rate.

The World Wars also facilitated developments in orthopaedic trauma, with particular emphasis on open reduction internal fixation, amputations, and wound care. Hugh Thomas, the father of modern orthopaedics, devised a splint with traction to treat knee and leg injuries. The Thomas splint reduced the mortality of compound ballistic fractures of the lower extremity and knee.

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Following the war, principles of trauma management were incorporated into implant design. The Walldius hinge joint brought increased mobility in 1951. This prosthesis replaced femoral and tibial articular surfaces, but could not replicate the complexity of human biomechanics. The material of this joint was a rigid cobalt and chrome alloy, but like many early implants for TKA, was prone to failure from overloading or infection. The Walldius implant was in many ways the first attempt at a TKA emulating natural human movement, and its success in that regard led to its use until 1970.

The next milestone was adopted from advancements in hip replacements. Sir John Charnley developed CMW bone cement to allow the fusion of joints during total hip arthroplasty. He later developed a metal-on-polyethylene articulation. Both of these features were tested in knee by Charnley’s colleague Frank Gunston, who developed a metal-on-polyethylene implant capable of rotation throughout knee flexion.

The flexibility of Gunston’s implant was due to the preservation of collateral and cruciate ligaments. Moreover, the design of the metal prosthesis involved tibial and femoral articulating surfaces that reduced wear and distributed load over a large area. Gunston’s design gained widespread acceptance through the 1980s.

The use of a metal prosthesis to replace the tibial and femoral articulating surface became standard by 1970. However, two different surgical approaches began to rise and created a rift that still exists today. Sumiki Yamamoto’s approach aimed to preserve the anterior and posterior cruciate ligaments. The knee replacement team at the Hospital for Special Surgery (HSS) developed a second approach that was more functional but substituted the posterior cruciate ligament with a total condylar knee prosthesis (1974). Walker’s iteration of the HSS design included a tibial stem, which was a prototype for modern posterior cruciate ligament substitution knee arthroplasty, and could flex to 70 degrees (1976).

Yamamoto’s more conservative approach complemented the invention of a kinematic duopatellar condylar prosthesis that preserved the posterior cruciate ligament. The femoral implant maintained a trochlear groove that interacted with the polyethylene patella. This design was used through the 1980s and had a knee flexion angle of 90 degrees.

Although Walker’s design ultimately became more widely used, complications continued to plague outcomes of all artificial knee implants. In particular, the patellofemoral joint was subject to wear and lateral displacement, which is documented in cases throughout the 1990s. Current knee arthroplasty attempts to use greater contact surface areas of the patellar implant to avoid displacement.

New research in the sizing of implants, surgical instruments, and materials with lower wear rates provide promising developments. Common patient concerns of durability, stability, and

range of motion serve as metrics for surgeons and researchers today. A recent study on the importan
tce of leg alignment in surgery has stimulated conversation about technique.  

One should note that TKA was not the only method of treating osteoarthritis and other knee joint pathologies. For example, Gross was working on the treatment of osteoarthritis involving biologic replacement (1975). Meyers attempted allograft transfers but was plagued with issues in cartilage preservation and tissue typing (1989). Perhaps this method of treatment for knee issues will resurface with modern immunotechnology. Other techniques in treating meniscus tears or advancements in anterior cruciate ligament reconstruction are outside the scope of this paper, but also made significant progress during this time.

Nonoperative management also saw gains in the modern era, with better categorization of knee injuries. For example, Schenck developed detailed criteria for knee dislocations that is now used worldwide (1994).

Conclusion

From ancient roots, knee pathology and treatment has been constantly shaped by technological development. Knee injuries are central to our history and affect all people, from an Egyptian queen to World War veterans. The complex interplay of knowledge often from other disciplines, has uplifted orthopaedic knee care with the culmination of the Total Knee Arthroplasty. Surgeons and researchers can benefit from studying orthopaedic history and appreciating the lessons of a rich narrative in which they play part. With a growing emphasis placed on minimally invasive procedures, outcomes, and value by today’s society, it will be interesting to see how this field continues to evolve.