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The Insall Legacy in Total Knee Arthroplasty

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John N. Insall was a pioneer in the field of knee surgery. He was a rare individual who accomplished unparalleled levels of success as a surgeon, designer, and teacher. During the past 4 decades, he was instrumental in evolving total knee arthroplasty to its current state of excellence. Insall's impact on orthopaedics is felt by all who have come in contact with him.

Four decades ago, total knee arthroplasty was in its infancy and surgeons were seeking alternatives for arthrodesis and fascial arthroplasties in the treatment of the arthritic knee. Innovative designers were developing various implants such as the Polycentric, the ICLH, and the Freeman Swanson prostheses.[3,15,23] It was then that John N. Insall (Fig 1) became involved in the design of modern total knee arthroplasty.

In 1970, at the Hospital for Special Surgery, the Duocondylar Prosthesis was designed as a modification of the Polycentric Knee prosthesis.[63] Although Insall contributed to the design of the Duocondylar prosthesis, which first was implanted in 1971 and the subsequent Duopatellar prosthesis (Fig 2), Peter Walker was the primary bioengineer on this project. Insall and Walker worked together on total knee implant designs until the era of the Insall-Burstein Stabilized Knee prosthesis.

These designs were followed by a rapid evolution in total knee arthroplasty design.[32,44,52] Although others were focused on nonconforming posterior cruciate-retaining implants or hinged implants, Insall directed his implant design toward a nonlinked surface replacement with conforming surfaces. Dissatisfied with the Duocondylar and Duopatellar prostheses, Insall was the major clinical investigator in designing the Total Condylar prosthesis[45,51] (Fig 3). This posterior cruciate-sacrificing design with a conforming articular surface, an anterior femoral flange, and a dome-shaped patella component became the first implant of modern design.[2,64] Critical to the success of the arthroplasty was the surgical technique. He recognized the limitations of posterior cruciate retention and was convinced that removal of the cruciate ligaments provided superior and more reproducible clinical results. Insall recognized that surgical technique was crucial for the success of any implant design and simultaneously described the surgical technique that included ligament releases for restoring axial alignment and balancing the flexion and extension spaces.

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Fig 1. John N. Insall, MD (Reprinted with permission from Brad Hess).

In February 1974, Insall implanted the first Total Condylar prosthesis. By 1976, he implanted more than 300 prostheses. As his clinical experience in total knee arthroplasty matured, Insall realized that the successful Total Condylar prosthesis required improvement and modification.[40,42,47,50,86,87] There were reported cases of flexion instability, which were most likely errors in surgical technique rather than implant design. Insall determined that to stabilize the knee in flexion, the posterior cruciate ligament, which was resected, would require some type of substitution. The first design modification was the Total Condylar Prosthesis II (TCP II) (Fig 4), with its high tibial post that was designed to be a passive stop against posterior displacement in flexion.[49] The TCP II was implanted between 1976 and 1977. Its life was short lived because of early loosening. Not discouraged by his failure with the TCP II and his desire to find a posterior cruciate-substituting knee design, Insall began to work with bioengineer, Albert Burstein. Together they designed the implant that bears their names, The Insall-Burstein posterior-stabilized knee prosthesis (IB I) (Fig 5). The implant was introduced in 1978 and has been the design against which all future posterior cruciate-substituting designs will be compared.[43] The IB I was designed with a dished articular surface and a tibial spine-femoral cam mechanism that substituted for the resected posterior cruciate ligament and controlled femoral rollback and improved the range of motion (ROM). The original IB I had an all-polyethylene tibial component; however, laboratory studies revealed that metal-backed tibial

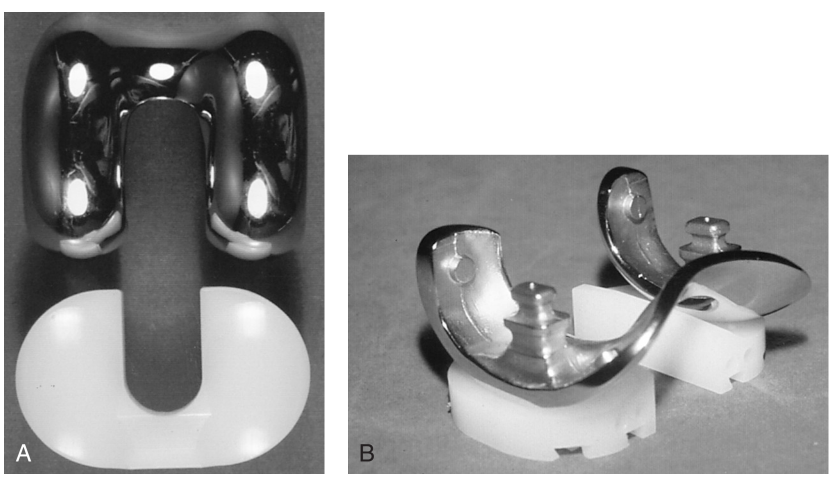

Fig 2A–B. (A) The Duopatellar Prosthesis and (B) the Duocondylar Prosthesis are shown.

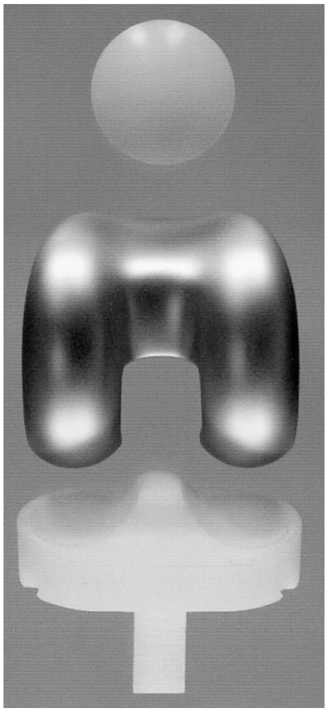

Fig 3. The Total Condylar prosthesis was a popular posterior cruciate-sacrificing prosthesis.

Fig 4. The Total Condylar II prosthesis was designed to have a passive stop against posterior displacement.

Fig 5. The Insall Burstein Posterior Stabilized I Knee prosthesis was designed to substitute for the posterior cruciate ligament. (Reprinted with permission from Zimmer, Warsaw, IN).

components transmitted the load better to the underlying bone and potentially reduced the incidence of tibial component loosening.[4] By November 1980, Insall was exclusively implanting the IB I prosthesis with a metal-backed tibial component. The IB I prosthesis had an exemplary history with both tibial components as shown with its excellent clinical performance and survivorship data.[9,65,67,72,79] In 1988, the Insall-Burstein Posterior-Stabilized II prosthesis (Fig 6) was introduced with a modular tibial tray and the ability to add augments and stem extensions to the core prosthesis.

By this time the concept of posterior cruciate ligament substitution was well entrenched in prosthetic knee design. This concept was gaining in popularity and always generated great debate and controversy at meetings. Recognized as one of the premier designing knee surgeons, Insall became the international spokesman for posterior cruciate substitution. Although others touted the merits of posterior cruciate retention, Insall responded with sound scientific information and excellent clinical reports. The fears of loosening and early failure in this semiconstrained implant, as announced by the contrarians, never materialized. Although cruciate-retaining knee designs changed their

Fig 6. The Insall Burstein Posterior Stabilized II Knee prosthesis introduced a modular tibial tray that would accommodate augments and stem extensions. (Reprinted with permission from Zimmer, Warsaw, IN).

articular geometry from a flat-on-flat design to a more dished design, Insall never significantly modified the original conformity of his posterior-stabilized implant. Although surgeons who implanted cruciate-retaining protheses began to use alternative methods of implant fixation, Insall always advocated cement fixation. He was unwavering in these ideas and it now is apparent that he was correct because many surgeons are embracing his concepts.

However, Insall was not finished with implant design. In the mid1990s, Insall improved on the IB II prosthesis with the introduction of the NexGen Legacy Posterior-Stabilized Knee Prosthesis (LPS) (Fig 7). This prosthesis is the direct descendent of the IB II prosthesis and was designed to improve patellar femoral tracking. The prosthesis, with more size options, offered an anatomic design with right and left femoral components, a raised lateral femoral flange, and a deeper trochlear recess to achieve optimal knee kinematics. In designing a longer trochlear groove, the femoral cam was moved more posteriorly on the femoral condyles, which had a beneficial effect on the spine cam mechanism.

Fig 7. The Legacy Posterior Stabilized Knee prosthesis is a direct descendent of the IB II prosthesis. (Reprinted with permission from Zimmer, Warsaw, IN).

Similar to the IB II prosthesis, the cam would engage the tibial spine at 70°. However, instead of riding up the tibial spine, as happens with the IB II, the LPS cam rides down the tibial spine as the knee flexes. This increases the jump distance and provides an inherent safety feature against flexion instability. Intrigued by the desire to bring total knee arthroplasty to regions of the world, such as Asia and the Middle East, where patients require higher degrees of flexion for their social and religious activities, Insall designed the LPS-Flex Knee Prosthesis (Fig 8).

Fig 8. The LPS-Flex fixed-bearing prosthesis was designed to accommodate high degrees of flexion safely. (Reprinted with permission from Zimmer, Warsaw, IN).

Coupled with the predictable kinematics of a posterior-stabilized and augmented posterior femoral condyles, the LPS-Flex Knee Prosthesis potentially can revolutionize total knee arthroplasty.

Although fixed-bearing knee designs always had been Insall's primary interest, he was open to newer design concepts that may improve implant durability and performance. While working on the LPS project, he also was working on a parallel project with mobile-bearing knee replacements.[8,33] It was becoming apparent, with reports in the literature of wear and osteolysis with other implant designs,[92,93] that prosthetic designs may need to increase their surface area to reduce contact stresses. This could be achieved by increasing the conformity of the tibiofemoral articulation, which also meant that a mobile-bearing tray would need to be designed to diminish any kinematic conflicts. The outcome of this project was the Mobile Bearing Knee (MBK) prosthesis, now popular in Europe and Asia (Fig 9). A spin-off of the MBK design is the LPS–Flex Mobile prosthesis (Fig 10), which is a rotating platform that is receiving a great deal of attention and excellent initial success.

Fig 9. The Mobile Bearing Knee prosthesis has greater articular conformity with a modular mobile bearing tray. (Reprinted with permission from Zimmer, Warsaw, IN).

Fig 10. The LPS-Flex mobile bearing prosthesis is a posterior-stabilized implant with a rotating tibial platform. (Reprinted with permission from Zimmer, Warsaw, IN).

During this rapid evolution of knee prosthetic design, instrumentation often lagged behind implant technology. The thought that better implant design would lead to a lower incidence of component loosening and an improvement in the ROM resulted in greater focus on prosthetic design. Although it initially was thought that ligamentous laxity and angular deformity in the arthritic knee could be compensated for by bone resection, it soon became apparent that this created the risk of instability and compromised the clinical outcome. However, Insall realized that meticulous surgical technique, in particular component positioning, knee alignment, and soft tissue balancing, was essential in obtaining a long-lasting total knee arthroplasty. He described soft tissue releases to correct fixed angular deformities and to create balanced flexion and extension gaps (Fig 11). The specific soft tissue technique for the correction of a varus deformity first was described in 1976.[45] This publication includes the original description of the medial release for a fixed varus deformity. Insall stressed the importance of a subperiosteal release of the medial collateral ligament, posteromedial capsule, and the pes anserinus tendon. This soft tissue release continues to be used today and essen-

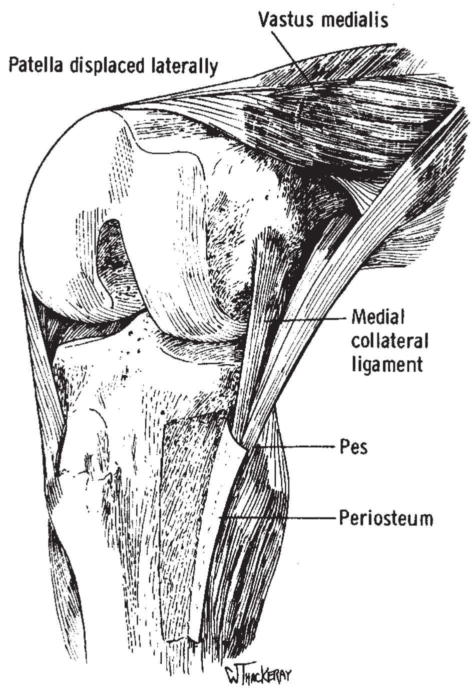

Fig 11. The varus release is shown. (Reprinted with permission from Insall JN: Total Knee Replacement. In Insall JN (ed). Surgery of the knee. New York, Churchill Livingstone 587–696, 1984.)

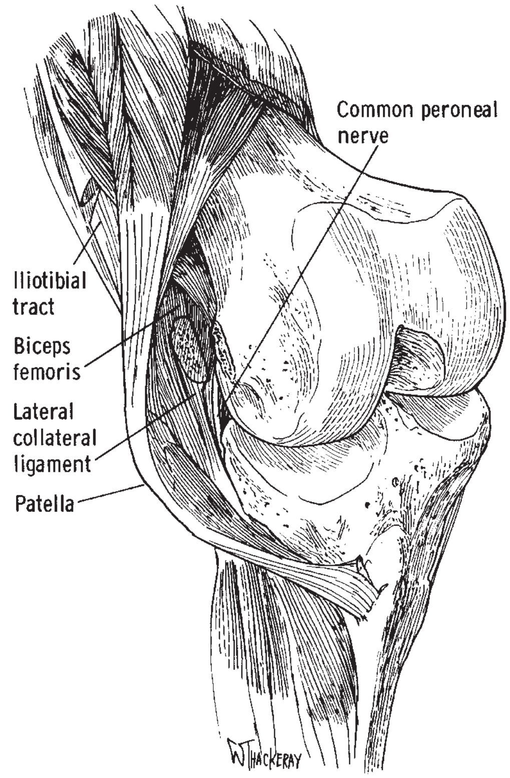

Fig 12. The complete valgus release is shown. (Reprinted with permission from Insall JN: Total Knee Replacement. In Insall JN (ed). Surgery of the Knee. New York Churchill Livingstone 587–696, 1984.)

tially is unchanged from Insall's first description. With almost subliminal coincidence, Insall's friend, Michael Freeman, independently developed a similar philosophy and technique concerning soft tissue balance in total knee arthroplasty. However, the valgus knee was a more perplexing problem and Insall continued to refine and improve his surgical technique. Between 1976 and 1979, he was doing an outside-in lateral ligamentous technique, with dissection and isolation of the peroneal nerve, to correct fixed valgus deformity (Fig 12). However, he was not satisfied with the potential risk of a peroneal nerve palsy, even though they were transient, and he began looking for alternative techniques.[82] This led him away from peroneal nerve dissection and to an all-inside technique in which the lateral supporting structures were stripped from the lateral femoral condyle. Although this technique restored proper axial alignment, he occasionally observed flexion instability. Seeking a more perfect solution for the fixed valgus deformity Insall used an all-inside soft tissue release that pie crusted the lateral supporting structures and preserved the popliteus tendon (Fig 13). Insall thought this was the ideal solution to a difficult problem. His most recent comments on soft tissue balancing and the quest for perfection can be found in the report of Griffin et al.[20]

These soft tissue releases always have been coupled with the philosophy of equal flexion and extension gaps (Fig 14). Adopting the tensor instrumentation of Freeman in 1974, Insall embraced the concept of balanced gaps. In 1976, Insall first coined the terms flexion gap

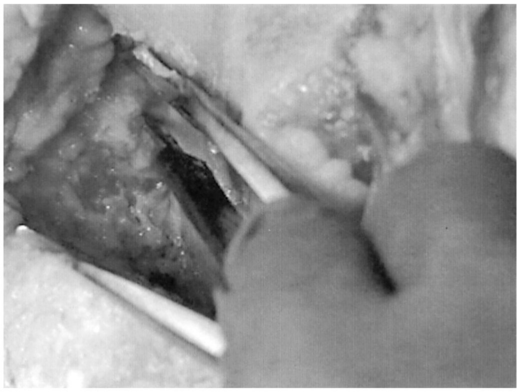

Fig 13. The pie crust technique for correcting a valgus knee is shown.

and extension gap.[45] To achieve balance between these two gaps, Insall described the classic method of bone resection and aforementioned soft tissue releases. He described the use of an alignment rod and spacer block to achieve the properly balanced gaps between the femur and tibia. This method of bone resection introduced the concept of rotational alignment of the femoral component. To create a symmetric flexion gap, the femoral component needed to be rotated externally. In 1988, Insall elaborated on his surgical techniques and offered solutions to flexion and extension mismatches.[30] Being receptive to new ideas that had sound scientific support, he developed instrument systems for improvement in the surgical technique. Realizing that the tensor was accurate, but not easy to apply, he began to use intramedullary instruments in 1986. These instruments resected a fixed amount of bone from the femur and tibia and relied on soft tissue balance and femoral component rotation to balance the gaps. Realizing that the shortfall of this instrument system was the accuracy of positioning the femoral component in the proper degree of external rotation, he sought an improved technique. Enamored by the concept of the epicondylar axis as the axis of knee flexion, Insall designed the epicondylar instruments[19,21,62,70] (Fig 15).

With the rapid evolution of total knee arthroplasty design in the 1970s and 1980s, the need for revision arthroplasty became apparent.[36,58] Insall was instrumental in the design of revision components, and in the diag-

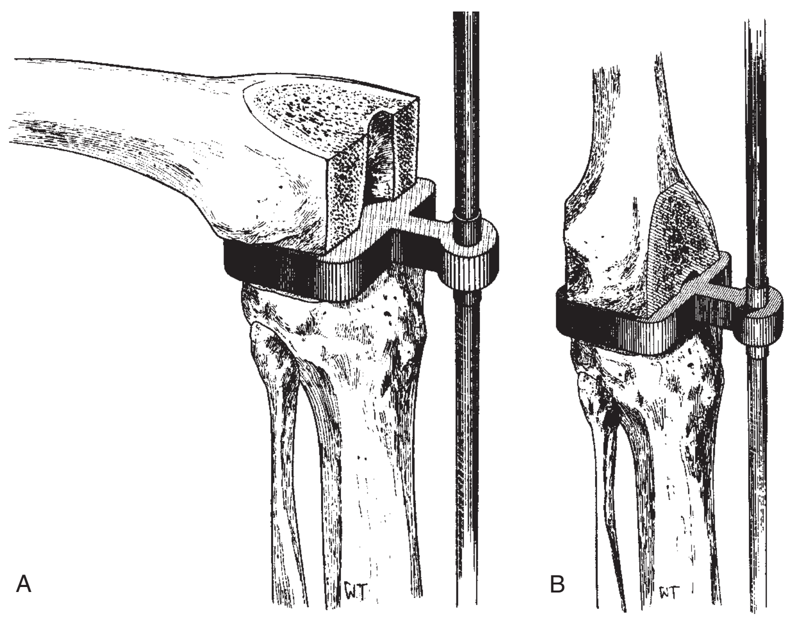

Fig 14A–B. Spacer blocks are used for balancing the (A) flexion and (B) extension gaps.

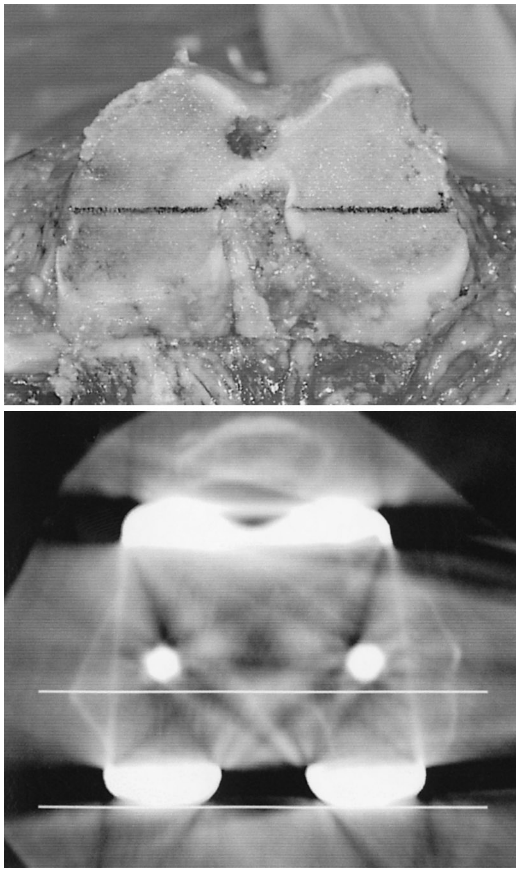

Fig 15. The epicondylar axis is shown.

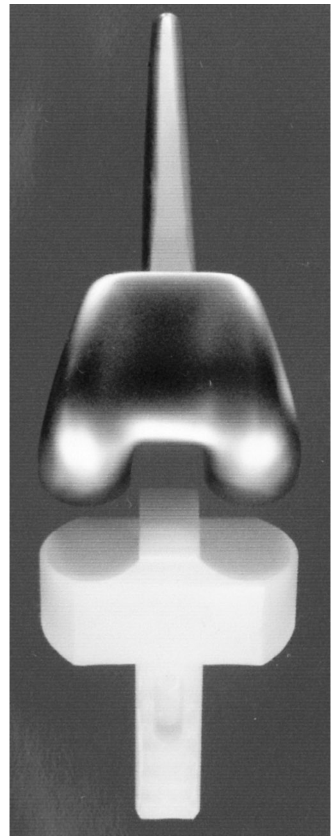

Fig 16. The Total Condylar III prosthesis was introduced as a nonlinked constrained implant.

nosis and treatment of failed arthroplasty.[68,69] In the arena of implant design, he was integral in the design of the Total Condylar III prosthesis (Fig 16). Introduced in 1977, the TCP III was the successor to the Stabilocondylar prosthesis and was designed as an alternative to fixed hinges (Fig 17). Historically, hinged implants, such as the Walldius, Shiers, and GUEPAR were easy to use because at the time of the arthroplasty all the ligaments were resected and the stems dictated the alignment. Unfortunately, reports of long - term results with these prostheses revealed high rates of loosening, significant patellar pain and instability, and high infection rates.[26,53,54] Also, severe bone loss made salvage by arthrodesis difficult. The Total Condylar Constrained Knee prosthesis (TCP III) was designed by Insall and colleagues to provide greater stability and constraint with a nonlinked implant. The indications for a constrained implant include medial collateral insufficiency, lateral collateral insufficiency, inability to balance the flexion and extension gaps, and severe valgus. The early results with the TCP III were very encouraging. Donaldson et al[12] reported on the use of the TCP III in complex primary and revision total knee arthroplasty. The majority of patients had excellent or good results with this nonlinked constrained prosthesis. In 1988, the TCP III eventually became the Insall-Burstein II Constrained Condylar Knee prosthesis (CCK) (Fig 18) with a full complement of stem extensions, augments, and wedges. This

Fig 17. The Stabilocondylar prosthesis was one of the first constrained implants.

modular knee system improved surgical versatility and enabled surgeons to deal with most intraoperative situations. This design also would accommodate a posterior-stabilized or constrained condylar tibial insert. This was the

Fig 18. The IB Constrained Condylar Knee prosthesis is a modular implant that permits the addition of femoral and tibial augments and stem extensions. (Reprinted with permission from Zimmer, Warsaw, IN).

Fig 19. The Legacy CCK prosthesis has a large assortment of modular options. (Reprinted with permission from Zimmer, Warsaw, IN).

first complete revision knee system. When Insall designed the LPS, he also introduced the Legacy CCK (LCCK) system (Fig 19). This revision system included all the modular features of the IB CCK, but increased the modu-

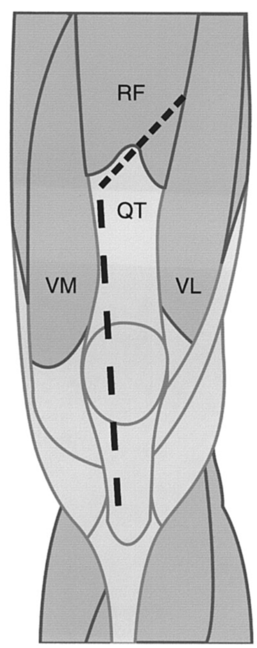

Fig 20. The Insall quadriceps snip is shown. RF = rectus ferrous; QT = quadriceps tendon; VM = vastus medians; VL = vastus lateralis.

lar options and stem extensions, including the introduction of offset stems.

Implant design is not the only variable that influences a successful outcome. Paramount to success is the identification of the cause of failure and then appropriate treatment. Numerous articles and chapters on the mechanisms of failure in total knee arthroplasty have been published.[57,58,60,66,69,71,75,90,91] Insall always stated that before considering a revision total knee arthroplasty, the etiology of failure should be defined. Revision surgery without a clear reason may fail to correct the underlying problem. Revision for infection also is a complex situation, which requires skill and meticulous technique to restore a functional outcome.[18,88] Insall et al[49] wrote the landmark article on the treatment of infected total knee arthroplasty with a two-stage procedure. The principles of revision total knee arthroplasty are similar to the principles of primary surgery. This is evident in a monograph, coauthored by Insall, which describes a nine-point grid for achieving appropriate balance in revision total knee arthroplasty.[84] These complex cases also present with difficulties in exposure and Insall has been credited with describing the quadriceps snip, which bears his name[17] (Fig 20).

During more than 30 years of orthopaedic practice, Insall shared his clinical experiences with the medical community.[27,31,37] Insall and coworkers wrote exhaustive articles on various conditions that affect the outcome of total knee arthroplasty such as osteonecrosis,[80] posttraumatic arthritis,[55,94] rheumatoid arthritis,[66] hemophilia,[56] psoriasis,[81] Charcot arthropathy,[77] poliomyelitis,[61] Parkinson's disease,[85] diabetes mellitus,[14] extraarticular deformities, bone defects,[65] ipsilateral hip fusion,[16] knee ankylosis,[59] chronic patella dislocation,[7] valgus deformity,[13,82] prior high tibial osteotomy,[89] and obesity.[22] He also cowrote articles on young active patients[11,78] and patients with bilateral disease who had total knee replacement.[76] He also had an interest in deep vein thrombosis and its impact on the results of total knee arthroplasty.[24,25,73] Recognized by his colleagues as a leader in the field of total knee arthroplasty, he was elected president of the Knee Society in 1987.[31] With time, his innovations have been embraced and, most importantly, his results have been reproducible.

John N. Insall's contributions to knee arthroplasty are legendary. He was a rare individual who accomplished unparalleled levels of success as a surgeon, designer, and educator. His academic influence was most powerful on an individual basis for those fortunate enough to have worked with him. For the entire orthopaedic community he laboriously worked on his book now in its third edition.[29,31,33] Although the current authors focus on Insall's contributions to the field of total knee arthroplasty, it is essential to remember that he also was a major contributor to the areas of osteotomy,[5,6,48,74] anterior cruciate ligament reconstruction,[41] posterior cruciate ligament reconstruction,[39] and patellofemoral disorders.[1,10,28,34,35,38,46] Similar to his life, John N. Insall's contributions in perpetuity will manifest his unparalleled influence on surgery of the knee.

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