# The History of Intramedullary Nailing

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The history of intramedullary nailing for the treatment of long bone fractures and nonunions is long and storied. From the earliest recorded examples in 16th century Mexico to the current procedures of today, there has been an evolution of design, materials, and basic science principles, which has resulted in a well accepted and successful technique for the past several decades. Interestingly, throughout the early history of intramedullary nailing, these advances in method, principle, and design appear to parallel advances in anesthetic and aseptic techniques, allowing for routine operative care of fractures to emerge.

Although intramedullary nailing is now the standard of care for the treatment of most diaphyseal lower extremity fractures, introduction of the technique was met with a great deal of skepticism in both Europe and North America during the first half of the 20th century. In the latter half of the 20th century, intramedullary nailing of long bone fractures revolutionized the care of the multiply injured patient.

## The Beginnings

Bernardino de Sahagun, a 16th century anthropologist who traveled to Mexico with Hernando Cortes, recorded the first account of the use of an intramedullary device.[1] De Sahagun witnessed Aztec physicians placing wooden sticks into the medullary canals of patients with long bone nonunions. Other pre-Twentieth century intramedullary techniques also seemed to be conducted in patients with nonunions and not in patients with acute long bone fractures.

During the mid 1800s through the first decade of the 1900s, most of the work in intramedullary nailing of nonunions appear to revolve around the use of ivory pegs. It had been observed that ivory pegs would reabsorb in the human body compared to metallic implants, which became encapsulated with fibrous material. The majority of this work was reported at the time in the German literature.[2,3] During the 1890s, Gluck recorded the first description of an interlocked intramedullary device.[4] The device consisted of an ivory intramedullary nail that contained holes at the end, through which ivory interlocking pins could be passed. Around the same time period, Nicolaysen of Norway described the biomechanical principles of intramedullary devices in the treatment of proximal femur fractures.[5] Nicolaysen proposed that the length of intramedullary implants be maximized to provide for the best biomechanical advantage. While ivory seemed to be the material of choice reported in the German literature, Hoglund of the United States reported the use of autogenous bone as an intramedullary implant in 1917.[6] He described a technique in which a span of the cortex was cut out and then passed up the medullary cavity across the fracture site.

During World War I, Hey Groves of England reported the use of metallic rods for the treatment of gunshot wounds.[7] These rods were passed into the medullary cavity through an incision made over the fracture site. This technique appeared to have a high infection rate and was not universally accepted. It was not until Smith-Petersen's 1931 report of the successful use of stainless steel nails for the treatment of femoral neck fractures, that the application of metallic intramedullary implants began to expand rapidly.[8] In the United States, Rush and Rush described the use of metallic Steinman pins placed in the medullary canal to treat frac-

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tures of the proximal ulna and proximal femur.[9] While these techniques provided a foundation of principles for the treatment of fractures with intramedullary fixation, there would be an explosion of principles and methods in the decades to come.

## Origins and Evolution of Küntscher Nailing

Gerhard Küntscher was born in Germany in 1900. His early interest in intramedullary devices resulted from his work with the Smith-Petersen nail in the treatment of femoral neck fractures. Küntscher believed the same basic science principles would be applicable in the treatment of diaphyseal fractures. During development of his "marrow nail," he conducted cadaveric and animal studies. His original intramedullary nail was a V-shaped stainless steel nail that was inserted antegrade. Küntscher first reported use of the V-shaped nail in 1940 and proposed the nail would act as an internal splint that created an elastic union with the inner medullary cavity.[10] It appears that early in the development of his technique, he recommended inserting the nail into the bone distant to the fracture site, thus, avoiding any disturbance of the zone of injury. Intraoperative reductions were achieved with the use of multiple slings; while head worn fluoroscopy was used for bony visualization. Küntscher believed that proper insertion of his nail would allow for immediate functional mobilization of the patient.

Küntscher's early work was not well received in Germany, and early in World War II he was sent to the northern Finnish front. There he collaborated with Finnish surgeons, which resulted in a report, in 1947, of 105 cases using the V-shaped nail.[11] By the late 1940s, Küntscher had begun to abandon use of the V-shaped nail design in favor of another Küntscher design, the cloverleaf nail.

While there was some interest in the use of Küntscher's technique in Europe during World War II, his method was essentially unknown in the US. The use of the Küntscher nail was first described in the US in a March 12, 1945, Time Magazine article, entitled "Amazing Thighbone." This article discusses the skepticism displayed by American surgeons on discovering the metallic rods implanted in US servicemen by German doctors. It would be several more years until the first report of the Küntscher nail would appear in the English medical literature.[11] During the 1940s, various other intramedullary designs were introduced. Westerborn reported his experience with a V-shaped nail in the Scandinavian literature in 1944.[12] In 1946, Soeur reported on his use of a U-shaped nail in the femur, tibia and humerus.[13]

In the US, the Hansen-Street nail was introduced in 1947.[14] This was a solid diamond-shaped nail, designed to resist fracture rotation via its compressive fit within the cancellous bone. These nails were originally inserted using a closed method in order to avoid the high infection rate reported earlier by Hey Groves. However, with the utilization of penicillin, Street transitioned to open retrograde nailing to avoid side effects of the radiographic techniques of the day.

### *1950s*

During the 1950s, two important techniques were developed and introduced. In 1942, Fischer had reported, in the German literature, the use of intramedullary reamers to increase the contact area between the nail and host bone, with the hope of improving stability of the fracture.[15] However, it took another decade with Küntscher's introduction of flexible reamers for the concept to take hold. Fischer also believed that reaming in combination with a larger diameter nail would enhance the stability of fractures by increasing the contact area.

He felt that, although the intramedullary vascular supply was obliterated through this technique, the periosteum and surrounding tissues would promote adequate bone formation for healing. Another currently used technique introduced in the 1950s was the application of interlocking screws to enhance stability of the construct. Modny and Bambara introduced the transfixion intramedullary nail in 1953.[16] This nail was cruciate-shaped, with multiple holes the length of the nail to allow for placement of screws at 90° angles from each other. Modny and Lewert later reported excellent results in a series of 261 femur fractures treated with this nail.[17]

### *1960s*

Enthusiasm for compression plating of long bone fractures exploded during the 1960s, and general advancement in the use of intramedullary nails "went on hiatus." Despite the emergence of compression plating, there were several advancements that changed the future practice of intramedullary nailing.

Cephalomedullary nails were first introduced in the 1960s, highlighted by the development of the Zickel nail in 1967.[18] The Zickel nail contained a hole in the proximal portion in order that a separate nail could be placed through the lateral cortex of the proximal femur into the neck and head. A set screw, which continues to be found on some current cephalomedullary designs, could be inserted through the proximal portion of the shaft nail to prevent backout of the head and neck nail.

During the 1940s and 1950s, many surgeons abandoned early radiological techniques, such as head worn fluoroscopy, because of the potential side effects to both surgeon and patient. This forced these surgeons to adopt an open nailing technique. The development of radiological image intensification, in the 1960s, allowed surgeons to readopt closed nailing techniques with a much lower risk to patient and surgeon alike.

### *1970s and 1980s*

The exuberance that accompanied the advent of compression plating for tibias and femurs in the 1960s quickly diminished in the 1970s and, thus, a renewed interest in refining closed nailing techniques appeared. This reemergence of closed

nailing has led to many of today's current techniques. As the use of reamed nailing gained more traction, unreamed nailing became reserved for open fractures. Also during this time, a rapid gain in experience occurred using reamed nails for treating tibial shaft fractures. The dominant design during this time period was the slotted cloverleaf-shaped interlocked nail, e.g., the AO and Grosse-Kempf nails.

As surgical techniques continued to expand during this time, there was a surge in clinical data regarding the use of reamed interlocking nails of both the femur and tibia. This was culminated by a three-part study of reamed interlocked femoral nails by Brumback and colleagues.[19-21] This work reported a 98% (85/87) initial healing rate with statically locked, reamed intramedullary nails in 87 femur fractures. Union was reported in the remaining two fractures after dynamization.

### *1990s and the 21st Century*

While there was certain progress as far as nail design and materials is concerned during the 1990s, the major advancements came with the expansion of indications for unreamed and reamed intramedullary nailing. Open tibial shaft fractures were now being treated with intramedullary fixation with good results. Likewise, open femur fractures that previously were managed with unreamed nails, were now being treated with reamed nails. In addition, very proximal and distal tibia and femur fractures, once thought to be unsuitable for nailing, were benefiting from intramedullary fixation. Design achievements of the 1990s included the introduction of new titanium nails, cephalomedullary devices such as the Gamma nail, and retrograde supracondylar intramedullary nails such as the GSH (Green-Seligson-Henry) nail.[22,23]

In addition, slotted cloverleaf cross-sectional designs were being replaced by nonslotted designs that provided greater torsional rigidity.

In 1999, Brumback and associates reported a two-part study looking at immediate weightbearing in patients with comminuted femoral shaft fractures that were treated with intramedullary nailing.[24] These investigators concluded that immediate weightbearing is advisable in patients who had their femur fractures fixed with larger diameter nails with high fatigue strength, as this allows for more rapid mobilization for the trauma patient with multiple injuries of the extremities.

## Future Advancements

While today's experience with intramedullary fixation for tibial and femur fractures has been quite good, there will most certainly be continued research to improve the technique. The most likely two areas of future research will revolve around different biomaterials and biologically active agents to promote bone healing. Two types of biomaterials that may hold promise include biodegradable polymers and shape memory alloys. Biologically active agents, such as bone morphogenic protein-2 and -7, have been used with good success in the promotion of bone healing in both animal models and humans. How to combine these bioactive agents with implants in a cost effective manner is yet to be determined.

## Conclusion

Intramedullary nailing has a long and interesting history that dates back, at least, to the 16th century. Modern intramedullary techniques were developed by Küntscher in Germany during the 1940s and were originally met with much skepticism. Despite these early doubters, intramedullary nailing has become the standard of care for the treatment of femoral shaft fractures and tibial fractures that require operative stabilization.

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