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REVIEW ARTICLE

One century of Kirschner wires and Kirschner wire insertion techniques : A historical review

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A century ago, in 1909, Martin Kirschner (1879-1942) introduced a smooth pin, presently known as the Kirschner wire (K-wire). The K-wire was initially used for skeletal traction and is now currently used for many different goals. The development of the K-wire and its insertion devices were mainly influenced by the change in operative goals and by the introduction of antibiotics. The first versions of the Kirschner wire were hammered through a predrilled hole into the bone, but later on drilling became the standard technique of insertion. Drilling is considered a simple way of implanting, with many advantages, such as percutaneous and atraumatic insertion. However, this technique also has its disadvantages like temperature elevation, resulting in osteonecrosis and heat-related complications. Despite these complications the K-wire is now standard for the treatment of hand fractures, worldwide.

Keywords : Martin Kirschner ; Kirschner wire ; history ; Steinmann ; World War II.

MARTIN KIRSCHNER

Martin Kirschner was born on the 28th of October 1879, in Breslau, Germany, today known as Wroclaw, Poland. He studied medicine in Freiburg, Zurich and Munich and received his MD degree from the University of Strasbourg in 1904 (*24,36,74*). In 1909 Martin Kirschner introduced one of his most important contributions to emergency medicine : thick, smooth pins which evolved over the years into thin, smooth, stainless steel wires with various tips (*30,48*). The latter we know today as Kirschner wires (K-wires). It took quite some years before the K-wire became what it is now. The development was influenced by various factors such as wound infection, refinement of the insertion method and change of its goals, e.g. it became very useful for small fragile bones rather than thick long bones. During his lifetime Martin Kirschner was promoted to professor of surgery at the University of Königsberg, the University of Tübingen and the University of Heidelberg in 1916, 1927 and 1934 respectively. He remained at Heidelberg until his death, due to an inoperable carcinoma of the stomach, on the 30th of August 1942 (*24,36,74*).

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KIRSCHNER WIRE AND INSERTION DEVICES

Steinmann versus Kirschner

At first, the K-wire was not a wire but a pin which Martin Kirschner used for "Nagelextension", i.e. skeletal traction for fractures of the long bones by means of a nail. The principle of the pin was based on the Steinmann nail which had been introduced by Fritz Steinmann in 1907 (*62*). Steinmann placed two nails in the distal fragment of a broken bone, laterally and medially, whereafter traction was applied to the protruding ends of the nails, so keeping the fragments in proper alignment. In contrast to Steinmann, Kirschner placed only one pin throughout the distal end of the fractured bone ; it was hammered through a predrilled hole. The pins Martin Kirschner used at that moment had a diamond shaped tip and diameters varying from 3.5 to 6.0 mm. Today they are surprisingly known as Steinmann pins (*30,33*).

Throughout the years it became more and more obvious that the Steinmann pins often resulted in infection (*31,62*). According to both Fritz Steinmann and Martin Kirschner, these infections were due to the thickness of the pins and thus the necessity of predrilling, which resulted in to and fro slipping of the pin (*13*). Therefore Martin Kirschner refined and improved an insertion apparatus which made it possible to insert small diameter wires without predrilling, which resulted in a diminished rate of infection. It was in 1927 that he showed his external accordion-like guide which made it possible to insert thin chromium-plated steel piano wires, varying in diameter from 0.7 to 1.5 mm, without the need of predrilling (*31,34*). From that moment on, K-wires could be driven percutaneously through skin, soft tissue and bone. Because predrilling was no longer necessary, the wire was rigidly seated within the bone, so that lateral slipping was avoided, as well as trauma to the soft tissues (*31*). Martin Kirschner called the procedure "Drahtextension" instead of "Nagelextension".

The external accordion-like wire guide could be combined with a hand drill or a power drill. It was, however, difficult to handle. This resulted in the development of an improved and simpler K-wire drill by Mathews in 1931 (*42*). In 1934 the first spiral key-way drive was described by Niedringhaus (*42,49*) ; only a small part of the K-wire protruded to prevent side bending. This particular key-way drive could also be connected to a motor.

More indications

From 1935 on, other indications for the K-wire were described, like maintaining reduction of fracture-dislocations of the ankle joint, the hip and the elbow (*10,55,67*). In 1937 the use of K-wires was advocated for the treatment of hand fractures, which is the main purpose they are used for today. This was because Meekinson (*44*) presented an even simpler hand device for K-wire insertion. In the same year Gerster (*18*) stated that " Kirschner wires, compared to nails, have proven to be less irritating to both soft tissue and bone".

Second World War

In the Second World War surgeons became progressively more innovative in the use of Kirschner wires because of the introduction of antibiotics and corrosion-resistant metals. K-wires with a diameter of 1.5 mm were generally used in World War II, and thinner ones (0.7-1.0 mm) for the fingers. In 1940 Murray (*46*) started to place K-wires in a relatively new manner, longitudinally through the medullary cavity of the clavicle. His enthusiasm pushed him to extend this intramedullary technique to the radius, the ulna and the fibula. Captain Berkman (*5*) from the Medical Corps, United States Army, applied this new technique to metacarpal fractures ; this treatment was very useful in the army where patients could be assigned to light duty immediately after surgery. Today the K-wire is universally used in hand fractures and for many other indications like foot and ankle surgery (*19,39,47,66*), fractures of the long bones in children and adults (*2,9,38,50*), sacral fractures (*70*), treatment of Buerger's disease (*25*), phalloplasty during female to male transsexual surgery (*12*) and stabilization of costal cartilage in nasal surgery to prevent wrapping (*21*).

K-WIRE CHARACTERISTICS

Besides the changes in K-wire insertion devices, the K-wire itself has changed over the years. In 1909 the original Kirschner nail had a diamond shaped tip (*48*). Over the past three decades, research has been done regarding K-wire characteristics like tip and diameter. Namba (*48*) took the initiative in 1987.The most frequently analyzed K-wire tips were the diamond (flat) and trocar (pyramid-shaped) tips (*20,28,48,51,75*). The trocar tip needs the highest insertion force resulting in a significantly higher temperature development compared to the diamond tip, but it results in a significantly better fixation, especially immediately after insertion (*51*). In 1999 (*37,57*) a newly designed tip was proposed : it had two steep flutes for the removal of bone fragments during drilling ; this tip provoked the lowest temperatures elevations during insertion, as compared with the trocar and diamond tip.

Another important K-wire characteristic is the diameter. K-wires with diameters smaller than 1.1mm generate more heat than thicker K-wires, regardless of the tip configuration.

As well as smooth K-wires, regularly used in hand surgery, there are fine-threaded K-wires for foot and ankle surgery (*57*). These threaded K-wires need significantly more extraction force than smooth K-wires.

DRILLING VERSUS HAMMERING

Kirschner's final publication (*32*) appeared on November 15th 1942, shortly after his death. In this publication he made some very interesting remarks. As he discussed the disadvantages of drilling K-wires, like wire migration and pin tract infection, he wondered how to prevent these disadvantages and finally mentioned the insertion of K-wires by hammering instead of drilling. He even described and produced a hammer device which he called the "Drahtnagler" and wrote "Die Kraft des einfachen Hammers versagt nie" ("The force of a simple hammer remains"). He stressed that hammering prevented heat development, which resulted in a longer and better fixation. For this hammer-device, K-wires with a diameter of 1.5 mm were used.

So, initially in 1909, Kirschner nails were hammered through a predrilled hole (*30*), whereafter in 1927 the Kirschner nail changed in a Kirschner wire which was inserted with a drill without predrilling (*31*) and finally, in 1942, the Kirschner wire was hammered into bone (*32*). In spite of Kirschner's last publication K-wires are still inserted with a drill. However, in 1993, Zegunis (*73*) introduced a pneumatic hammer for K-wire insertion. His results showed that hammering resulted in lower temperatures. Based on these results Zegunis suggested that hammering may reduce the risk of thermal injury. After this publication no other papers were published concerning hammering of K-wires, until 2006, when Wassenaar (*69*) showed that, *in vitro*, hammering resulted in a shorter insertion time and better fixation. In 2008 the first author (*16*) showed that hammering resulted in significantly less death of osteocytes, which indicates less or even no thermal damage to the bone.

ADVANTAGES

One advantage of the K-wire is the relative ease of insertion with minimal trauma to the soft tissue and the tendons (*11*). But the greatest advantage is the possibility of atraumatic percutaneous insertion (*71*). This technique is easier than open reduction and internal fixation, has less associated risks, minimizes swelling and stiffness and is still preferred today (*8,26*). Percutaneous K-wire fixation achieves rigid fixation after adequate reduction and will allow early mobilization to prevent permanent deformity and stiffness.

Percutaneous transverse K-wire fixation diminishes and even avoids complications which occur after open reduction and internal fixation, including infection, difficulties in fracture healing, stiffness due to extensive soft tissue dissection, fibrosis, extensor tendon adhesion, plate loosening or breakage and complex regional pain syndrome (*27*). Intramedullary metacarpal K-wire fixation is even more simple and puts the least strain on the tendons (*26*).

DISADVANTAGES

Besides its advantages the use of K-wires has its drawbacks. In 1939 (*59*) the first publications appeared in which the use of K-wires was discouraged. Migration of K-wires, and lack of rigidity and strength when used in femoral neck fractures were described. In 1943, the first cases of K-wire migration from the clavicle to the lungs were reported (*43*). K-wire migration still occurs today and is a serious problem because it can result in non-fatal to devastating complications and even in death (*43,63*). In most of the reported cases the K-wires migrated from the shoulder girdle to the aorta (*17*), heart (*63*), lung (*43,45*), trachea (*14*), mediastinum (*68*), neck (*72*), spleen (*52*) and spinal canal (*54*). There are also reports of migration from other anatomical sites like migration from the hip to the heart (*3*), liver (*4*) or popliteal fossa (*56*) and, even from the left hand into the heart (*22*). The explanation of the K-wire migration remains obscure but in most cases migration can be prevented by bending the distal end of the K-wire (*15*). Nevertheless, even bent wires can migrate after breakage, so follow-up radiographs should be made until the K-wires are removed (*41,45*).

Pin track infections have occurred ever since the introduction of the K-wire (*32*). This complication was one of the factors which resulted in the development of thinner K-wires. But even with smaller diameter K-wires, pin track infections still occur. This is why Stone (*65*), in 1954, described a system of sterile dressings covered with foam rubber anchors, to be placed where the K-wire penetrates the skin, to prevent skin necrosis and infection. The incidence of pin track infections should not be underestimated. Presently, the use of K-wires results in pin track infections in 2.2 to 21% of the cases (*1,7,23,26,61*). This complication may lead to earlier pin removal and thus to non-union (*60*). Early treatment of pin track infection is important, either by immobilization, antibiotics or removal of loose pins. Less infections are seen when K-wires are buried (*23,53*).

Other complications described through the years are damage of peripheral structures (*2,7,26,29,58, 61,64*), traumatic subarachnoid-pleural fistula (*6*) and toxic shock (*40*). Restriction of active motion until the wires are removed can result in diminished function after bone healing (*35*).

CONCLUSION

The increasing use of the Kirschner wire, especially in hand surgery, proves that it has an excellent perspective for the future. The K-wire itself and the K-wire insertion technique have undergone refinements resulting in less complications, but these still occur. Therefore the most important goal is to further minimize these complications by adequate cooling during drilling, bending the protruding ends or if possible burying the wires. Hammering in may be a further step, if the right devices are developed.

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