REVIEW ARTICLE

A Legendary Implant that has Stood the Test of Time and its Current Utilization

C Rex[1], M Harish Kumar[2], C Premanand[3], AS Satish Kumar[4]

Abstract

Aim and objective: To elaborate the current stand on K-wire usage in orthopedic clinical practice.

Background: K-wire is a commonly used implant, and is an inevitable instrument in orthopedic practice. Even with the rampant usage of this implant for centuries, the literature stating the basic details, principles of use, current clinical indications, complications encountered and techniques to avoid the same is not many. In this review article, we have taken into consideration the essential details, techniques, various clinical scenarios and extended indications for which a K-wire can be used. We believe that this article will comprehensively enlighten all the perspectives of K-wire usage, yet unmentioned and highlighted so far in any available literature.

Review results: K-wire has been introduced into orthopedic practice more than 100 years ago. This is the oldest implant that has stood the test of time in the management of many fractures of both upper and lower limbs. The indications for which the K-wire was invented has changed completely and current indications are totally diverse. With recent developments of newer technologies to stabilize fractures or reconstructive procedures with the newer implants, K-wire still has an important role in the management of fractures. This flexible implant has an immense role in minimally invasive surgical management.

Conclusion: A gap exists in the literature on the techniques and procedures employed using K-wires, which warrants more research. This article serves to enlighten the current rationale of the use of K-wires in orthopedic practice and its future perspectives.

Clinical significance: Considering the cost of healthcare, this implant satisfies cost-effective management with good functional outcomes in fixation of a certain peripheral skeleton and pediatric fractures with the least complication rate. K-wire has many advantages like ease of application, minimally invasive, easy availability on the shelves of operating rooms, in any nook and corner of the world, and the versatility of its use in difficult scenarios.

Keywords: Closed/open reduction, Forefoot injuries, Kirschner wire, K-wire Fusion, Kirschner wire, Orthopedic K-wire, Trauma, Trauma surgery.

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Introduction

A K-wire is a straight stainless-steel wire of varying thickness from 0.75 to 4 mm in diameter with either a diamond or trocar tip. The tip of the K-wire can be a smooth pin or threaded type and used for different purposes. The advent of insertional devices, antibiotics and corrosion-resistant metals were the important historical events that played a major role in the evolution of K-wire current design, usage, and indications.

Evolution of K-wires

Introduced by *Martin Kirschner* in 1909, K-wire was initially a thick smooth pin with a diamond-shaped tip of 3.5–6 mm in diameter, utilized as *Nagel extension* (nail extension) for skeletal traction for long bone fractures, based on the same principle of Steinmann's nail.[1] However, use of thick pins required predrilling, into which the wire is hammered and had the adverse effect of infection (because of to and fro movement of the pin). With the advent of external accordion-like devices in 1927, it became possible to insert small diameter wires of 0.7–1.5 mm without pre-drilling, resulting in a stable fixation and also a reduction in pin tract infection. From 1935, it was utilized for maintenance of reduction of fracture-dislocations, especially of the elbow, hip, and ankle. In 1937, K-wires were used for the treatment of hand fractures (the mainstay of the current use of K-wire. The first intramedullary placement of K-wire for treatment of fracture was done by *Murray* in 1940 for clavicle fracture. This idea was later extended to use in radius, ulna, fibula, metacarpal fracture, especially in World War II. The hand drill was replaced by a power drill, which gave more precision and solved many issues.

[1–4]Department of Orthopedics, Rex Ortho Hospital, Coimbatore, India

Corresponding Author: M Harish Kumar, Department of Orthopedics, Rex Ortho Hospital, Coimbatore, Tamil Nadu, India, Phone: +91 9003891759, e-mail: arthro.harish@gmail.com

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Parameters to Consider

The tip design and thickness of K-wire has impact in clinical utility.[2] K-wires of diameter less than 1.1 mm generate more heat than thicker wires. The most commonly used K-wires have either a diamond-shaped (flat) or pyramid-shaped (trocar) tip. Of the two, trocar tip will require a higher insertion force and in turn, generates more heat but may result in a better initial fixation. The tip can be either threaded or non-threaded. K-wires with threaded tip are especially useful in the shoulder, foot and ankle surgeries with the advantage of reduced chances of pin migration or loosening and having a better hold in osteoporotic bone.

Current Indications

K-wire as an Implant

K-wire is an inexpensive, cost effective implant of choice available globally in developed and developing countries, including peripheral rural centers. It is definitely an implant of choice in the indications given below and also in the management of certain fractures where there is limited access to more expensive fixation devices.

- K-wire is used for fixing small bone fractures in hand and feet, distal radius fractures, pediatric metaphyseal fractures like supracondylar humerus fractures and for transfixing and maintaining the reduction of unstable joint dislocations.
- In pediatric patients, K-wire is used as a flexible intramedullary nail, for fixation of long bone diaphyseal fracture and Salter-Harris type of physeal fractures. It is very safe to use a smooth pin, provided a gentle and apt fixation is done without multiple attempts. The only detrimental effect is pin tract infection and if it is severe can lead to osteomyelitis and physeal damage. Scrupulous treatment of early infection is recommended with antibiotics and early pin removal to avoid this complication.
- Other indications for K-wire usage includes fusion of small joints (e.g., interphalangeal, intercarpal, and intertarsal joints), stabilizing excision arthroplasty (e.g., claw toe, hammer toe, trapezectomy, Keller arthroplasty, etc.), deformity (e.g., club foot corrective surgeries) and contracture corrections.
- K-wires are utilized as a part of tension band wiring in fixation of malleolar fractures, patellar fractures, olecranon fractures, greater trochanter fractures, and acromioclavicular fixations.
- Comminuted phalanx fractures can be treated using a single snug-fitting intramedullary K-wire like a locking nail, using the principle of ligamentotaxis[3] across the fracture.
- K-wire is used as a component of external fixator devices for transfixing the bone in mini external fixator used in the management of hand fractures as well as for lengthening of small long bones. In the Ilizarov ring fixator, K-wires of 1.8 mm thickness[4] is used in tension for long bone fracture treatment, limb lengthening, infections, and non-unions.
- K-wires can be used for temporary stabilization of reduced fragments intraoperatively, prior to definitive plate/screw or nail placement (subtrochanteric fractures, Basi cervical neck of femur fractures, supracondylar femur fractures).
- Sometimes threaded K-wires can be used for definitive fixation of proximal humerus fractures[5] and comminuted calcaneum fractures.[6]
- As an internal splint for soft tissue healing and plastic procedures (e.g., mallet finger, open finger injuries, heel flap avulsion).

K-wire as a Tool

- K-wires are used as a percutaneous closed reduction tool in most of the closed reduction techniques including meta-diaphyseal fractures (to manipulate or angulate fracture fragments by using thick K-wires as a crowbar).
- It is used as a guidewire for placement of cannulated screws and for appropriate positioning of a plate (especially LCP).
- Thick K-wires can be used as a polar device for guiding the path of intramedullary nail.
- It can be used as a soft tissue retractor in special situations like foot surgeries (K-wires applied into talus can be bent and used to retract soft tissue in calcaneal fracture plating) and hip surgeries (to retract the abductors during acetabular exposure).
- It can be used as a drill for passing suture material through the tract for pulling out stitches (e.g., mallet finger), for placing locking bolts, especially in distal anteroposterior locking of the humeral nail (better safety in avoiding neurovascular tethering unlike a drill bit).
- It is also helpful for making an entry for the femur and tibial interlocking screw by freehand technique if one has made several wrong entries with the drill bit and it becomes difficult. K-wire can be used instead to change the entry point or drilling on a sloping surface or a bony ridge. It is useful for beginners to centralize the interlocking screw hole and mark a K-wire entry before using a proper drill for locking screws to prevent slippage.
- K-wire in combination with a special K-wire retractor device can be used to provide adequate workspace during foot and ankle surgeries and to prepare for cage placement in cervical spine surgeries by distraction.
- It can be used as an identification marker or as a reference in fluoroscopy for proper placement of the implant (e.g., placement of dynamic condylar screw or angled blade plate in the distal femur, in spine pedicle and level identification).
- In revision arthroplasty, K-wire is used in the removal of uncemented femoral stems. Here multiple K-wires are stacked around the uncemented femoral component which helps in breaking the stem-bone interface with minimal bone loss, thereby facilitating stem removal.
- K-wire can be used to remove the overgrown bone on the plate (especially over the corners and margins of a plate) and screw heads as a drill before implant removal. Also, K-wire can be used to drill the bone around the impacted or broken screw to disengage for safe removal as the drill bit often breaks on metal-to-metal contact.
- K-wire is a useful tool for removing the bone debris/impacted guidewire from a cannulated drill bit.
- Apart from operating table usage, K-wires are used to clean the bone debris out of various surgical instruments such as a curette, drill bits, disk punches, cannulated instruments, etc. and for removing blockage of the suction apparatus.

Using K-wires for Fixing Fractures and Dislocation

K-wires can be utilized for fixing fractures in two ways–*Direct & Indirect*.

Direct fracture fixation: This is of two types:

Transosseous interfragmentary short purchase fixation: This is practiced in periarticular or metaphyseal fracture fixation. For example, distal radius fracture fixation, supracondylar fracture fixation, uni-condylar fracture of phalanges, patella, and olecranon fracture fixation with supplementary tension band stainless steel wire.

Transosseous intramedullary long purchase fixation: This is practiced in shaft fractures of short long bones or long bones of extremities. For example, Metacarpal, or metatarsal shaft fracture fixation, proximal phalanx fracture, pediatric both bone forearm and pediatric humerus shaft fractures.

Indirect fracture fixation

In most of the partial intra-articular fractures with joint dislocation or subluxation, the primary importance is given to joint reduction and maintenance of articular surface congruity. A joint transfixing

K-wire will suffice to treat and maintain the fracture fragments in its position indirectly. For example, Bennett's fracture-dislocation, Dorsal Proximal interphalangeal joint fracture dislocation with a large volar marginal fracture (managed with dorsal blocking K-wire[7]), mallet finger, etc. K-wire can also be used to buttress the fracture as in intra-focal pinning in distal radius fracture (Kapandji technique) and certain bony mallet finger fixation are other examples.

Biomechanics of K-wire Fixation

The entry point for K-wiring is usually from the distal free fragment end, as it allows utilization of the inserted wire as a joystick, thereby allows for fine tuning the fracture reduction. However, exceptions do exist, as in proximal humerus fracture fixation, where the entry is made from the shaft to hold the fractured humeral head and neck.

On fixation of metaphyseal fractures with two K-wires, the entry points of the wires used must be as apart from each other as possible. Utmost care should be taken to avoid the wires crossing each other at the fracture site, as this configuration results in inferior rotational stability (Fig. 1).

In general, K-wires should be applied perpendicular to the fracture line, provided the anatomy permits. However, mechanical stability is more important than the k-wire configuration. Biomechanical studies have proven that two cross pins are better than two lateral pins, on evaluating the torsional strength. But, two divergent lateral pins are better than two parallel or convergent lateral pins (Fig. 2).[8]

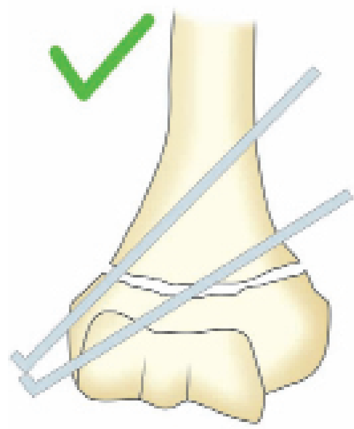

Fig. 1A: Correct technique

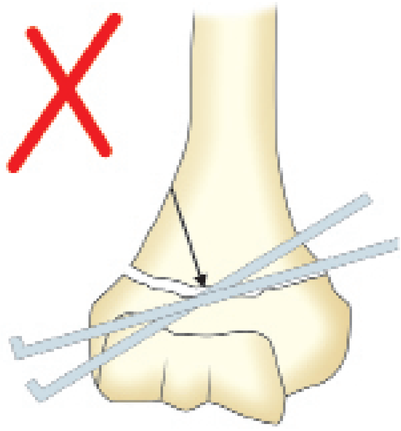

Fig. 1B: Incorrect technique

General Technique for K-wire Placement[2]

K-wire size for appropriate site and purpose is selected. An overview of the same is provided in the table below (Table 1).

For precise work, working length (distance between the tip of the wire to the base of wire attached to the drill bit) of the wire should be short, which makes the K-wire implant rigid to drill on the bone with more precision. Quick coupling K-wire drivers are very helpful for this purpose. As the wire is flexible, it may wobble or bend during drilling if the working length is long. For an ante/retrograde wiring technique in a zigzag manner, K-wires with sharp ends on both sides should be used. Once the far cortex is drilled, one should be careful to stop proceeding further (overshoot) to avoid the impalement of soft tissues. Also pulling back the wire because of overshoot will reduce the pull-out strength of the wire resulting in early loosening. The feel of piercing the bone, checking under fluoroscopy and gentle progression are important to stop the K-wire at the desired final position to avoid reversing the wire. Smooth pins can be propagated forwards and backward by drilling clockwise always. While using a threaded K-wire, forward and reverse mode

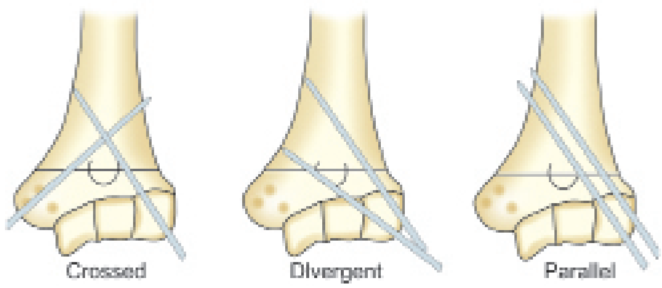

Fig. 2: Types of K-wire configurations for supracondylar fracture fixation

Table 1: Appropriate K-wire sizes for different location

Site	*K-wire size*
Clavicle	2.5/3 mm
Acromioclavicular joint	2/2.5 mm
Proximal humerus	2.5/2.7 mm threaded tip or guide wire
Supracondylar humerus	1.5/2/2.2 mm depending on the age and bone size
Distal radius	2/2.5 mm
Scaphoid	1.5/1.8 mm
Metacarpal/Metatarsal	1.8/2 mm
Proximal phalanx (hand and feet)	1.5/1.8 mm
Middle phalanx	1.2/1.5 mm
Distal phalanx	1/1.2 mm
Ankle medial malleolus fracture	1.8/2 mm
Ankle lateral malleolus intramedullary	Isthmus diameter in distal fibula 1.5–3 mm
Ankle Tibio-calcaneal pin	4 mm/5 mm

of drilling is important for propagating in and out respectively. In case the wire is not buried, adequate release incisions should be made at the entry point to reduce soft tissue tension and thereby reducing the chances of infection. Soft tissue release reduces pain, improves mobility, and reduces the chance of stiffness.

Bending the K-wire is mandatory to prevent the disastrous complication of pin migration. An important rule while bending the K-wire is to ensure that no force is transmitted to the K-wire by holding it with a wire holder or a plier. The nose plier is kept flush with the bone or soft tissue and the wire bender is placed at least 3 mm away from the plier to avoid wire pull out while bending. A 90° bend is given. To achieve a bend more than 135°, the technique suggested by Reza Firoozabad et al. can be utilized.[9] During bending one should try to avoid sudden rotation or twisting of the wire. Once the wire is bent, do not twist or turn the wire as it may again make it loose. A loose wire must be substituted.

In tension band wiring, the K-wire is pulled back by 5 mm from its final position with the K-wire driver. This prevents the over-penetration through the far cortex after the wire is bent and impacted into place. Saline irrigation in open K-wiring or painting with Betadine (povidone-iodine) in closed procedures reduces the thermal necrosis and thereby loosening. The best thing that should be focused on is that the surgeon should place the wire with as minimal attempts as possible, to have the best possible hold in any given patient. At the end of the procedure, irrigating the pin with normal saline removes the bone debris. The pin is then dressed in betadine-soaked gauze to prevent infection. The sharp end of the K-wire is protected with a needle sheath or rubber wrap in view of preventing injury to the surgeon or the operating team during the procedure.

Complications

Loss of fixation/reduction: Multiple attempts of entry, osteoporosis, insufficient far cortex purchase, inadvertent K-wire placement in soft tissues are the most common causes for early loss of fixation. Inadvertent pull out of K-wire can happen while cleaning and dressing the wire, or by getting caught in clothes or bedspread. Threaded K-wires provide better hold than smooth pins. Patient education plays an important role in preventing undue loading of the precariously fixed extremity (K-wiring not being a rigid fixation) and to avoid inadvertent wire pull out. Fractures not fixed in accordance with the fracture pattern may fail to neutralize all the forces acting across the fracture and may fail early. Most important of all is that the surgeon has the proprioception and feel of how good the fixation is and if not, happy it is better to redo rather than accept a flimsy fixation that is bound to fail in the immediate postoperative period.

Pin tract infection: This is a common complication especially in patients with risk factors such as diabetes, prolonged steroid intake, and skin diseases. Infection can vary from minor pin tract infection to a severe form of osteomyelitis. Pin tract infections are rarely encountered in immobilized fractures such as pediatric supracondylar humerus fractures.[10] Adequate soft tissue release around the entry site, dressing the entry site at weekly intervals, good diabetic control often prevents infection. Inadequate soft tissue release results in the collection of sebum underneath the scab, which acts as a nidus for bacterial growth. Early removal of loose pins and initiation of antibiotic coverage in suspected patients often prevents aggravation of infection.

K-wire migration: This is a disastrous complication in humerus and clavicle fixation (intrathoracic migration).[11] Bending the wire to at least 90°, leaving the pin outside the skin, prevents migration beyond the near cortex. The use of threaded wire is encouraged in humerus fixation for preventing migration and for a better purchase. Anticlockwise rotatory movements are required to remove threaded k-wires, as pulling hard may cause pain while removal. The unburied K-wire getting buried under the skin is also a problem. One can overcome this by cutting the K-wire at least 2 cm away from the bend. The use of a paraffin gauze dressing around the wire can prevent the migration to some extent. Migrating wire indicates loss of fixation and that wire needs to be removed at the earliest.

Skin tethering: This is a result of technical inadequacy. Using a liberal release incision at the entry point and use of artery forceps to spread the tissues apart to reach the bone avoids this complication. Adequacy of soft tissue release is assessed by the ability to move the adjacent joint through a full range. This may prevent pain, infection, and stiffness.

Stiffness: A multitude of problems such as skin tethering, soft tissue impalement, infection, the tip of K-wire irritating the joint surface or soft tissue, intentional or unintentional trans-fixation of a joint, inadequate fracture reduction with fracture ends tethering the soft tissues, prolonged immobilization, inadequate physiotherapy, reflex sympathetic dystrophy or personality disorder could result in stiffness.

Breakage of K-wire: This is a rare event. Intraoperatively this can happen while the surgeon exerts undesirable bending force while drilling. Again, this is possible when K-wire encounters another metal not allowing advancement of the wire. In such scenarios one can remove the wire easily under fluoroscopy guidance, in case the broken tip is extramedullary. In case of intramedullary breakage, one can attempt removal of the broken wire by over drilling the entry point, thereby facilitating the use of a straight mosquito forceps or small disk punch to remove the remnant wire. However, this results in excessive soft tissue trauma and compromise of distal fragment bone stock. Another alternative method is to angulate the extremity to open up the fracture site. A percutaneous incision can then be made to reach the fracture site to facilitate passing a mosquito forceps to hold the wire to push it out through the entry hole. Patients with joint trans-fixation K-wires, for example, distal radioulnar joint trans-fixation for distal radio-ulnar joint instability or humero-ulnar K-wiring will require an additional above-elbow cast to prevent movement and breakage of wire. Intra-articular wire migration may require arthroscopy for removal.

Future Perspectives

K-wires with various coatings aimed at reducing the infection rate, either in the form of a coating to resist infection (monolaurin-coated K-wires,[12] tobramycin-PDLLA-coated titanium Kirschner-wire,[13] Antimicrobial Silver Multilayer Coating[14]) or elute antibiotics (nanofiber composite-coating technology[15]) over a period of time are in an experimental stage. Other coatings such as nanostructured hydroxyapatite[16] coated wires have proven satisfactory results in lab results, enhancing bone formation around the wires. However, these special coatings are still in laboratory evaluation and require further validation to look for any adverse effects and their cost-effectiveness. This may be considered for use in selected patients such as uncontrolled diabetes, patients on chronic steroid therapy and, poor skin condition.

Conclusion

K-wire is an inevitable, simple, cost-effective device used in day-to-day practice, by common Orthopedic surgeons, Hand, and Plastic surgeons not only for fracture treatment but also as an instrument of multifarious nature. K-wires are an immensely useful implant in the current clinical scenario, which has stood the test of time. They are *"designed to last and be around forever."*

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