Special Article

Multipurpose External Fixator for Intraarticular Fracture of Distal Radius

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Fracture of distal radius is one of a complicated injury which can be difficult in reduction and maintaining its alignment and may result in malunion and shortening following a variety of fixation. Since Anderson's and O'neil described the use of sustain traction by extraskeletal device anchored to the radius and the first metacarpal of the hand. Vidal et al [1979] demonstrated that the ligamentotaxis could be used to reduce the fracture around the wrist, ankle, hip and knee. The external fixation frame can maintain radial length and inclination by the pullout force from the radial styloid.

External fixation is useful for management of complex intraarticular fracture of distal radius. There are few types of commercially available fixator. It is important to use one that allow versatility and follow biomechanic principles of ligamentotaxis, which can be used to reduce the severe comminution and the most difficult fracture by distraction and stabilization effectively. The ideal characteristic of the external fixation are : Telescoping connecting frame fixed externally. Compose of two joints which can be easily adjust in any direction, Two pins clamp connected to the external connecting rod. Our TU Multipurpose external fixator can be designed as a multiplana, can be used as a Bridge or Non Bridge fixation, and can be adjusted to any direction which require for the treatment of distal radius fracture. It is differed to other commercially available devices.

Keywords: *External fixtion, Distal radius fracture, TU external fixator*

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External fixation of distal radius fractures is one of several ways to manageme distal radius fractures by ligamentotaxis.

Insertion of the anchoring pins and construction of the external supporting frame requires closer supervision and follow-up for mechanical and biologic reasons [clamp retighten, angular adjustment, pin site care].

There are few available devices to choose. It is important to use one that allows the surgeon adequate versatility and follow biomechanical principles.

Type of application

Application of an external fixator to a traumatized extremity may be intended as a temporary measure or a definitive one.

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Temporary external fixation

Occasionally, an external fixator is applied temporarily to an injured extremity with the intention of removal after few days, at which time it can be replaced by other methods of fracture stabilization, such as internal fixation. Indication for such use are:

1. To manage the severe grade open fractures with extensive soft tissue loss.
2. To resuscitate a polytraumatized patient, reduce internal hemorrhage.
3. Pending transfer to a tertiary referral facility.

Definitive external fixation

The fixator also may be left in place for the duration of fracture healing rather than just as a temporizing measure pending soft tissue repair.

Basic mechanics of an external fixator

Initial fixator designs consisted of transfixing pins passed through the extremity with a frame on either side, called "bilateral frames". By the late 1960s, the improvement of biomechanical understanding and metallurgy led to less complicated frame applied on one side of the limb using threaded Schanz screws called "unilateral frames[1]". Newer concepts of limb lengthening and three-dimentional deformity correction, most recently various hybrid fixators consisting of combinations of distal transfixion pins and proximal Schanz screws are being proposed for use in distal radius fractures[2].

Components

An external fixator is a modular system that require assembly at the time of use to create a stable construct.

Fixators frames vary considerably in their appearance, but all have the same basic components: An external frame consisting of longitudinal rod that are connected by clamps to pins that are anchored into the bone. Clamp, hold the anchoring pins which inserted into the bone plays an important role in stability of the construct.

Anchoring pins

Anchoring pins vary from 2.5-6.0 mm for use with different bones. Because they are subjected to bending force, the pins should be sufficiently large and strong but should not exceed a third of the bone diameter to prevent secondary pinhole fractures. Unilateral frame use one half threaded pins that are anchored into the bone from one side, whereas bilateral frames and ring frames use tranfixation wires that pierce the extremity from one side to the other.

Connecting rods and joints

The longitudinal connecting rods are the strongest elements of the frame and may be constructed of metal or lighter radiolucent material, such as carbon fiber. The rods can be more complex in design with a built-in articulation to allow angular correction or they may have a complex telescopic design that allows changes in length for distraction or compression. The largest design variation among fixators from different manufactures is in the way the clamps join anchoring pins to the connecting rods. A simple articulation or joint connects a single pin to a longitudinal rod. A joint with multiple degrees of freedom is referred to as a universal joint. Some frames incorporate clamps for connecting multiple anchoring pins to the longitudinal rods. These clamps typically accommodate two or more pins that must be inserted parallel and at a set distance to each other to fit into the clamp.

Frame configuration

The modularity of most external fixation systems allows the creation of several different constructs with varying stability. It is obvious that the use of more pins and connecting rods improve stability but potentially cause more soft tissue tethering and may increase difficulty of management of the pins tracks and open wounds. It is thus important to achieve a balance between the mechanics and biology to provide a frame that is suitably strong but with minimal interference with soft tissues.

Most fixator designs for distal radius fractures have four pin unilateral configuration. In situations with extreme instability, such as in the presence of significant bone loss, two unilateral frames may be combined to create a unilateral two-plane triangular frame with significant increase in stability.

The most common configuration of external fixation for distal radius fractures is Bridge-fixator, the fixator fix across the wrist joint. In minimal comminution fracture and sufficiently large distal fragment, it may be possible to use a non-bridge fixator or radio-radial fixator[3] to achieve fixation in the proximal and distal fragments without immobilizing the wrist: This concept was proposed firstly by Jenkins and later supported by Melendez et al[4].

Frame stability

Stability of a fixator construct is determines by the following variables[1].

1. Frame configuration (unilateral, bilateral or triangular)
2. Pin size, number of pins and pin spread along bone
3. Pin-bone interface
4. Frame-bone distance
5. Fixator placement along plane of major displacement
6. Injury characteristics: anatomic reduction, comminution of fracture, and use of bone graft
7. Supplemental fixation with K-wires, augmentation with graft

Several of these factors can be controlled by the surgeon and hence it is of utmost importance that surgical principles of pin insertion, clamp application, and frame construction are followed meticulously.

The strength of the fixator depends on the rigidity of the connecting rods and the clamps. Rod diameter and strength must be weighed against their weight. The connecting rod must be placed as close to the extremity as possible, and additional rods may be added for increased stability[5].

The pins are subjected to witstand bending forces and minimal pullout forces.

Modern threaded [schanz]pins are designed with a larger core diameter and less core-thread diameter difference to allow the pin to withstand bending. Furthermore, where the pin engages both cortices, it is mainly the far cortex that is subjected to pullout forces, whereas bending forces act on the pin fixation at the near cortex. A pin with a short thread placed bicortically such that the threads engage the far cortex and the thicker shaft engages the proximal cortex thus provides the best pin-bone fixation. Compared with 3mm pins, 4mm self-tapping half-pins are 145% stronger in bending and have significantly higher pull-out strength of 76% and only 8% decrease on torsional load strength of the bone(6).

Cylindrical pins (also known as Schanz pin) are prefered to tapered or triangular pins. The latter were first designed allow further tightening by advancing a wider part of the screw into the cortex at first signs of loosening. These tapered screws, once inserted too deep cannot be backed out because they will be loose.

Bone can tolerate compression better than tension or shear forces. One way to reduce pullout and increase compression forces at the pin-bone interface is to preload or prestress the pins before fixing to the external fixation system(5). When a fixator is applied to neutralize forces in an unstable fracture fragments cannot be compressed against each other. Compression at the pin-bone interface can be generated by pre-stressing the pins of each fragment against themselves as they are attached to the frame. This is done by elastic deformation of the pins as they are attached to the frame by squeezing them together(compression) or separating them (distraction). Although it is a sound biomechanical principle, preloading a pin can cause excessive unilateral cortical pressure and subsequent necrosis and loosening, and its use in the radius is no longer recommended(7).

Compression and radial preload is more effective than bending preload in reducing the resorption from predrilling(8). The optimal amount of radial preload to be applied by pre-drilling is not clear.

To achieve stable fixation and reduce the lever arm of displacing forces, pin fixation also should be gained close to the fracture site.

It follows that the optimal and minimal pin placement would be with at least two pins in each fragment, one pin as close to the fracture as possible and the second as far as feasible along the shaft of the bone(1). Some fixator designs have multiple pin clamps in which the pins have to be inserted at predetermined distances, limiting the ability to create a good pin spread.

To increase fixation in the bone with a four-pin frame, best fixation can be achieved with two pins placed in the proximal radius. Distal metacarpal fixation can be enhanced with a six cortical hold by inserting the proximal metacarpal pin through the base of the index and long metacarpals without violating the interosseous musculature(9).

Augmentation of fixation

Augmentation of external fixation with percutaneously placed K-wires has been shown to increase the stability of a distal radial fracture(10) and reduces the need for excessive traction(10, 11). In addition,

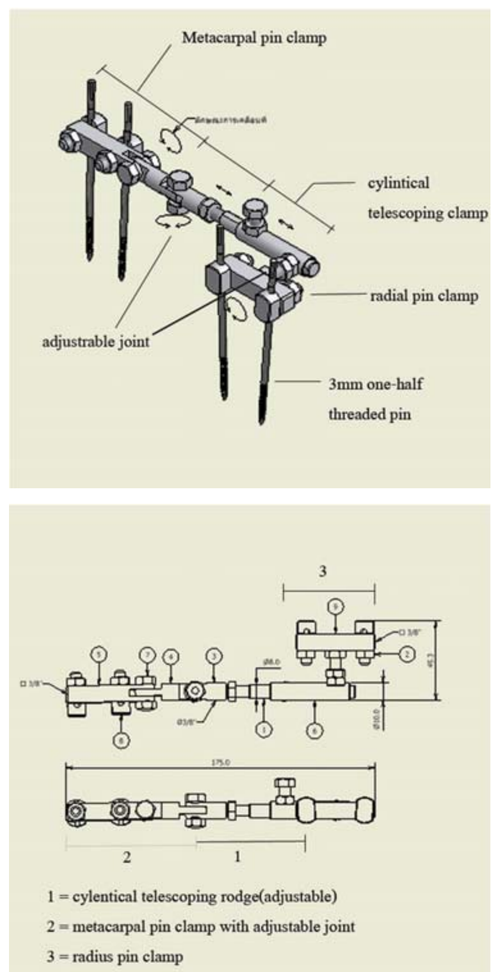

Fig. 1 and 2 Conceptual framework: The characteristics of TU multipurpose external fixator for distal radius fractures the K-wire helps maintain palmar tilt that can be difficult to restore with external fixation alone.

Normal forces through radius and rehabilitation

It is important to take fracture stability into account when planning rehabilitation. Force applied when mobilizing digits is magnified as it is transmitted to the distal radius. A cadaveric study had estimated that for each 10N of grip force, 26-52N of force was transmitted through the distal radius metaphysis, depending on the wrist position[12]. The average male grip with a strength of 463N can result in more than 2000N force at the distal radius, a much higher force than can be tolerated in a fresh fracture that is internally or externally fixed. Assuming maximal force transmission through the radius, the maximal rehabilitation grip force in early phase of fracture healing should not exceed 10-140N to avoid fixation failure[12].

Static external fixation

The fundamental goal of external fixation is to obtain and maintain an acceptable reduction until the fracture has gained sufficient stability. The fixator can be applied before or after reduction is achieved. One method of application is closed reduction by the time-tested maneuver of traction, flexion, and pronation. The fracture then can be stabilized by percutaneous pins, the wrist brought to a neutral position without distraction.

The ability to reduce the fracture after fixator application varies with the fixator clamp and frame design Some fixator clamps do not have sufficient degrees of freedom in all axes.

Dynamic external fixation

Jones in 1977 suggested that it was possible to move the wrist during bridging external fixation by placing a flexible tube between connecting rods[13]. A decade later other similar dynamic external fixators have been designed. All based on a frame that allows movement at a ball joint[14,15]. For an external fixator to be truly dynamic and to allow joint movement during fracture healing, it should be kinematically compatible with the wrist joint to allow unconstrained movement. Several commercially available dynamic external fixator devices. can not replicate normal wrist kinematics that involves rotational and sliding movements. Movement with these fixators in place thus risks forcing the carpal bones into an abnormal pattern of movement or causing displacement of fracture fragments[15].

A clinical comparative study has demonstrated poorer results with loss of reduction and increased complications with the use of ball joint-type external fixator compares with static fixator[16].

Only one type of movement(flexion-extension or radioulnar deviation) for the single ball joint, thus can be synchronous with the center of rotation of the wrist.

A new fixator design has been proposed by AO Research Institute. (Davos, Switzerland) that uses two sliding discs connected with a screw. This creates a sliding mechanism with a center of rotation that is projected 50mm away from the fixator over the capitate. Further more the sliding mechanism simultaneously allows rotation about all these axes without a change of the center of rotation[17]. Cadaveric studies with this fixates compared with conventional ball joint designs have confirmed the kinemetic similarity with the sliding disc mechanism and absence of increased loads at the pins in all planes of wrist motion.

Ligamentotaxis

Principles and biomechanics

In 1944 Anderson and O'neil described the mechanism of ligamentotaxis traction by an extra skeletal device anchored to the radius and first metacarpal for the closed treatment of comminuted distal radius fractures[18].

Bartosh demonstated in a cadaveric study that straight traction of the hand with the wrist in full supination was able to anatomical reduction of the comminuted fragments[19].

Radial length and inclination usually are restored easily except for the volar tilt, because of the pull on the radial styloid by the attachments of the strong volar ligaments. Several clinical series have shown that palmar tilt often is restored inadequately.

Clinical studies have also shown that distraction by ligamenttaxis alone is not able to reduce volar marginal intra-articular fractures(AO type B or volar Barton pattern). These fractures require an additional volar buttress plate[21, 22]. In addition, severely impacted fragments may not be reduced with traction and require percutaneous manipulation using supplementary K-wires[14].

Agee has refined further the concepts of ligamentotaxis as applied to the distal radius[20]. He has termed conventional ligamentotaxis that is applied in one plane as uniplannar ligamentotaxis which did not achieved restoration of the palmar tilt. Longitudinal traction can be combined with radioulnar and dorsopalmar translation, to provide multipalmar ligmentotaxis that is capable of restoration of normal anatomy of the distal radius.

For this purpose, agee has developed an external fixation system, that has a gear mechanism incorporated into the longitudinal supporting frame to allow supplemental translational forces after application of distraction. In this technique, after longitudinal traction is applied the hand is translated in a palmar direction, producing a palmar vector at the midcarpal joints. The volar displacement of the capitate creates a rotatory force on the lunate and tilts palmar-ward, restoring the normal palmar inclination.

Traction then is reduced until the fingers can be fully passively flexed into the palm. The final maneuver consists of ulnar translation of the carpus to create a radial soft tissue hinge that helps restore radial inclination.

Biologic effects of distraction of the wrist can result in strains as high as 20% in the volar and dorsal ligaments[22]. Excessive prolonged distraction of the radiocarpal ligaments associated with adverse outcomes, in function, pain, motion, and grip strength.

This may cause wrist stiffness by ligament fibrosis from compromise of circulation or micro-failure of the already injured ligaments, with poorer scores for function, pain, motion, and grip strength[23].

Overdistraction can be avoided by checking that all fingers can be passively flexed into the palm after application[20] or, radiographs can be used.

The carpal height ratio increases with distraction for the first 10-20lb of traction, but then remained static despite increased tension. Similarly, the ability to passively flex fingers into the palm was not lost at higher loads of distraction.

Fracture of the distal radius has a higher incidence of carpal tunnel syndrome and complex regional pain syndrome. The development of carpal tunnel syndrome may be related to increase pressure within the carpal tunnel[24]. Distraction of the wrist has been shown to cause a linear increase in carpal tunnel pressure, with pressure exceeding 40 mmHg over baseline after 2.72 kg of distraction force with the wrist in neutral. Placing the wrist in extension further magnifies this effect[25].

Bone healing with external fixation

It has been established that bone healed without callus formation after rigid internal fixation. In less rigid environments, the healing process includes an intermediate fibrocatilaginous phase or callus formation[26].

Lewallen et al compared bone healing with the application of a unilateral frame with that achieved by dynamic compression plating in a canine tibia model[27]. Internally fixed osteotomies were significantly stronger and healed with endosteal bone formation.

After controlled osteotomies stabilized by external fixation have suggested that healing is a combination of different processes[28]. Bone healing mechanisms are different and depend on the rigidity of the devise used. With more rigid fixation achieved by six-pin bilateral frames, there is early clinical union with similar appearance to that of internal fixation.

On the other hand, with four-pin unilateral frames, periosteal callus formation and local bone resorption is significantly increased because of the less rigid fixation. The distribution of callus is greater in the biomechanically weaker plane-the anteroposterior plane if a fixator is applied along the mediolateral plain.

When the fixator is used in distraction as in the wrist, overdistraction or actual bone void from impaction may result in secondary loss of reduction in 10%-50% of cases after fixator removal[21]. Bone graft or substitute placed in the subchondral defect provides additional stability, prevents ingrowth of fibrous tissue, and has been shown to reduce secondary collapse in clinical studies[29].

Biology of the pin-bone interface

The pin-bone interface is the link between the patient and the fixator. Failure of this link affects not only the outcome of the fracture, but it may also result in serious complications, such as osteomyelitis. Pin loosening leads to failure of fixation and predisposes the pin track to infection. Pins holding of unstable fracture and those subjected to static loading are more likely to loose. Histologically, loose pin tracks demonstrate inflammatory exudates and extensive bone resorption[30]. Rehabilitation should take into account the fracture stability to minimize excessive pin loading and subsequent loosening.

It is also possible that the coating creates a roughness that increases the initial interference fit of the pins[34]. Such pins are certainly advantageous when a fixator is to be placed for prolonged periods of time.

Infection around anchoring pins is one of the commonest complications of external fixation, and the reported incidence ranges from 0.5%-30%. The incidence of more serious infection leading to ostemyelitis is much lower and ranges from 0%-4%.

Recent measures to lower incidence of pin track infection being studied are silver coatings[31], hydroxyapatite and chlohexidine coatings, and antibiotic pin sleeves[32,33].

Thermal damage to local tissue at the time of anchor pin insertion is believed to be one of the important factors in pin loosening in cortical bone. It was an effect of high temperatures and the duration of exposure to high temperatures.

Pin care may also have a significant impact on overall incidence of pin track sepsis. There is con troversy how to take care of pin-skin interface. Necrotic skin and bone at the pin site interface also provide a medium for the growth of bacteria, and it is important to ensure that skin tension around the pin is relieved by an adequate incision.

Additional factors that may cause pin tract infection include the thickness of the soft tissue mantle between the skin and bone and mobility at the pin-skin interface. Pin track infection is more common because of early mobilization of the wrist that is possible with nonbridging fixators. Wrist immobilization in a splint between periods of exercise has been recommended to reduce this complication[3].

1. The external connecting rod may be a metal or carbon fibers telescoping connecting rod with two articular joint which can be adjusted in varying degree of flexion/extension, abduction/adduction and some degree of rotation to be able to of reduce for the fracture, and to distract for ligamentotaxis effect

2. Bone anchoring pin must be one haft threaded and triangular shapes with 2.5-3mm in diameter

3. The external fixator may be designed into both non-bridge and bridge constructtion that can construct in to any purpose of treatment

4. The design has 2 pins at the proximal fragment of the distal radius and the other 2 pins fixed at the 1st or 2nd metacarpal bone on the same wrist.

5. It can resist at least 500 NT for grips strength and 750 NT for wrist flexion and avoiding of compression effect

6. The fixator is designed as a static fixator and can be adjusted into multiple axis of rotation to provide an adequacy of immobilization after reduction, so called multiplana external fixation, non bridge fixator can allow the early movement of the wrist joint at the dynamic fixation model

7. The fixator has telescoping rod which can distracted longitudinally without translation or sliding of the carpal joint,it is one axis distraction

8. The clinical result of bone healing and treatment must be studied by clinical trial later

The pin must be self tapping and inserted by a high speed drill, it can be fixed with the bone rigidly by the triangular schanz pins. This will decrease the necrosis of bone and prevent loosening of the pins.

Summary

There are many commercially available external for distal radius fractures.

It is important to use the one that allows the surgeon adequate versatility and follow biomechanical principles. Understanding the basic mechanical principles and pin-bone biology allows for successful use of external fixation with minimal complications.

Our new designed TU external fixator for distal radius fractures is composed of the overall properties as the conceptual frame work and it can be used in various perpose such as Bridge or non Bridge fixation, can be distracted longitudinally and fixed in any direction for the appropriate reduction position of the distal radius.

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อุปกรณ์ชุดโลหะที่ใช้ยึดกระดูกส่วนปลายของกระดูกข้อมือแบบที่สามารถปรับหลายทิศทาง

ยงยุทธ ศิริปการ, ทรงยุติ ศิริปการ

การรักษาภาวะการแตกหักของกระดูกแขนส่วนปลาย เป็นการบาดเจ็บที่ซับซ้อน และอาจมีผลการรักษาที่ไม่พึงประสงค์ เช่น กระดูกติดผิดรูป โดยเฉพาะกรณีที่การแตกหักชิ้นเล็กๆ และแตกเข้าข้อ ตั้งแต่ปี พ.ศ. 2487 Anderson และ O'neil ได้รายงานการรักษาการแตกหักของกระดูกชนิดนี้โดยการยึดด้วยโลหะจากภายนอกได้ผลดี Vidal และคณะ ได้อธิบายหลักการจัดกระดูกให้เข้าที่โดยอาศัยหลักการดึงของเนื้อเยื่อรอบๆ ข้อจากนั้นมา จึงมีผู้พยายามประดิษฐ์อุปกรณ์ที่ใช้ยึดกระดูกแขนส่วนปลายจากภายนอก

อุปกรณ์ที่มีผู้ผลิตขายในท้องตลาดมีจำนวนไม่หลากหลาย และมีราคาแพง ด้วยความจำเป็นทางเศรษฐกิจและความหลากหลายของทิศทาง ที่จะต้องดึงคณะผู้นิพนธ์จึงได้ศึกษาคุณลักษณะที่ต้องการ และได้ออกแบบอุปกรณ์ที่ใช้ยึดกระดูกแขนส่วนปลายให้มีราคาที่เหมาะสมและสามารถปรับใช้ได้หลายรูปแบบ