**Методики дистракционного остеогенеза при лечении
приобретенного и врожденного укорочения костей кисти
с использованием модифицированного внешнего мини-фиксатора**

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***Distraction osteogenesis techniques in treatment of acquired and congenital
shortening of the hand bones using a modified external mini-fixator***

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Дистракционный остеогенез по Илизарову – самый распространенный метод удлинения и коррекции деформаций костей, включая кости кисти и стопы. Основные методики, которые используются для удлинения костей кисти, основываются на этом методе. В статье описываются технические спецификации мини-фиксатора, разработанного для коротких трубчатых костей, представляются схемы его наложения на фаланги пальцев и пястные кости и приводятся иллюстрирующие их клинические примеры. Удлинение костей кисти было применено у 394 пациентов (566 сегментов кисти) в нашем центре в период с 1999 по 2012 г. Произведенное удлинение улучшило внешний вид и функции кисти.

Ключевые слова: фаланга пальцев кисти, пястная кость, приобретенное и врожденное укорочение, удлинение, дистракционный остеогенез, мини-фиксатор.

Distraction osteogenesis according to Ilizarov is the most common method of bone lengthening and deformity correction including the hand and foot bones. This method forms the basis of the main techniques used for the hand bone lengthening. The author described the technical specifications of the mini-fixator developed for short tubular bones, demonstrated the diagrams of its application to finger phalanges and metacarpal bones, as well as he presented the illustrative clinical cases. The hand bone lengthening performed in 394 patients (566 segments of the hand) at the Center within the period of 1999 and 2012. The performed lengthening procedure improved the hand appearance and functions.

Keywords: phalange, metacarpal bone, acquired and congenital shortening, lengthening, distraction osteogenesis, mini-fixator.

INTRODUCTION

Distraction osteogenesis has become the most used method for bone lengthening and deformity correction including the bones of the hand and foot. The lengthening techniques for management of congenital and posttraumatic hand bone pathology started to develop at our center after the Ilizarov external mini-fixator had been developed [1]. In 1999, a novel external mini-fixator design for hand pathology management was introduced into clinical practice [2], but in 2005 the mini-fixator was modified again (RF patent № 45616 from 27.05.2005), and the techniques were improved. The application of the external mini-fixator to short tubular bones is low traumatic and the performance of the operation is not difficult. Moreover, the set of mini-fixator parts and instrumentation used for surgeries is neither complex nor costly. The lengthening of hand bone segments is realized by producing regeneration in the osteotomised bone or stump. Bone grafting is not used. The mini-fixator can be applied to several bones simultaneously for producing distraction osteogenesis in two or more bones in order to reduce a number of interventions, shorten the treatment and rehabilitation periods. Lengthening procedures can be combined with traditional methods of phalangization, web-plasty, and bone deformity correction. The modified variant of the mini-fixator has been used by us for 15 years for various hand pathologies.

Indications to lengthening of hand bones

Hand bone posttraumatic stumps and congenitally shortened segments in adults and children of 3 years and older.

Instrumentation and techniques used

Lengthening procedures are performed with the use of the external wire mini-fixator for management of hand pathology supplied with additional parts such as plates, hinge posts bushings, and threaded rods (Fig. 1). Favorable technical characteristics include its stainless-steel design and light weight. Thin 1-mm or 1.5-mm Kirschner wires which are suitable for pediatric and adult hand bones have three sharpened end facets.

The mini-fixator is composed of fixation units (Fig. 1) for attaching the wires into the slots (7) of slotted washers (3) and their fastening with a fixation nut (8) (Fig. 2). Distraction or compression along a flat-side threaded rod (1) is produced by turning the nuts (2) on both sides of the bolt (5) that has a threaded hole in the head for a locking screw (6) that rests on a flat of the rod.

Surgical techniques

Placement of the mini-fixator and osteotomy

Step 1: Two or three proximal wires are drilled at 90° to each other from the dorsolateral bone surfaces and should pass both cortices but exit only to one or 2 mm from the cortex opposite to the direction of insertion. They are bent so that the support (wire fixation unit) is located three or 4 mm over the skin and are attached one by one into the slots of slotted washers (Fig. 1). Next, the wires are fixed in the proximal fixation unit which must lie parallel to the bone axis. The flat-side rod for distraction is inserted into the proximal wire fixation unit.

Fig. 1. General view of a wire mini-fixator unit and its additional parts

Fig. 2. Threaded rod (1), nuts (2) and wire-fixation unit (A) composed of slotted washers (3, 7), space washer (4), bolt (5) with an axial hole and perpendicular threaded hole in its head, locking screw (6), fixation nut (8)

Step 2: Distal wires are drilled the same way as described above and are fixed in the distal wire support after bending. The locking screws of both units must be positioned at 90° to each other.

Step 3: The rod is turned so that the flat is perpendicular to the threaded hole of the bolt head in the distal support and the screw locks the distal assembly on the flat. Next, the locking screw of the proximal support strongly fixes the threaded rod with the bolt.

Step 4: Prior to osteotomy, the locking screw of the distal support that contacts with the flat must be released. Percutaneous osteotomy of the segment is performed through a 0.6-cm dorsolateral skin incision so that the soft tissues are minimally injured. The accuracy of its completion is checked with radiographs following an acute distraction to four or five mm. The bolt screw in the distal unit must be locked again once the contact between the fragments ends has been achieved by compression. The wound is closed. Radiographic checking is desirable followed by application of dressings.

Lengthening techniques

The choice of a lengthening technique with the mini-fixator depends upon the length of a posttraumatic bone stump or a bone segment that is short due to a congenital disorder. Lengthening of a stump or a segment that is shorter than 30 mm requires bridging of the joint that is located proximally to the segment under lengthening while a segment which is longer than 30 mm does not require joint fixation.

1. Bone segments longer than 30 mm

Diagram 3 shows the placement of fixation units on phalangeal stumps or hand bone segments that are longer than 30 mm (Fig. 3). The lengthening runs under favorable functional conditions for joints as physical exercises are possible after the operation (Fig. 4).

Fig. 3. Diagram of the lengthening technique for a phalanx or stump that is longer than 30 mm

Fig. 4. A posttraumatic stump at the level of the left proximal thumb phalanx in a 50-year old male was osteotomized. Distraction initiated on the 6th postoperative day continued for 24 days to lengthen 15 mm. The mini-fixator was removed after 46 days of fixation

2. Bone segments of 30 mm or shorter

When the length of a bone segment or a stump is 30 millimeters or shorter the proximal fixation unit lies over the segment which is proximal relative to the segment under lengthening (Fig. 5) and has two wires. One or two wires pass in the base of the segment under lengthening, and they are also fixed in the proximal support. Three or two wires are inserted in the distal part of the segment under lengthening and should be fastened into the distal fixation unit.

Lengthening of the middle phalanx in a congenital anomaly requires adjacent distal and proximal joints bridging (Fig. 6). The technique foresees gradual stretching of the bridged joints by a total amount of six or 8 mm performed two weeks prior to removal of the fixator. The wires that are in the lengthened segment must be cut and

taken off in order not to hinder to stretch the joint (Fig. 7).

3. Lengthening of proximal finger phalanges and web space skin bulk growing

This technique is indicated for lengthening of short proximal phalanges of the 2nd through 5th rays and simultaneous skin bulk growing for deepening the web spaces (Fig. 8). Mounting of the mini-fixator follows the rules described in point 2. Additionally, transverse traction with the rate of 0.5 mm or one millimeter a day for growing interphalangeal skin stock is performed along the regular threaded rods placed into the bushings connected to the fixation units with posts. Skin plasty for web space skin division follows in three to four weeks since the cessation of transverse traction. It provides improvement of esthetical appearance and functions (Fig. 9).

Fig. 5. Diagram of the lengthening technique for a bone that is 30 mm or shorter

Fig. 6. Variant of the mini-fixator mounting for lengthening the middle phalanx in a congenital anomaly

Fig. 7. Lengthening of a middle phalanx of the 3rd digit in a 5-year old girl with a congenital anomaly. One and a half centimeters were obtained during a 30-days' distraction (0.5 mm per day), and fixation continued 50 days

Fig. 8. Diagram of the lengthening technique for proximal phalanges and skin stock growing in the web spaces

Fig. 9. Posttraumatic proximal phalangeal stumps of the right hand digits 3 and 4 in a 27-year old female were distracted for 40 days after the osteotomy in their basic phalanges. Fixation took 50 days including 15 days for skin bulk growing in the interphalangeal space followed by web plasty

4. Technique for lengthening of the 1st metacarpal bone and its phalagization

This lengthening technique is used for amputation stumps at the level of the first metacarpal and is aimed at improving the gripping function in the 1st web space. Two wire fixation units are placed on the second metacarpal bone and the medial transport along the transverse threaded rod is performed in order to grow skin for subsequent web-plasty (Fig. 10). Double osteotomy of the metacarpal bone is possible if there is enough soft tissue on the stump end

(Fig. 11). The technique completion requires MCJ stretching by four or 5 mm during distraction and fixation periods.

Fig. 10. Diagram of the 1st metacarpal bone lengthening and skin stock growing in the 1st web space

Fig. 11. Bifocal lengthening of the 1st metacarpal bone after double osteotomy in a 22-year old patient with posttraumatic stumps at the metacarpal level. Distraction took 53 days and fixation continued 68 days followed by web-plasty

Distraction period

Distraction is initiated within five to seven days after the operation with an increment of 0.25 mm made three times a day to reach 0.75 mm of daily lengthening. To produce the distraction increment, the locking screw of the distal fixation unit is released so that there is some contact between the screw end and the flat of the threaded rod for moving the distal unit that should not rotate. The screw must be locked upon completion of the nut turning.

Callus distraction is checked with regular radiography taken every 10 days. Once an uneven regeneration density is seen in the radiographs or distraction callus is shaped like an hour-glass, the distraction rate must be decreased or even stopped. The amount lengthened at a single osteotomy level is within one to 2 cm on average.

Fixation period

Fixation of the lengthening achieved lasts from four to 8 weeks and depends on the quality of regeneration and lengthening amount. The mini-fixator can be removed once the density of the regenerated bone approximates the density of the bone areas adjacent to regeneration and when the cortex on the radiographs is uninterrupted. Clinical test for mechanical stiffness of the regenerated bone is obligatory.

Postoperative care

Dressings are changed on the first postoperative day and then every two weeks, or when it is required. Dressing should be applied so that it must not hinder to produce distraction.

The rehabilitative measures should be undertaken during the course of treatment and include exercise therapy, massage of the hand joints and wrist if possible. If necessary, physical therapy procedures to improve blood

circulation and joint motion are also applicable after the mini-fixator has been taken off.

Complications

We would like to focus on general complications that may be encountered. The most frequent one is cutting of the skin with a wire at its insertion point during distraction. Therefore, it is recommended to fold the skin in the area between the proximal and distal wires during their drilling. The skin unfolds during distraction. Antiseptic cleaning is obligatory while changing dressings.

Wire tract infection is possible when the wire persists to cut the skin. It must be immediately treated in the stage of infiltration by using ultraviolet radiation and local antibiotic injections into the soft tissues around the wire tract. Such a wire must be taken out if the latter measure fails to stop infection. Very rarely, a premature dismounting of the mini-fixator due to infection developed may be necessary followed by application of a plaster cast. Deformity of the regenerated bone portion could be expected in such a situation but it does not exceed 5 degrees and is seen only in the radiographs.

An excessive skin tension happens due to distraction forces. Distraction efforts should be decreased or even stopped if the skin turns pale. Once the blood flow restores, distraction is continued.

Another problematic issue or complication that is encountered is an extrusion of a sharp bone end out of the thin soft tissue layer. This problem is resolved by cutting the sharp bone end and covering it with local tissue using skin plasty after the fixator removal.

The scars caused by the incision for the osteotomy or wire entrance points turn almost invisible over time.

DISCUSSION

The method of distraction osteogenesis is a reliable method for lengthening of short tubular bones using external fixation both in cases of amputation stumps or congenital malformation [1-6]. Lengthening procedures and web plasty improve the esthetical appearance and functioning of the hand [2, 7-9]. Callotaxis of the proximal phalanx of the thumb or the first metacarpal bone in posttraumatic stumps is an effective reconstruction method to compensate for the loss of functions [9, 10].

A short summary of the technical solutions that are based on the author's long practical experience has been presented above. They were used in 394 individuals with an acquired or congenital pathology in hand bones that required lengthening. Posttraumatic cases were 144 subjects aged from six to 54 years in whom 244 hand segments were lengthened (129 metacarpals, 104 proximal phalanges, nine middle phalanges, and two distal phalanges). Forty six patients had web plasty, and associated deformities were corrected in 24 of them alongside with bone lengthening. Congenital hand bone shortening was managed in 198 individuals aged from three to 63 years. A total of 322 segments were lengthened (214 metacarpal bones, 99 proximal phalanges, and nine middle phalanges). There were 91 cases of skin plasty in the congenital group. Associated deformities were corrected in 24 cases. Web-plasty was an additional procedure in 46 cases.

Minor complications during the course of treatment neither affected final outcomes nor prolonged treatment time. Wires cut the skin during distraction in 7% of patients. It resulted in wire tract infection that happened

in 6% of our cases. Five percent of the cases treated had premature dismounting of the mini-fixator due to infection developed and plaster casts were applied. There was no functionally limiting loss of joint motion in any patient. Joint subluxation or dislocation, regenerate fracture, non-union, arthritis or nerve injury was not observed.

This series of the cases treated by a single surgeon with the mini-apparatus designed showed a lower complication rate as compared to other series [11]. It may be attributed to the features of the mini-fixator construct that incorporates thin wires instead of half-pins that results in a lesser invasiveness during the intervention and distraction. Moreover, the wires are drilled at 90 degrees to each other and relative to the longitudinal bone axis and retain the bone from both sides thus excluding deformities.

The recommended distraction rate is of great importance and must not be accelerated to allow the regeneration process run in a steady pace suitable for a short tubular bone to exclude nonunion but could be decreased in the circumstances mentioned previously. Motion of bridged joints recovers if their stretching has been completed with the mini-fixator prior to its removal.

One of the principle features of the mini-fixator set is its versatility that provides assemblies for lengthening of both hand phalanges and metacarpal bones. Other advantages of the techniques are the possibility to apply the mini-fixator to several bones simultaneously and its ability to be adjusted to grow the skin bulk in the interphalangeal space both in congenital and posttraumatic cases. Skin plasty for web space skin division was described by us in

the previous work [2]. The lengthening techniques with the mini-fixator designed provide individual solutions basing on a specific medical condition and patients' wishes.

Source of Funding

There was no external funding source for this investigation.

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Рукопись поступила 02.02.2016.

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