Metacarpal and phalangeal lengthening in traumatic finger amputations

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Abstract: Objectives: To present our experience of distraction osteogenesis in Metacarpal and Phalangeal lengthening of the hand andanalyze the factors which influence the period of healing. In Zagazig university hospitals in the period fromNovember 2009 to may 2012.Distractionhas been performed in four metacarpal bones and five phalangeal bones in seven patients. The age ranged from 13 to 49 years. All the digits hadtraumatic amputations. The injury was in the right hand (dominant) in 5 patients and in the left hand in 2 patients. An isolated injury to the thumbwas seen in 4 patients, while in the remaining patients other fingers had been injured. All patients were operated by the same surgeon usingsimilar lengthening technique. Patients were followed regularly and assessed for bone lengthening by clinical and radiological methods. **Results**: The achieved elongation of the metacarpal bones varied from 26 mm to 39 mm (average 34.5 mm), and of the digital phalanges from11 mm to 15 mm (average 13 mm). Average healing time was 2.01 months (range from 0.8 – 3.7). Average healing index was 0.89 month/cm(range from 0.73 – 1.00). Complications observed were pin tract infection (5 cases), delayedspontaneous bone union (2 cases), volar angulation (1 case) and refracture (1case). Webplasty was performed in 3 cases. Strength of pinch improved by anaverage of 37% and that of grasp by 48% compared to the preoperative values. All patients were able to pick up a paper and a cup of water. **Conclusions:** Distraction osteogenesis is a successful and reliable method for the lengthening of short metacarpals and phalanges. However, some complications such as stiffness, angulation, subluxation of the MCP joint and delayed union associated with thisprocedure. To avoid these complications, we suggest protection of the periosteum, refraining from distraction rates of more than 4×0.25 mm/dayand, if possible, avoid lengthening a bone by more than 40%.
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1. Introduction

When a functional deficit of the thumb or multiple digits involving the metacarpals and/or phalanges is present, the technique of digital lengthening can restore a very functional prehensile unit by distraction of the existing skeletal architecture or the addition of transplanted bone(1).

The power of the human hand depends on the length, strength, free lateral motion and perfect mobility of the thumb(2). Thumb amputation thus causes a marked functional limitation of the hand, especially of the pinch and grasps(3). An amputated thumb should definitely be reconstructed and replantation is the first preferred method. If replantation cannot be performed successfully, secondary reconstruction procedures (toe-to-hand transfer, osteoplastic reconstruction, callus distraction) and thumb prosthesis should be considered(4,5). Metacarpal lengthening was firstly described by Mansoor in 19691. In 1967, Matev presented his experience with satisfactory results on many cases and he suggested metacarpal lengthening for thumb amputations (6,7) Although distraction osteogenesis of digits has become an established option for reconstruction in congenital anomalies and after traumatic amputation,(8,9) the technique remains controversial. Some surgeons prefer gradual lengthening followed by bone grafting(10). Others do not recommend the procedure because of the long periods of treatment and the risk of complications, such as fracture or pseudarthrosis(9,11).

Distraction osteogenesis is a surgical process used to reconstruct skeleton deformities and lengthen the bones of the body1. It is also called as callus distraction, callotasis and osteodistraction(12,13) There are three main phases to distraction osteogenesis: latency, activation, and consolidation. Latency is that period immediately following the osteotomy and application of distractor; it ranges from 1 to 7 days. After the latency phase is the activation phase. During this phase, the distraction device is activated by turning some type of axial screw, usually at 1 mm/day in four equal increments of 0.25 mm each. Once activation is complete, the third and final phase is the consolidation phase. Typically, the consolidation phase is twice as long as the time required for activation(12-14). A corticotomy is used to fracture the bone into two segments, and the two bone ends of the bone are gradually moved apart during the distraction phase, allowing new bone to form in the gap. (12-15) When the desired or possible length is reached, a consolidation phase follows in

which the bone is allowed to keep healing.(12,15) Distraction osteogenesis has the benefit of simultaneously increasing bone length and the volume of surrounding soft tissues(16).

In 1905, Alessandro Codivilla introduced surgical practices for lengthening of the lower limbs (17). Early techniques had a high number of complications, particularly during healing, and often resulted in a failure to achieve the goal of the surgery.(18,19)

The breakthrough came with a technique introduced by Russian orthopedic surgeon Gavril Ilizarov.(19) Ilizarov developed a procedure based on the biology of the bone and on the ability of the surrounding soft-tissues to regenerate under tension; the technique involved an external fixator, the Ilizarov apparatus, structured as a modular ring.(19) Ilizarov technique reduced the frequency and severity of the complications.(20) The Ilizarov technique made the surgery safer,(12) and allowed the goal of lengthening the limb to be achieved.(21)

We have evaluated the clinical results of digits of the hand which were lengthened by distraction callotasis. We present our findings and an analysis of the factors which influence the period of healing.

2.Patients and Methods

A total number of 7 patients (four males, three females).of amputated digits were selected and admitted to orthopedic department in Zagazig university hospital in the period fromNovember 2009 tomay 2012. Lengthening of metacarpals anddigital phalanges by a distraction apparatus has beenperformed in four metacarpal bones and six phalangealbones. The ageranged from 13 to 49 years (average 27). The injury was in the right hand (dominant) in 5 patients and in the left hand in 2 patients. All patients were operated by the same surgeon using similar lengthening technique.

The lengthened bones involved five thumbs (4metacarpals and 1 proximal phalanx), two index fingers(one metacarpal and one proximal phalanges) and three lateral fingers (3 proximal phalanges). After a latent period of about 7 days, gradual lengthening was begun at a rate of 0.25 mm 4 times daily.

The clinical results were assessed to determine whether the expected length had been achieved. The healing index (HI) was determined. The HI is the time taken to achieve consolidation in the gap for 1 cm of lengthening (Table 1). Functional status of the patients was evaluated with the pick-up test. Patients were asked topick up a pencil (tip-pinch), a cup of water (grasp) and a sheet of paper (key pinch). Patients were asked for functional and cosmetic satisfaction. Any complications were recorded.

Surgical Technique

All procedures were performed under general anesthesia. Distraction was performed with the use of mini monolateral external fixator. Subperiostealdiaphyseal osteotomies were made in all cases. After a 7-days interval; lengthening was started with 0.25mm/day. Distraction was stopped after adequate length was obtained. The ossification of the distracted callus was confirmed with X-rays. External fixators were removed after completion of the consolidation radiologically. After appearance of a new digit at the web space; web plasty was performed in three patients with metacarpal lengthening for gaining enough web depth.

3.RESULTS

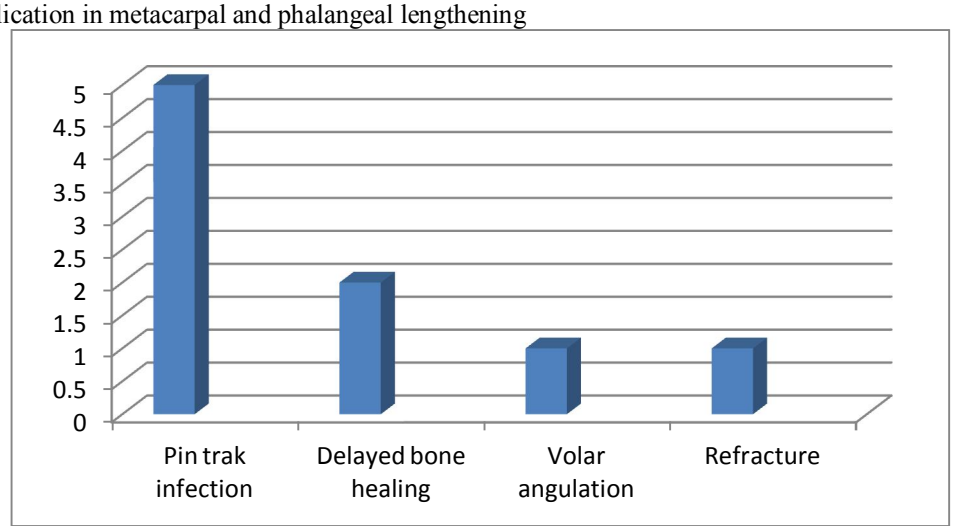
The follow-up period was from 2 to 28 months (average 16 m). The achieved elongation of the metacarpal bones varied from 26 mm to 39 mm (average 34.5 mm), and of the digital phalanges from 11 mm to 15 mm (average13 mm).

Average healing time was 2.01 months (range from.8 – 3.7). Average healing index was 0.89 month/cm (range from 0.73 – 1). (Table 1) During distraction the following complications were observed (Table 2) Pin tract infection (5 cases) (Fig.2:H), delayed spontaneous bone union between the fragments (2 cases), volar angulation (1 case) (Fig.2C) and fracture after frame removal (1 case). (Fig.2:D) Webplasty was performed in three cases of metacarpal lengthening. Strength of pinch improved by an average of 37% and that of grasp by 48% compared to the preoperative values. In the pick-up test all patients were able to pick up a pencil(Fig.1g) but writing ability was worse in on patient with the injury of the dominant hand the patient had begun to use the other hand as a dominant hand. All patients were able to pick up a paper and a cup of water.

Table 1: Results of metacarpal and phalangeal lengthening

Case no	age	gender	Site of distraction	Length of distraction in mm	Healing time in M	Healing index M/cm	Patient satisfaction
1	28	male	Thumb M	39	3.7	0.95	yes
2	13	male	Thumb PP	11	0.8	0.73	No
3	24	female	Index M	38	3.2	0.84	yes
4	17	male	Thumb M	35	3	0.86	yes
5	26	female	Middle PP	13	1.3	1.00	yes
			Ring PP	15	1.4	0.93	
			Little PP	12	1	0.83	
6	49	female	Thumb M	26	2.4	0.92	yes
7	33	male	Index PP	14	1.3	0.93	yes

Table 2: complication in metacarpal and phalangeal lengthening



Case report

FIGER: 1 Male patient 28 years old work as long vehicle driver. He underwent car accident, his right thumb was amputated.He cannot obtain driving license because he cannot writ or grasp the driving wheel. After lengthening thumb metacarpal he restored writing and driving activity and can obtain driving license

Fig.1A: Preoperative photo of amputated thumb at the level of MPJ

Fig.1B: Early post operativeXray showing amputated thumb at the level of the MPJ with applied minifixator

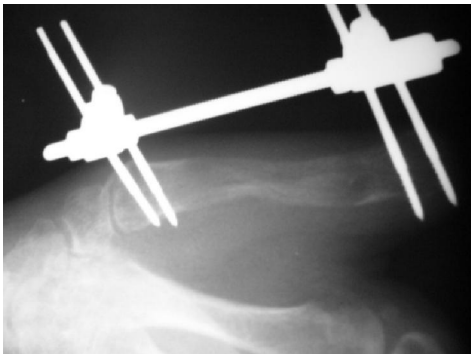


Fig.1C: X ray show full lengthening and good callus formation

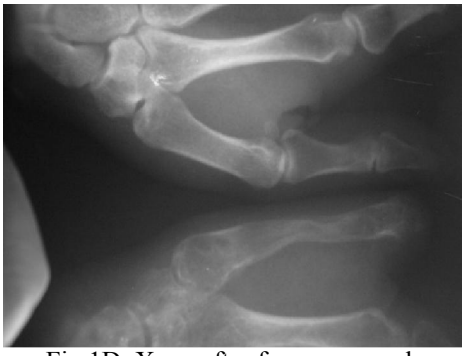


Fig.1D: X ray after frame removal

Fig.1E: Photo after full correction

Fig.1F: Photo after full correction

Fig.1G: Patient can grasp pen between the newly lengthen thumb and index

FIGER: 2 Female patient 26 years old prone to accident with amputation of her lateral three fingers at the level of the PIPJ. She psychologically suffer from this problem and also suffer from grasping ability. We did lengthening of the proximal phalanges 13, 15, and 12 mm respectively. The cosmetic appearance and the grasping ability greatly improved. The patient is satisfied

Fig.2A: Preoperative X ray shows amputated lateral three fingers at the level of the PIPJ

Fig.2B: Preoperative photo shows amputated lateral three fingers at the level of the PIPJ

Fig.2C:Postoperative X ray during lengthening of the middle finger proximal phalanx

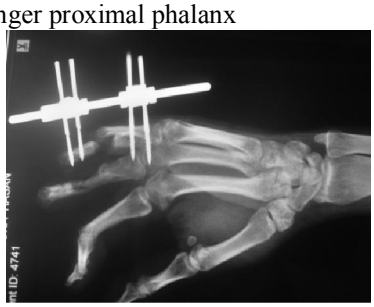


Fig2D:Fracture of the middle finger proximal phalanx after lengthening

Fig.2E:Healing of proximal phalanx of middle finger and lengthening of the proximal phalanx of ring finger

Fig.2G: During lengthening of proximal phalanx of little finger

Fig.2H: Pin track infection with pin loosening

Fig.2 I: After complete lengthening of proximal phalanges of middle, ring and little fingers

4.Discussion

Distraction osteogenesis is a standard method of bonelengthening nowadays and is based upon the "tension-stress principle", as proposed by Ilizarov(22). The essence of this technique is the gradual distraction of afracture bone after low-energy corticotomy with preservation of the soft tissue surrounding the bone(23). Amputation of the fingers, and especially of the thumb,considerably affects hand function such as pinch and grasp(3). Functional reconstruction of an amputated finger differs depending on which finger is injured, level of injury and the patient choice or expectations. This affects the choice of treatment(24). If primary replantation is impossible or fails, different methods are used for thumb and phalangeal reconstruction(3). Various techniques involving osteotomy and intercalary bone grafting have been used in the treatment of short metacarpals and phalanges. It is difficult to achieve sufficient lengthening with these techniques, and acute lengthening carry a risk of neurovascular complications(25). The most frequently used technique is either one-stage lengthening with an intercalary bone graft or gradual lengthening by distraction osteogenesis(26,27). One-stage lengthening of metacarpals has several advantages, including a relatively short union period with less scar tissue formation(26,28). However, there are some disadvantages of one-stage lengthening, such as a small gain in length, morbidity of the donor site, neurovascular impairment caused by rapid stretching graft problems related to multiple lengthening and the limitation of range of motion due to cast immobilization(28,29). Distraction osteogenesis is an alternative method by which greater lengthening can be achieved with fewer complications. Matev reported the first case of metacarpal lengthening by distraction osteogenesis in 1970, and reported his experience with the first metacarpal lengthenings in 1989(10,25). Many authors have followed up on this recommendation, performing two-stagesurgery(8,30,31).

The advantages of this method is the achievement of greater final bone length, avoidance of bone grafting, no morbidity at the donor site, suitability for multiple lengthening procedures, and a lower incidence of neurovascular damage(32). However, some morbidities like pin-tract infection, limitation of range of motion, subluxation or dislocation of the MCP joint, volar angulation and non-union, have been reported(33). In our series, we achieved a greater degree of lengthening (average gains: 34.5 mm for metacarpals and 13 mm for phalanges) and also avoid some of the major post-operative complications.

Many authors reported that a healing index of less than 1.5 months/cm could be achieved by applying an extension rhythm of 0.25 mm twice a day(33,34). A healing index of more than 2.0 months/cm can be achieved by applying an extension rhythm of 0.75–1 mm/day31,34.

In our study, the average healing index was 0.89 months/cm for both metacarpal and phalangeal lengthening. Our healing index is nearly the same as reported by other authors(32,36). We feel that these results are due to a greater amount of lengthening (average lengthening of 22.6 mm) achieved in our study similar to others (average lengthening not less than 17.6mm)(33,34)

MCP joint angulation, subluxation or dislocation and delayed union or non-union are the most frequent complications encountered in the lengthening of metacarpals and have been observed in instances in which the mean lengthening percentages were more than 40% and the lengthening rhythms were greater than 0.5 mm/day(32,33,34). Unfortunately, we also observed similar complications. We also encountered pin tract infection (n=5), delayed bony union (n=2), fracture after frame removal(n=1) and volar angulationafterb frame removal (n=1). In order to prevent subluxation (in some instances), the phalanges and MCP joints were temporarily fixed with an axial K- wire. There is a problem of decrease interdigital web space after distraction osteogenesis in the hand.The web space's depth and width are enlarged by lengthening of the digits and by performing webplastyoperations(13). In our series, we performed webplasty in 3 cases with metacarpal lengthening with more than30 mm of distraction. The depth and width of the web space were observed to be adequate after the webplasty operations and the functions of tip-pinch, key pinch and grasping improved and the aesthetic appearance was better.

There are several advantages and disadvantages of distraction in the hand. It is less invasive than other techniques since bone grafting is unnecessary, gradual distraction is possible, exercise can be carried out during treatment and sensation is maintained(37). Disadvantages include longer treatment times with an

associated higher rate of complications and a need for complicated and bulky instrumentation(37).

Conclusions

The distraction osteogenesis method is successful and reliable for the lengthening of short metacarpals and phalanges. However, severe complications such as stiffness, angulation, subluxation of the MCP joint and delayed union are associated with this procedure. To avoid these complications, we suggest protection of the periosteum, refraining from distraction rates of more than 4×0.25 mm/day and, if possible, avoid lengthening a bone by more than 40% of preoperative bone length.

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