METACARPAL AND PHALANGEAL LENGTHENING OF THE HAND; UTILITY OF DISTRACTION OSTEOGENESIS

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ABSTRACT... Objectives: To present our experience of distraction osteogenesis in Metacarpal and Phalangeal lengthening of the hand and analyze the factors which influence the period of healing. **Design:** Experimental study. **Period:** December 2008 to April 2011. **Setting:** Department of Plastic and Reconstructive Surgery, Khyber Teaching Hospital, Peshawar. The patients were admitted through out-patient department and detailed history, clinical examination and necessary investigations were carried out. Informed consent was taken. Distraction has been performed in six metacarpal bones and four phalangeal bones in nine patients. The age ranged from 3 to 59 years. All the digits had traumatic amputations. The injury was in the right hand (dominant) in 6 patients and in the left hand in 3 patients. An isolated injury to the thumb was seen in 4 patients, while in the remaining patients other fingers had been injured. All patients were operated by the same surgeon using similar 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 30 mm (average 27.66 mm), and of the digital phalanges from 10 mm to 17 mm (average 13.5 mm). Average healing time was 2.05 months (range from 1.8 – 2.5). Average healing index was 0.75 month/cm (range from 0.65 – 0.88). Complications observed were pin tract infection (3 cases), necrosis of free grafted skin (2 cases), delayed spontaneous bone union (2 cases) and volar angulation (1 case). Webplasty was performed in all cases. Strength of pinch improved by an average 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, severe complications such as stiffness, angulation, subluxation of the MCP joint and delayed union or non-union are associated with this procedure. To avoid these complications, we suggest protection of the periosteum, refraining from distraction rates of more than 2×0.25 mm/day and, if possible, avoid lengthening a bone by more than 40% or not more than 20 mm of the preoperative bone length.

Key words: Metacarpal, Lengthenings, Distraction Osteogenesis.

INTRODUCTION

Distraction osteogenesis is a surgical process used to reconstruct skeleton deformities and lengthen the bones of the body[1]. It is also called as callus distraction, callotasis and osteodistraction[1,2]. 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[1,2,3]. 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[1,3,4]. When the desired or possible length is reached, a consolidation phase follows in which the bone is allowed to keep healing[1,4]. Distraction osteogenesis has the benefit of simultaneously increasing bone length and the volume of surrounding soft tissues[5].

In 1905, Alessandro Codivilla introduced surgical practices for lengthening of the lower limbs[6]. Early techniques had a high number of complications, particularly during healing, and often resulted in a failure to achieve the goal of the surgery[7,8].

The breakthrough came with a technique introduced by Russian orthopedic surgeon Gavril Ilizarov.8 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[8]. Ilizarov technique reduced the frequency and severity of the complications[9]. The Ilizarov technique made the surgery safer,[11] and allowed the goal of lengthening the limb to be achieved[10].

The power of the human hand depends on the length, strength, free lateral motion and perfect mobility of the thumb[11]. Thumb amputation thus causes a marked functional limitation of the hand, especially of the pinch and grasps[12]. 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[13,14]. Metacarpal lengthening was firstly described by Mansoor in 1969[11]. In 1967, Matev presented his experience with satisfactory results on many cases and he suggested metacarpal lengthening for thumb amputations[15,16].

Although distraction osteogenesis of digits has become an established option for reconstruction in congenital anomalies and after traumatic amputation,[17-18] the technique remains controversial. Some surgeons prefer gradual lengthening followed by bone grafting[19]. Others do not recommend the procedure because of the long periods of treatment and the risk of complications, such as fracture or pseudarthrosis[18,20].

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.

PATIENTS AND METHODS

A total no. of 9 patients were selected and admitted through out-patient department from December 2008 to April 2011. Detailed history, clinical examination and necessary investigations were carried out. Informed consent was taken. Lengthening of metacarpals and digital phalanges by a distraction apparatus has been performed in six metacarpal bones and four phalangeal bones in nine patients (four females, five males). The age ranged from 3 to 59 years (average 28). All the digits had traumatic amputations. The injury was in the right hand (dominant) in 6 patients and in the left hand in 3 patients. An isolated injury to the thumb was seen in 4 patients, while in the remaining patients other fingers had been injured. The subjects had contraindication for replantation due to either severe injury or stump revision. All patients were operated by the same surgeon using similar lengthening technique.

The lengthened bones involved five thumbs (4 metacarpals and 1 proximal phalanx), four index fingers (2 metacarpals and 2 proximal phalanges) and one middle finger (1 proximal phalanx). After a latent period of about ten days, gradual lengthening was begun at a rate of 0.5 mm twice daily. The overall mean distraction was 0.32 mm per day (0.11 to 0.64).

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

SURGICAL TECHNIQUE

All procedures were performed under general anesthesia. Stump revision was applied to all fingers at the initial operation. Distraction was performed with the use of mini Ilizarov type external fixator. Subperiosteal diaphyseal osteotomies were made in all cases. After a 10-days interval; lengthening was started with 0.5 mm/day. Distraction was stopped after adequate length was obtained and ossification of the distracted callus was confirmed with X-rays (Figure 2). External fixators were removed after completion of the consolidation radiologically. After appearance of a new digit at the web space; webplasty was performed in all patients for gaining enough web depth.

RESULTS

The follow-up period was from two to 28 months (average 16). The achieved elongation of the metacarpal bones varied from 26 mm to 30 mm (average 27.66 mm), and of the digital phalanges from 10 mm to 17 mm (average 13.5 mm). During the operation, the bone was distracted primarily about 5 mm and thereafter it was gradually distracted at a rate of 0.5 to 1 mm per day.

Average healing time was 2.05 months (range from 1.8 – 2.5). Average healing index was 0.75 month/cm (range from 0.65 – 0.88). Blood supply and subjective complaints were examined carefully. During distraction, following complications were observed: Pin tract infection (3 cases), necrosis of free grafted skin (2 cases), delayed spontaneous bone union between the fragments (2 cases) and volar angulation (1 case). Webplasty was performed in all cases; simple in 6 cases, four flap Z-plasty in 2 cases and local flap in 1 case (in which a distraction of 3.7 cm was performed). 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 but writing ability was worse in patients with the injury of the dominant hand and some of them 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.

DISCUSSION

Distraction osteogenesis is a standard method of bone lengthening nowadays and is based upon the "tension-stress principle", as proposed by G.A. Ilizarov [21]. The essence of this technique is the gradual distraction of a fracture bone after low-energy corticotomy with preservation of the soft tissue surrounding the bone[22]. The indications of distraction osteogenesis have been rapidly widened in the fields of orthopedic, craniofacial, and maxillary surgery, since the introduction of this technique to the western world in early 1980s[22].

Amputation of the fingers, and especially of the thumb, due to gunshot wounds considerably affects hand function such as pinch and grasp[12]. 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[23]. If primary replantation is impossible or fails, different methods are used for thumb and phalangeal reconstruction[12].

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 lengthenings carry a risk of neurovascular complications[24]. The most frequently used technique is either one-stage lengthening with an intercalary bone graft or gradual lengthening by distraction osteogenesis[25,26]. One-stage lengthening of metacarpals has several advantages, including a relatively short union period with less scar tissue formation[25,27]. 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[27,28]. 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[19, 24]. Many authors have followed up on this recommendation, performing two-stage surgery[17,29,30].

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[31]. 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[32]. In our series, we achieved a greater degree of lengthening (average gains: 27.6 mm for metacarpals and 13.5 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[32,33]. A healing

Table-I. Results of Metacarpal and Phalangeal lengthening by distraction

Case No.	Age (years)	Gender M/F	Site of distraction	Length of distraction	Healing time (M)	Healing index M/cm	Patient satisfaction
1	25	M	Thumb M	26mm	02	0.87	Yes
2	45	M	Thumb P index M	12mm 27mm	1.8 2.2	0.78 0.67	Yes
3	59	F	Thumb M	28mm	2.5	0.70	Yes
4	03	F	Index M	26mm	1.10	0.79	No
5	14	M	Thumb M	29mm	2.3	0.85	Yes
6	43	F	Index P	15mm	02	0.74	Yes
7	20	F	Thumb M	30mm	2.4	0.68	Yes
8	29	M	Index P	10mm	1.9	0.71	Yes
9	54	F	Middle P	17mm	2.3	0.80	Yes

index of more than 2.0 months/cm can be achieved by applying an extension rhythm of 0.75–1 mm/day[31,34].

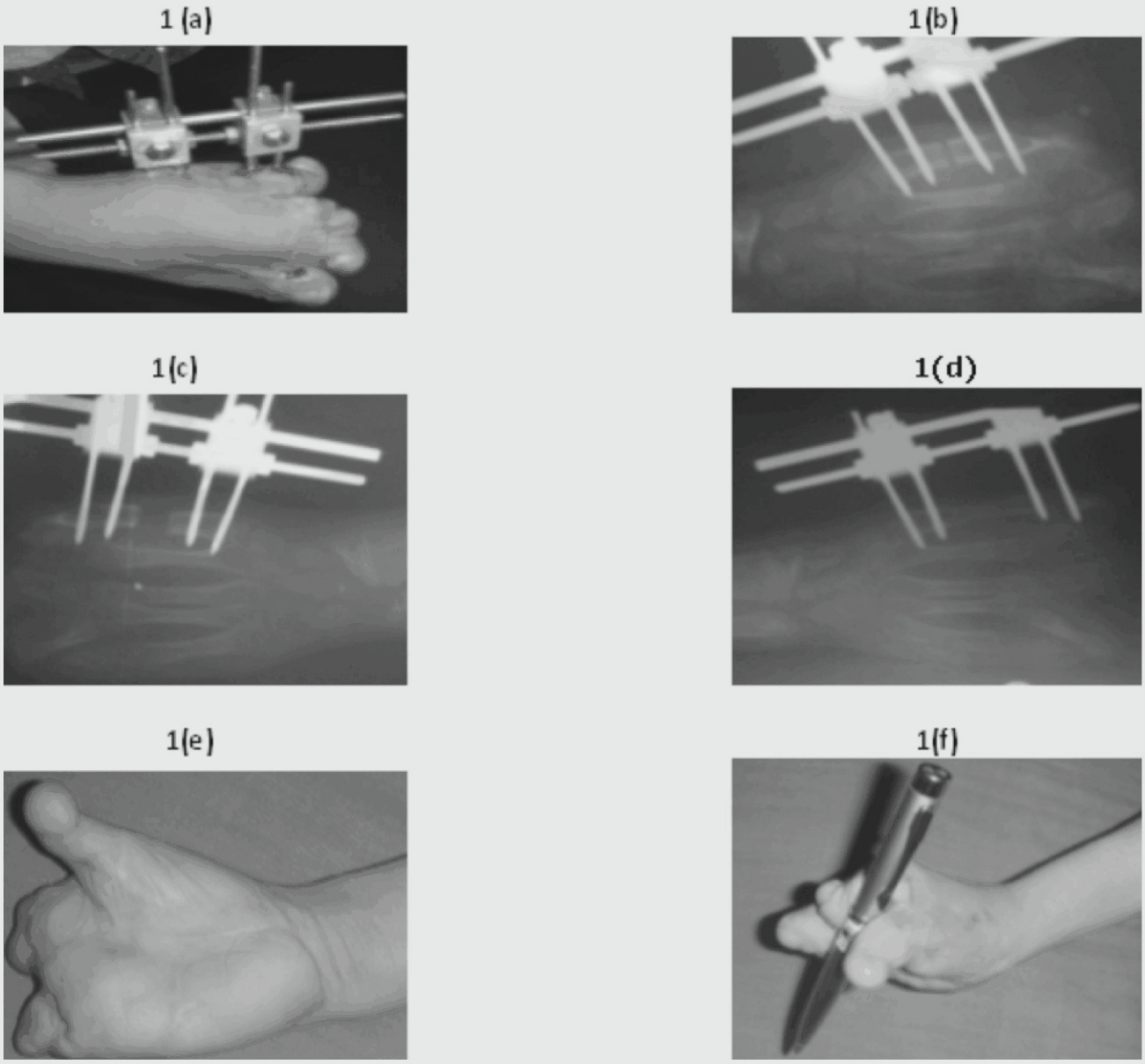
In our study, the average healing index was 0.75 months/cm for both metacarpal and phalangeal lengthening. Our healing index for phalangeal lengthening is same as reported by other authors[31,35]. We feel that these results are due to a greater amount of lengthening (average lengthening of 27.66 mm) achieved in our study similar to others (average lengthening not less than 17.6mm)[32,33].

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[31,32,33]. Unfortunately, we also observed similar complications. We also encountered pin tract infection (n=30), free skin graft necrosis (n=2), delayed bony union (n=2) and volar angulation (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 webplasty operations[12]. In our series, we performed webplasty in cases with up to 29 mm of distraction, simple Z-plasty in cases between 29 and 32.5 mm of distraction and webplasty with a local flap in a case with 32 mm 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[36]. Disadvantages include longer treatment times with an associated higher rate of complications and a need for complicated and bulky instrumentation[36]. In our study, the mean HI was 0.76 months/cm (0.67 to 0.87) in the metacarpal and 0.75 months/cm (0.71 to 0.80) in the proximal phalanx. These data show that prolonged periods are needed for distraction in adults. For lengthening of digits, distraction remains our first choice. Depending upon the patient's background, both the length of treatment and the discomfort during distraction may be unacceptable. For this reason the option of an additional bone graft should

Fig-1. Distraction osteogenesis in a 9 years old girl for traumatic amputation of the thumb (a,b) Immediate picture and x-rays after distracter application. (c,) Distraction after one week started at 5mm/day. No consilodation seen. (d) After six week post-distraction, consolidation is seen and metacarpal lengthened.(e,f) Final result with sufficient bone length and adequate pinch.



always be considered.

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 or non-union are associated with this procedure. To avoid these complications, we suggest protection of the periosteum, refraining from distraction

Fig-2 Distraction in severely burn right thumb of a laborer
(a) Before distraction (b) Immediate post operative with distractor in situ
(c) Corticotomy seen (d) Early signs of consolidation seen.

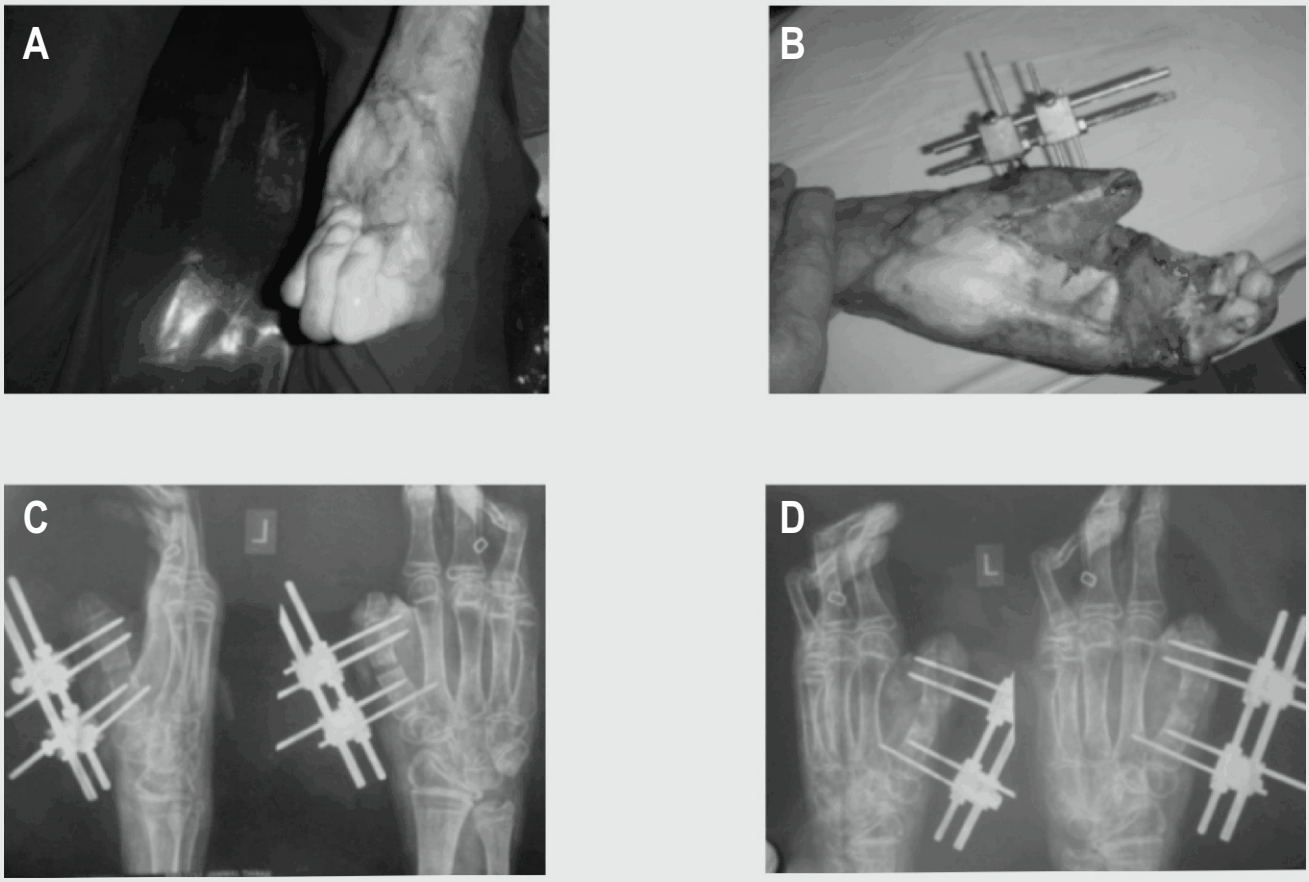
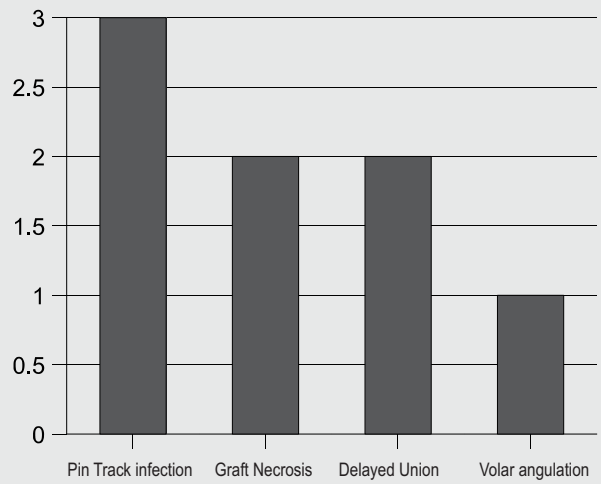


Fig-3. Complications of distraction in hand



rates of more than 2×0.25 mm/day and, if possible, avoid lengthening a bone by more than 40% or not more than 20 mm of the preoperative bone length.

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Injustice anywhere is a threat to justice everywhere.

Martin Luther King Jr. (1929-1968)