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Lengthening of the phalanges by callus distraction in traumatic amputations of the fingers

El parmak travmatik amputasyonlarında kallus distraksiyonu yöntemi ile falangeal uzatma

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Amaç: El parmaklarının travmatik amputasyonlarında kallus distraksiyonu ile falangeal uzatma uyguladığımız olguların sonuçları değerlendirildi.

Çalışma planı: El parmaklarında travmatik amputasyon olan 13 erkek hastanın (ort. yaş 27.7; dağılım 12-43) 16 falanksı kallus distraksiyonu yöntemi ile uzatıldı. Uzatma tek taraflı dinamik eksternal fiksasyon cihazı ile 1 mm/gün şeklinde uygulandı. Ortalama izlem süresi 42 ay (dağılım 12-80 ay) idi.

Sonuçlar: Başparmaklarda ortalama 24 mm (dağılım 18-26 mm), diğer parmaklarda 21 mm (dağılım 18-26 mm) uzama sağlandı. Başparmaklarda oluşan yeni parmak boyu ile birinci web derinliği ve açıklığı yeterli hale geldi ve elin uc-uc, uc-yan ve kaba kavramalarında fonksiyonel açıdan artış görüldü. Başparmak gücü, fleksör pollisis longusun katkısı ortadan kalktığı için, sağlam tarafın %65'ine karşılık gelecek şekilde, ortalama 7 kilogram (dağılım 5-9 kg) olarak ölçüldü. Diğer parmaklardaki uzama elin kullanım fonksiyonunu artırdı. İyileşme indeksi (1 cm uzama için geçen ay sayısı), başparmaklarda ortalama 1.7 ay/cm (dağılım 1.6-2.1 ay/cm), diğer parmaklarda 1.6 ay/cm (dağılım 1.4-1.9 ay/cm) bulundu. Dört parmakta çivi dibi enfeksiyonu görüldü.

Çıkarımlar: Başparmak distal falanks kayıplarında, başparmak kısalığının yol açtığı fonksiyonel sorunların giderilmesinde, proksimal falanksa yapılan uzatma osteotomisi etkin bir rekonstrüksiyon yöntemidir. Diğer parmaklarda ise, ray rezeksiyon veya ray rezeksiyon ve transpozisyon yöntemini kabul etmeyen hastalarda uygulanabilir bir yöntemdir.

Anahtar sözcükler: Amputasyon, travmatik; kemik uzatma/yöntem; eksternal fiksatör; parmak yaralanmaları/cerrahi; osteogenez, distraksiyon/enstrümantasyon/yöntem; osteotomi/yöntem; hareket açıklığı, artiküler; başparmak/cerrahi; traksiyon/enstrümantasyon.

Objectives: We evaluated the results of lengthening of the phalanges by callus distraction in traumatic amputations of the fingers.

Methods: We treated traumatic amputations of 16 fingers of 13 male patients (mean age 27.7 years; range 12 to 43 years) by callotasis of the phalanges. Callus distraction was performed with a rate of 1 mm/day using a unilateral dynamic external fixation device. The mean follow-up period was 42 months (range 12 to 80 months).

Results: The mean lengthening was 24 mm (range 18 to 26 mm) and 21 mm (range 18 to 26 mm) for the thumbs and the other fingers, respectively. The achieved thumb length provided adequate depth and width of the first web space and enabled functional improvement in the ability of gripping, and pulp-to-pulp and pulp-to-side pinching. In the absence of flexor pollicis longus, the mean strength of the thumbs was 7 kg (range 5 to 9 kg), amounting to 65% of the normal side. Lengthening of the other fingers resulted in improved functioning of the hand. The mean healing index (number of months per centimetre of lengthening) was 1.7 months/cm (range 1.6 to 2.1 months/cm) and 1.6 months/cm (range 1.4 to 1.9 months/cm) in the thumbs and the other fingers, respectively. Pin tract infections were observed in four phalanges.

Conclusion: Callotasis of the proximal phalanx of the thumb is an effective reconstruction method to compensate for the loss of distal phalanx and to alleviate functional problems due to shortness. It may also be applied to the phalanges of the other fingers in patients who do not accept ray resection with or without transposition.

Key words: Amputation, traumatic; bone lengthening/methods; external fixators; finger injuries/surgery; osteogenesis, distraction/instrumentation/methods; osteotomy/methods; range of motion, articular; thumb/surgery; traction/instrumentation.

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The main objective in treatment of traumatic amputations of the fingers is to achieve complete or the highest possible level of functional capacity. A series of reconstructive surgical procedures including replantation may be performed for this purpose. If amputation is in the thumb, restoration is mandatory. Losses in other fingers and loss of a single finger do not cause severe functional deficit, except for rare cases. However, functional insufficiency is inevitable after the loss of two or more fingers. The absence of especially centrally located fingers have a bad prognosis in terms of the effect of opposing forces and gripping slippery objects.

Phalangeal lengthening osteotomy is one of the functional reconstructive procedures which may be used in cases when replantation surgery has failed or when severe injuries preclude replantation. Lengthening technique for thumb losses was first described by Mathev in 1970 for metacarpal lengthening,[1] however, according to the amount of the loss, daily lengthening may be performed for phalangeal stumps.

Patients and method

The study group consisted of 16 fingers of 13 male patients (mean age 27.7 years, range 12-43 years) with total amputation of various fingers at various locations, treated between 1996-2002. In all study cases, either replantation was not indicated after an examination with a surgical microscope, or replantation had failed or primary amputation and stump revision was performed in another center. The injury involved the right (dominant) side in 11 patients, the left side in two patients. Among the 16 fingers treated, five were thumbs, two were index fingers, five were middle fingers and four were ring fingers. In two cases, lengthening was performed on more than one finger.

In a patient with loss of the first, second and third fingers, a long stump was present on the proximal phalanx in the thumb and index finger, and a short stump on the proximal phalanx of the second finger. First the second ray was resected and the second finger was transposed into three, followed by lengthening of the transposed finger and the proximal phalanx of the thumb.

After examination using a surgical microscope, replantation was not indicated in four patients and lengthening on the stump phalanx was initiated immediately after the injury; however, in eight patients reconstruction through phalangeal lengthening was initiated after the replantation procedure had failed. In one patient in whom stump revision had previously been performed in another institute, reconstruction was completed in our center. All patients were operated on by the same surgeon,

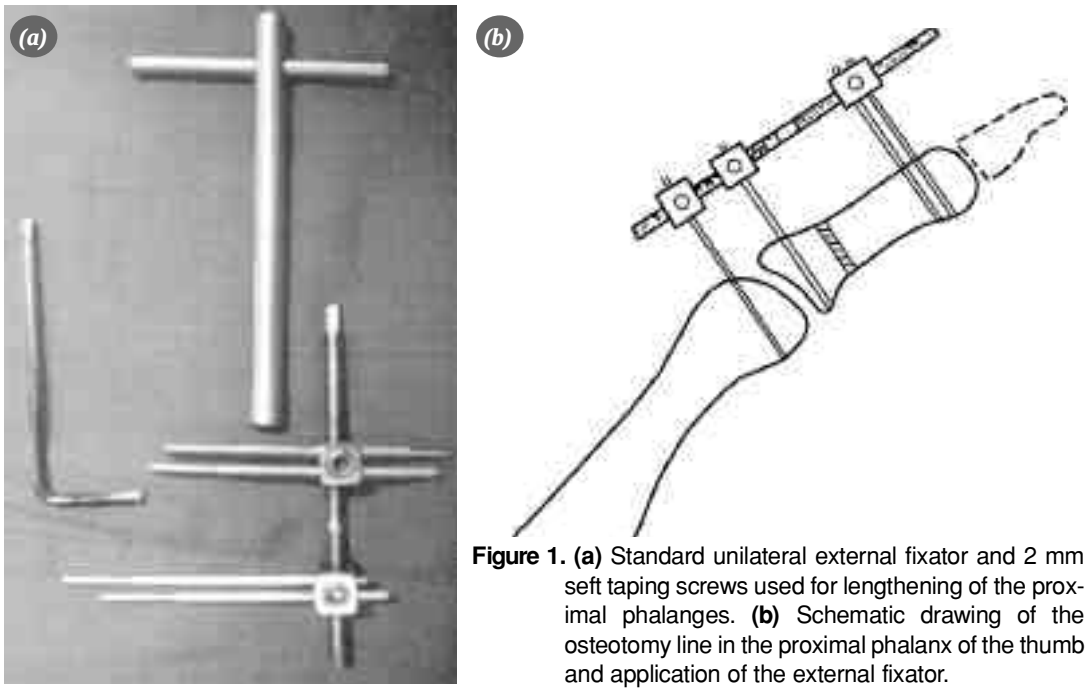

Figure 1. (a) Standard unilateral external fixator and 2 mm seft taping screws used for lengthening of the proximal phalanges. **(b)** Schematic drawing of the osteotomy line in the proximal phalanx of the thumb and application of the external fixator.

using the same lengthening technique.

Surgical technique

Surgery was performed under axillary blockage anesthesia and pneumatic tourniquet control. If at initial admission lengthening was preferred, stump revision was completed. On the lengthening area, an anterolateral/anteromedial incision was performed on the central fingers and a lateral incision on the side fingers. Four 'self-taping' screws of 2 mm in diameter and a unilateral dynamic mini external fixator were used (Figure 1a). For the thumbs, during extension of the metacarpophalangeal joint, the first screw was placed in the basis of the first proximal phalanx, the second screw in the head of the metacarpal (first group), the third and fourth screws in the distal part of the proximal phalanx (second group) perpendicular to the bone and parallel to each other, with the help of a perforator. In the same way, two 'self-taping' screws each were placed in the proximal and distal metaphyses of the phalanx to be lengthened. Following this, a subperiosteal transverse osteotomy was performed near the basis of the phalanx between the two screw groups. The skin was sutured using a 4/0 nonabsorbable surgical suture, after which a unilateral dynamic external fixator was placed (Figure 1b). After a waiting period of ten days, lengthening was initiated at a rate of 1 mm/day. Lengthening was performed under the surgeon's surveillance in the first few days, aiming to teach the patient, after which the patients were allowed to continue at a rate of 1 mm/day in a single session. When adequate lengthening was achieved, ossification of the distracted callus was controlled using radiographs. Following radiological completion of consolidation, the external fixator was extracted and patients were referred to the physical therapy department. The mean follow-up period was 42 months (range 12-80 months).

Results

Mean amount of lengthening was 24 mm (range 18-26 mm) in the thumbs, 21 mm (range 18-26 mm) in the other fingers and 22 mm (18-26 mm) in total (Figure 2a-c). At the end of the treatment, finger tip sensations did not show any differences and were adequate as compared to the preoperative status. There was no sensory deficit since all lengthening procedures were performed on stumps and at tip points, since care was taken not to create tight skin on the stumps and since no truncal nerve sensitive to

Figure 2. Patient with distal phalangeal amputation of the thumb. **(a)** preoperative view, **(b)** during lengthening of the proximal phalanx and **(c)** end result.

lengthening was present on the lengthening area.

Since the contribution of the flexor pollicis longus was eliminated when using a pinchmeter, the pulp-pulp pinch of the lengthened fingers were measured as 7 kilograms (range 5-9 kg), reaching to about 65% of the normal side. Two patients received lengthening for two separate fingers. No major loss of strength was noted in these patients due to preservation of the superficial tendons. Since the contribution of forearm muscles to the strength of the other fingers were cancelled out, providing an anatomical integrity, preventing possible deformities and correcting the carrying angle were the major concerns for lengthening. Strength measurements were not performed since the new anatomical structures contributed little to grip strength.

In four fingers, pin track infection responsive to oral antibiotics and local wound care were observed. None of the patients experienced complications like vascular compromise, fracture of the callus, early or late consolidation, pseudoarthrosis, deformity, angulation or limited range of motion.

Healing index (number of months required for 1 cm lengthening) was found to be 1.7 months/cm for the thumbs (range 1.6-2.1 months/cm), 1.6 months/cm for the other fingers (range 1.4-1.9 months/cm) and 1.7 months/cm average for all fingers (range 1.4-2.1 months/cm).

Depth and width of the web space of the thumb developed to be sufficient, functional capacity of the hand increased and an aesthetic improvement was observed (Figure 3a, b).

Functional improvement for the other fingers was also noticed in terms of hand hollow formation and also holding aqueous objects. Moreover, for the loss of more central fingers, deformities due to deviation of the neighboring fingers on both sides of the defect were prevented, thus hindering a possible functional deficit.

Discussion

The objective of treatment for hand injuries is to provide the best anatomical and functional improvement possible compared to the preinjury state by using the present capacity. For this purpose, when primary treatment options like primary replantation cannot be applied or have failed, another safe treatment modality with less morbidity should be preferred for reconstruction. Functional reconstruction varies with the position and level of injury to the fingers. The aim of the treatment also shows variations for the two major locations of injury, namely the thumb and other fingers.

The major joint of the thumb is the carpometacarpal joint. If full function of this joint and the active stable control of the first metacarpal have been preserved, thumb reconstructions performed according to various techniques all provide sufficient results. The choice of treatment modality depends on the level of the defect. One of the reconstruction methods is inguinal lamboiliac bone graft-neurovascular island flap combination. Nonvascularized bone grafts used in this method may cause resorption, sequestration or nonunion.[2,3] The distal phalanx and skin of the great toe may be transfered for thumb reconstruction. Iliac

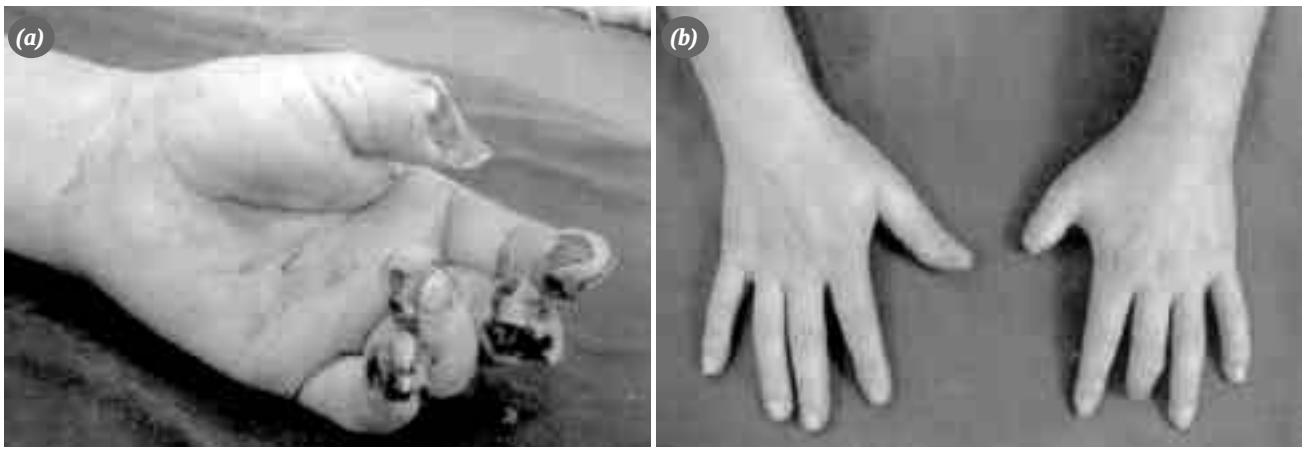

Figure 3. Amputation of the thumb **(a)** photograph after injury and **(b)** photograph at the end of treatment with adequate web depth and space, thus improving function

bone graft is interposed and the skin is wrapped around the graft.[4-6] Similar problems concerning the bone may also be observed in this technique; thus, reconstructions using pedunculated or free vascularized bony skin flaps were designed.[7-9] One of the most common and effective methods used for thumb reconstruction is pollisation of the index finger.[10] However, toe transfer and pollisation of the index finger cause a certain amount of morbidity, which is generally met with patient noncompliance. Similarly, techniques requiring microsurgery may result in loss of the finger and is, therefore, limited due to patient noncompliance.

When all of these features are considered, in reconstructing distal phalangeal losses of the thumb, a safe, less morbid method would be required, providing a sufficient grip surface with stability and sensitivity and not necessitating cortical adaptation in terms of sensual capacity. Lengthening technique for the hand was introduced by Mathev, first for the metacarpals, then for the phalanges.[1] Functional capacity is generally considered adequate after distal phalangeal losses and thus no treatment is applied,[10] however, increase in the depth and width of the first web space secondary to lengthening of the index finger increases functional capacity of the hand and provides an aesthetically more acceptable appearance. Since the osteotomy line is distal to the attachment of intrinsic muscles to the proximal phalanx, the first web space is not increased in height, neither are the muscles themselves. Therefore, inadequate depth of the first web space does not create technical problems in reconstructions performed with lengthening of the first metacarpal. Following transpositioning, pinch and grip strengths showed a significant increase and reached values of 83.3% and 80.2% respectively, compared to the normal side.[11]

Reconstruction using bone lengthening techniques are also performed for the congenital finger defects as well as traumatic finger amputations, and secondary bone grafting is not necessary in most of these cases. [12,13] The stepwise lengthening for finger reconstructions may be considered to be superior to traditional methods using bone grafting.[14] A piano player was treated with the lengthening procedure for loss of the fifth finger and he could continue to play the piano.[15] Distraction and secondary grafting were reported to be effective for shortening seen after osteomyelitis.[16] Various bony and developmental defects in skeletally immature children were successfully treated with this method and a mean lengthening of 2.13 cm was acquired in 20 metacarpals and seven phalanges.[17] In another study, seven metacarpals and four metatarsals of a child with congenital anomalies, lengthening of 20 and 25 mm respectively could be acquired and cosmetically better results were reported.[18] The good results obtained have contributed to the search for and development of better devices.[19]

In loss of the third and fourth fingers which are called the central fingers, transpositioning of the second to third finger and fifth to fourth finger is an accepted treatment option.[20,21] When the central fingers are left short following the loss, the radial fingers deviate to the ulnar side with the pressure from the thumb and the ulnar fingers are deviated to the radial side when the hand contacts hard surfaces and

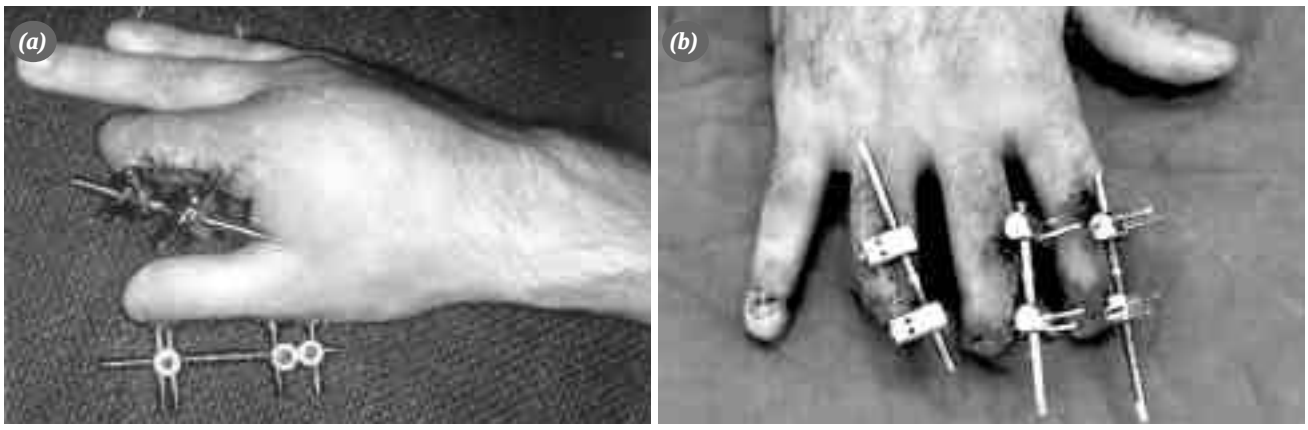

Figure 4. It is possible to lengthen multipl phalanges in the same session. **(a)** Thumb and index finger transpozed into three after ray resection and **(b)** simultaneous lengthening of middle phalanges of the second, third and fourth fingers.

thus a scissoring deformity is formed. This situation disturbs hand anatomy and causes functional defects. Nevertheless, when the length discrepancy of the central fingers are eliminated, a strong support is obtained against the thumb when the contact between the three fingers forms a block, especially during pulp-pinch grips. The primary functional treatment modality after central finger losses is ray resection and transpositioning. Patients who do not accept this procedure may be offered reconstruction by lengthening as an alternative method. If the loss is in the middle phalanx and in the presence of an intact proximal interphalangeal joint, satisfactory functional results may be obtained through lengthening. In case of losses at the proximal phalangeal level, deformities expected after deviation of the fingers towards the defect may be prevented and functional improvement may be obtained in forming a hollow of the hand and holding aqueous objects, despite the fact that grasping and gripping functions were not improved.

Phalangeal lengthening may be performed on more than one finger simultaneously (Figure 4a, b). In one patient who received ray resection and transpositioning, simultaneous lengthening was performed on the thumb and the second finger transposed to the third. Thus, transpositioning and lengthening techniques were combined.

Lengthening for the short stump of the index finger creates functional improvement in pulp-pulp and pulp-pinch grips of the thumb. Lengthening of the fifth fingers may be considered for cosmetic concerns since it has no functional contribution, expect for special circumstances.

The most important factor in patient selection should be a good quality and loose skin covering the stump at the distraction area.[13] Another important aspect of the technique is that angulation may develop in the bone when the device is removed before ossification of the newly formed bone occurs.[22] Taking the widely used Ilizarov device as a model, devices were developed specially for the fingers.[23] Lengthening with this technique was also used for treating length discrepancies seen after replantation.[24] When compared to other methods, lengthening is a less invasive procedure, it does not require bone grafting, is suitable for segmental lengthening and allows rehabilitation applications during the procedure; however, it has disadvantages like a long treatment period and the necessity to wear hardware.[25] If distraction exceeds 3 cm, there is a risk that spontaneous ossification does not occur.[25]

Volar angulations may be observed during distraction. This problem was prevented in one patient by placing an intramedullary K-wire.[26]

In conclusion, even though the stump left after distal phalangeal losses of the thumb has a certain degree of functional capacity, the first web width and space should be wide and long enough respectively for a better grip, pulp-pulp and pulp-pinch grip. Cosmetically, a longer thumb would be more acceptable. Using this technique, in terms of stability and sensitivty, good quality skin is acquired at the grip surface and carpometacarpal and metacarpophalangeal joints may be completely controlled by the intrinsic muscles. For the other fingers, a functional improvement in grasping and forming a hollow of the hand for carrying aqueous material may be observed. For losses of central fingers, deformities due to deviation of neighboring fingers towards the defect and the functional deficit resulting from this phenomenon may be prevented. The only disadvantage of reconstruction by lengthening is the difficulty in catching thin and small objects with smooth surfaces since no nail exists on the thumb and the relatively unacceptable cosmetic appearance. In the loss of distal phalanges of the thumb, phalangeal lengthening osteotomy is an effective reconstruction method for correcting functional problems arising from the shortness of the thumb. For the other fingers it may be considered an alternative method for those patients who do not accept ray resection and transpositioning.

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