The clinical results of 26 digits (18 patients) lengthened by distraction callostasis were evaluated and the factors which influenced healing were analysed. There were 14 men and four women, with a mean age of 39 years. All digits had suffered traumatic amputation. There were eight thumbs and 18 fingers. The level of the site of the osteotomy was at the proximal metaphysis in ten, the middle diaphysis in 13 and the distal metaphysis in three.

Although the proposed length was achieved in 23 of the 26 digits, five required additional bone grafts. The rate of healing was 96 days/cm in the digits without complications such as callus fracture or poor callus formation, and 158 days/cm in those with complications. Lengthening at the proximal metaphysis gave a better result than at the diaphysis or distal metaphysis.

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

Patients and Methods

Between 1989 and 1999, we carried out distraction callostasis on 36 digits in 23 patients. In order to consider the factors which influenced the period of healing, we excluded children from the study. This left 26 digits in 18 patients. There were 14 men and four women, with a mean age of 39 years (18 to 62). All the digits had had traumatic amputations.

The lengthened bones involved eight thumbs (7 metacarpals and 1 proximal phalanx), nine index fingers (1 metacarpal and 8 proximal phalanges), seven middle fingers (2 metacarpals, 4 proximal phalanges and 1 middle phalanx) and two ring fingers (2 proximal phalanges). In all digits, an Orthofix M-100 (Orthofix Srl, Verona, Italy) lengthener was used. The level of the osteotomy was at the proximal metaphysis in ten digits (3 metacarpal and 7 proximal phalanges), at the middle diaphysis in 13 digits (7 metacarpals, 5 proximal phalanges and 1 middle phalanx) and at the distal metaphysis in three digits (3 proximal phalanges). In the patients whose digits were lengthened at the level of the diaphysis, two pins were inserted into the bone on either side of the osteotomy (Fig. 1). In the digits which were lengthened at the proximal or distal metaphysis, one of the two pins of the proximal or distal clamp was inserted into the adjacent bone across the joint (Figs 2 and 3).

In our earlier patients, after a latent period of about ten days, gradual lengthening was begun at a rate of 0.5 mm twice daily. We varied the rate of distraction depending on the pain, sensory disturbance and contracture of the digit during lengthening. As distraction increased there was often pain or contracture and the rate of distraction had to be decreased. The overall mean distraction was 0.32 mm per day (0.11 to 0.64). More recently, we have used a rate of distraction of 0.35 mm per day distributed between two sessions. When we began using this technique there were few data on lengthening of fingers and we tried various latent periods, with a mean of 9.1 days (7 to 14). We have recently decided on ten
days as a suitable latent period since this is the approximate
time taken for wound healing to occur.

Having achieved the proposed length, periods of neutral-
isation and dynamisation were necessary until the area had
filled with newly-formed bone. We used passive dynamisa-
tion, in which patients lengthened in the morning and
shortened at night. The lengthener was removed when the
radiographs showed consolidation of the gap throughout
the width of the bone. If the patients could not continue to
use the external fixator, but bone consolidation appeared to

Metacarpal lengthening in a 54-year-old woman with a traumatic amputation through the proximal phalanx
of the left thumb. Figures 1a and 1b – Radiographs show a) distraction callotasis after 20 days and b) callus
filling the distraction gap after four months. Figure 1c – Clinical photograph shows a good pinch movement
after four months. Figure 1d – Radiograph taken two years after operation shows bony consolidation but
slight angulation after fracture of the callus.
be inadequate, one or two intramedullary Kirschner wires were inserted. During this programme, active exercises and splint therapy were undertaken if necessary.

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 recovery such as pinch action, sensation in the lengthened digits and patient satisfaction were also evaluated. Any complications were recorded.

**Statistical analysis.** Comparison of the HI for patients with and without complications was assessed by the Mann-Whitney U test and that of the HI between the three osteotomy levels was by the Kruskal-Wallis test. Differences were considered to be significant when the p value was less than 0.05.

**Results**

Table I gives the details of the results. The mean length of follow-up was 3.8 years (2 to 8). In three digits (2 patients) the proposed length could not be achieved. One
Patient (2 digits) had early consolidation and did not wish to undergo further surgery. In the other patient, fracture of the lengthened bone caused loss of length in one digit. The patient requested a secondary lengthening of 13 mm of this digit 14 months after the primary operation. This was achieved by gradual lengthening and bone grafting.

In the remaining 23 digits, the proposed lengths were achieved.

Fracture of the lengthened bone occurred in four digits. For these patients, external fixation was continued in two, and Kirschner wire fixation was used in one and cast immobilisation in one. All four ultimately achieved solid, bony fusion. Early consolidation occurred in three digits. For one of these, additional lengthening was undertaken at the proximal phalanx when the middle phalanx had consolidated early. For the remaining two (in one patient) further surgery was declined (see above). In five digits, bone formation was poor and bone grafting was required. Minor pin-track infection occurred in two digits, but this healed after local treatment. During lengthening of the thumb, an adduction contracture occurred in four metacarpal lengthenings and a flexion contracture of the metacarpophalangeal joint occurred in two similar procedures. In the other digits, a flexion contracture of the metacarpophalangeal joint occurred in five digits (1 metacarpal and 4 proximal phalangeal lengthenings). An extension contracture of the proximal interphalangeal joint occurred in two proximal phalangeal lengthenings. In the four patients with an adduction contracture of the thumb and one with lengthening at the proximal phalanx, we used a Z-plasty to deepen the first web space. In the remaining patients, active exercises and splint therapy reduced these contractures, although a flexion contracture of the metacarpophalangeal joint of 20° remained after one metacarpal lengthening and one proximal phalangeal lengthening.

In the five digits which required additional bone grafting, the mean age of the patients was 32 years (19 to 47). The lengthened bones included the metacarpal of the thumb (2 digits) and the proximal phalanx of the fingers (3 digits). The level of the osteotomy was at the middle diaphysis (2 digits) and the distal metaphysis (3 digits).

In the four digits which had fracture of callus, the mean age of the patients was 28 years (18 to 54) The lengthened bones were the thumb metacarpal (1 digit), the proximal phalanx of the fingers (2 digits) and the middle phalanx of the fingers (1 digit). The level of the osteotomy was the middle diaphysis in all patients. There was no significant correlation between the HI and the age of the patient. The HI for those with major complications, such as callus fracture or poor callus formation, was significantly longer (158 days/cm; range 88 to 320) than for those without major complications (p < 0.01).

There was no significant relationship between the length of distraction and the HI or the EFI, although 71% of the digits (5 of 7) with a length of distraction of over 20 mm required an additional bone graft or had a fracture of callus.

The site of the osteotomy did not significantly affect the HI (p = 0.0974, Table II).

Clinical outcome. In two 18-year-old patients who had lengthening of the proximal phalanges and one 25-year-old patient with lengthening of the middle phalanx, the operations were performed for cosmetic rather than functional improvement. These patients were satisfied with the results of the lengthening although the 25-year-old patient was unhappy about the unexpectedly long period of treatment.

In the remaining 15 patients, surgery was undertaken in order to improve pinch function. Of these, all but one were satisfied with the result and a stable pinch grip was obtained. The mean pinch power of the 14 satisfied patients (2 digits) had early consolidation and did not wish to undergo further surgery. In the other patient, fracture of the lengthened bone caused loss of length in one digit. The patient requested a secondary lengthening of 13 mm of this digit 14 months after the primary operation. This was achieved by gradual lengthening and bone grafting.

In the remaining 23 digits, the proposed lengths were achieved.

Fracture of the lengthened bone occurred in four digits. For these patients, external fixation was continued in two, and Kirschner wire fixation was used in one and cast immobilisation in one. All four ultimately achieved solid, bony fusion. Early consolidation occurred in three digits. For one of these, additional lengthening was undertaken at the proximal phalanx when the middle phalanx had consolidated early. For the remaining two (in one patient) further surgery was declined (see above). In five digits, bone formation was poor and bone grafting was required. Minor pin-track infection occurred in two digits, but this healed after local treatment. During lengthening of the thumb, an adduction contracture occurred in four metacarpal lengthenings and a flexion contracture of the metacarpophalangeal joint occurred in two similar procedures. In the other digits, a flexion contracture of the metacarpophalangeal joint occurred in five digits (1 metacarpal and 4 proximal phalangeal lengthenings). An extension contracture of the proximal interphalangeal joint occurred in two proximal phalangeal lengthenings. In the four patients with an adduction contracture of the thumb and one with lengthening at the proximal phalanx, we used a Z-plasty to deepen the first web space. In the remaining patients, active exercises and splint therapy reduced these contractures, although a flexion contracture of the metacarpophalangeal joint of 20° remained after one metacarpal lengthening and one proximal phalangeal lengthening.

In the five digits which required additional bone grafting, the mean age of the patients was 32 years (19 to 47). The lengthened bones included the metacarpal of the thumb (2 digits) and the proximal phalanx of the fingers (3 digits). The level of the osteotomy was at the middle diaphysis (2 digits) and the distal metaphysis (3 digits).

In the four digits which had fracture of callus, the mean age of the patients was 28 years (18 to 54) The lengthened bones were the thumb metacarpal (1 digit), the proximal phalanx of the fingers (2 digits) and the middle phalanx of the fingers (1 digit). The level of the osteotomy was the middle diaphysis in all patients. There was no significant correlation between the HI and the age of the patient. The HI for those with major complications, such as callus fracture or poor callus formation, was significantly longer (158 days/cm; range 88 to 320) than for those without major complications (p < 0.01).

There was no significant relationship between the length of distraction and the HI or the EFI, although 71% of the digits (5 of 7) with a length of distraction of over 20 mm required an additional bone graft or had a fracture of callus.

The site of the osteotomy did not significantly affect the HI (p = 0.0974, Table II).

Clinical outcome. In two 18-year-old patients who had lengthening of the proximal phalanges and one 25-year-old patient with lengthening of the middle phalanx, the operations were performed for cosmetic rather than functional improvement. These patients were satisfied with the results of the lengthening although the 25-year-old patient was unhappy about the unexpectedly long period of treatment.

In the remaining 15 patients, surgery was undertaken in order to improve pinch function. Of these, all but one were satisfied with the result and a stable pinch grip was obtained. The mean pinch power of the 14 satisfied

---

### Table I. Details of the 18 patients (26 digits) who underwent lengthening by callotasis

<table>
<thead>
<tr>
<th></th>
<th>Digits without complication</th>
<th>Digits requiring bone graft</th>
<th>Digits with callus fracture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of digits</td>
<td>17</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Length of distraction in cm (range)</td>
<td>17 (4 to 34)</td>
<td>23 (14 to 30)</td>
<td>14 (6 to 19)</td>
</tr>
<tr>
<td>Percentage increase in length (range)</td>
<td>45 (7 to 85)</td>
<td>58 (39 to 81)</td>
<td>31 (15 to 40)</td>
</tr>
<tr>
<td>EFI in days/cm (range)</td>
<td>90 (57 to 153)</td>
<td>101 (83 to 131)</td>
<td>173 (98 to 320)</td>
</tr>
<tr>
<td>HI in days/cm (range)</td>
<td>96 (58 to 153)</td>
<td>120 (88 to 171)</td>
<td>204 (136 to 320)</td>
</tr>
</tbody>
</table>

### Table II. Site of the osteotomy and the subsequent course after distraction lengthening by callotasis in the hand

<table>
<thead>
<tr>
<th>Osteotomy site/phalanx</th>
<th>Metacarpal</th>
<th>Proximal phalanx</th>
<th>Middle phalanx</th>
<th>HI (days/cm; range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distal metaphysis (n = 3)</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>96 (88 to 108)</td>
</tr>
<tr>
<td>Middle diaphysis (n = 13)</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>125 (61 to 320)</td>
</tr>
<tr>
<td></td>
<td>2 requiring bone graft</td>
<td>2 callus fracture</td>
<td>Callus fracture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 callus fracture</td>
<td>3 uneventful</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 uneventful</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal metaphysis (n = 10)</td>
<td>3</td>
<td>7</td>
<td>0</td>
<td>84 (57 to 153)</td>
</tr>
<tr>
<td></td>
<td>All uneventful</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
patients was 6.8 kg (4.8 to 10.1) which corresponded to 76% of that of the contralateral hand. The remaining patient could not pick up small objects, but could hold large ones. After lengthening, all patients maintained sensation of the finger pulp, as assessed by the Semes-Weinstein test.8

All but one patient, the 25-year-old with lengthening of the middle phalanx, indicated that they would accept the same procedure if they had the same problem again.

Discussion

Distraction lengthening in the hand has become an established option for reconstruction in congenital anomalies and after traumatic amputations.1-4,9 For lengthening of long bones, the success of distraction osteogenesis (callotasis) has been known since 1987.9 In 1979, Matev10 first reported gradual distraction osteogenesis of digits.

There are several advantages and disadvantages of callotasis 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. Disadvantages include longer treatment times with an associated higher rate of complications and a need for complicated and bulky instrumentation. Paley11 described numerous complications which may occur during the course of distraction.

In children, good results without complications have been achieved with callotasis regardless of the original pathology or the lengthening required.12-14 Pensler et al13 concluded that distraction osteogenesis of the digits was superior to other methods and offered safe, reliable and predictable results.

In adults, complications such as fracture of callus or poor consolidation are more common. Matev15 recommended that a gap of 3 cm or more in patients over 20 years of age should be filled with bone graft without delay because spontaneous consolidation is doubtful. Most authors have followed this procedure, which entails gradual lengthening and bone grafting.16-20 Finsen and Russwurm21 reported successful results after five metacarpal lengthenings of a mean of 30 mm (17 to 36) using callotasis alone. Treatment was complete by a mean of 326 days (140 to 489). They reported that this method of treatment was prolonged, but provided a valuable alternative to more complex reconstructions. In our study, the mean HI was 139 days/cm (61 to 320) in the metacarpal and 101 days/cm (58 to 216) in the proximal phalanx. These data show that prolonged periods are needed for callotasis in adults.

Aronson and Shen22 stated that the formation of new bone and mineralisation in the experimental healing of distraction osteogenesis was better and quicker in metaphyseal site for the osteotomy during distraction osteogenesis.23,24 Our results show that the siting of the osteotomy is an important factor in the healing process and that the proximal metaphysis is preferred. When the osteotomy was at the distal metaphysis of the digit there was poor callus formation and additional bone graft was often required. There were too few digits from which to draw firm conclusions, but we suggest that this poor callus formation may be due to the smaller surface area of the distal as compared with the proximal metaphysis. In addition, our patients had experienced traumatic amputations, so that the distal metaphysis may have had poorer vascularity. The site of the osteotomy also influenced bone maturity. There was no digit which needed additional bone grafting when the osteotomy was in the proximal metaphysis. This location is our preferred site of osteotomy. The decision on the site depends not only on the ability to form new bone, but also on the remaining length of the bone after trauma. Finsen and Russwurm21 reported that if the base of the phalanx is present, the most distal pin should be placed in it in order to prevent flexion of the metacarpophalangeal joint during distraction. In this situation, the site of the osteotomy is the distal metaphysis.

In this series, when the intended lengthening was more than 20 mm, approximately 71% of the digits required further procedures. In a separate series, with patients treated by gradual lengthening and bone grafting, there were three digits with elongation of more than 20 mm. The mean lengthening of these three was 28 days/cm (22 to 32) and the mean EFI was 36 days/cm (36 to 64). This is significantly shorter than for the patients treated by callotasis alone in this study.25

For lengthening of digits, callotasis remains our first choice. Depending upon the patient’s background, both the length of treatment and the discomfort during callotasis may be unacceptable. For this reason the option of an additional bone graft should always be considered.

We thank Dr Lamont Cardon (Berkeley Orthopaedic Medical Group) for his suggestions and advice during this investigation.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References