An algorithmic approach to posttraumatic nail deformities based on anatomical classification

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Summary  Background and aims: Most of the clinical series on posttraumatic nail deformities (PTNDs) address an individual deformity and its correction. The aim of the study was to classify PTND on the basis of its anatomical defect, devise the reconstructive modality and propose an algorithmic approach to PTND. We have also analysed our results of surgical correction and compared the data with the published literature.

Method: A 5-year retrospective study of 45 patients with PTND was conducted. The deformities were classified into three groups: intact nail bed, partially amputated nail bed and completely amputated nail bed on the basis of the remnant nail bed.

Results: PTNDs with intact nail bed were present in 78%, with partially amputated nail bed in 16% and with completely amputated nail bed in 7% of the patients. Deformities in intact nail bed group were nonadherence (33%), ridged nail (31%), split nail (9%) and nail horn (4%). All patients with partially amputated nail bed presented with hooked nail deformity. A satisfactory result was seen in 87% of nonadherence, 71% of ridged nail, 50% of split nail and 57% of hooked nail. None of the patients with nail horn and absent nail showed a satisfactory result.

Conclusion: PTND with intact nail bed are consistently benefitted when the option is only split-thickness sterile matrix (STSM) grafting. Appreciable correction of hooked nail deformity can be achieved by the reconstruction of lost components. In our opinion, there is

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Nail is important for both aesthetic and functional capability of the finger. The nail unit consists of nail plate, proximal and lateral nail folds, nail bed consisting of sterile and germinal matrix and hyponychium. The germinal matrix is the primary generative centre of the nail and forms the bulk of the nail plate. The sterile matrix is involved in shaping and adhering of the advancing nail. Lunula is white, semilunar-shaped area extending beyond the edge of the proximal nail fold. It marks the transition from germinal matrix to the sterile matrix and is an important surgical landmark for harvesting nail matrix graft. Nail grows at a rate of 0.1 mm day$^{-1}$ or 0.5 mm week$^{-1}$. Finger nail grows faster than toe nail by a ratio of 4:1.

The most common cause of nail bed deformity is trauma, and chronic nail deformities are difficult to treat. Nail bed matrixes (sterile and germinal) are specialised tissues and attempts to replace them with skin or dermal graft is rarely a success. Numerous techniques of nail matrix transfer have been described but each has its own drawbacks. Free nail grafting techniques are split thickness, full thickness and composite grafts. Vascularised nail transfer techniques include long- and short-pedicle free flaps.

**Method**

A 5-year retrospective study from November 2007 to December 2012 of 45 patients operated for posttraumatic nail deformities (PTNDs) of fingers and toes was conducted. Patients with healed and closed wound with deformed nails were only included in the study. The deformities were classified into three groups according to the size of the existing nail bed: intact, partially amputated and completely amputated nail bed. The intact nail bed group included nail beds normal or near normal in size but scarred, leading to deformed nails. This included split nail, nonadherence (onycholysis), ridged nail and nail horn. The partial amputation group included nails in which germinal matrix with varying length of sterile matrix was intact, leading to hooked nail deformity. In the complete amputation group, whole of sterile and germinal matrix was absent and patient required total nail reconstruction. All sterile and germinal matrix grafts for nail bed reconstruction were harvested from the great toe. All grafts were split thickness, and no full thickness or composite grafts were used. Prior to surgery, an X-ray of the involved digit was performed to visualise the bony abnormality, and a dermatological opinion was taken to rule out fungal infection of the nails. Patients were also shown previous postoperative results to give them a realistic level of expectation from the surgery.

As the anatomic basis of PTND could be easily ascertained preoperatively and subsequent reconstruction technique was based on the replacement of component losses, an algorithm was designed to guide the surgeon in a standardised manner (Figure 1).

**Operative technique**

The surgery was performed under digital blocks and tourniquet with loupe magnification as a day-care procedure. In the intact nail bed group, the scar tissue over exposed nail bed was delineated and excised, and the nail matrix graft harvested from the great toe was applied. When required, the nail fold flap was raised to define the proximal limit of the scar into germinal matrix. The donor toe nail was used to split both the donor and recipient areas. Bony spurs, seen in X-ray in the cases of ridged nails, were filed to correct the bony curvature.

In the partially amputated group, the treatment involved sub-periosteal freeing of hooked nail bed, local flap (volar V→Y advancement flap, cross finger flap) to gain additional distal pulp and de-epithelialisation and split-thickness sterile matrix (STSM) grafting of the advancing edge of skin flap to lengthen the nail bed (Figure 2).

Total nail reconstruction was done in the patient with a completely amputated nail bed. The technique involved de-epithelised skin ‘turnover’ flap with sterile matrix grafting for proximal nail fold reconstruction, de-epithelialisation with split-thickness germinal matrix (STGM) and STSM grafting for nail bed creation and full-thickness skin grafting of the turnover flap. In one case, unicortical bone graft from olecranon was used for distal phalanx reconstruction.

First-check dressing was done 10 days after surgery and nail splints were removed after 3 weeks. Serial photographic records were maintained and results were graded as satisfactory and unsatisfactory based on the shape of the nail, adhesion to the underlying bed and donor site morbidity.

**Results**

**Gender and age group**

Amongst 45 patients included in the study, 24 were female and 21 were male. The patient age group ranged from 13 to 57 years with a mean age of 28 years.

**Causes of injuries**

Crush injury was the commonest aetiological factor accounting for 84% of the total cases. This included crush injury in doors (33%), car doors (27%) and under heavy
object (24%). Road traffic accident accounted for 9% and sharp cut for 7% of the cases.

**Hands, fingers and toe**

Right hand was more commonly involved (73%) and nail of index finger was the commonest site of deformity (33%) followed by middle finger (31%), ring finger (20%) and thumb (11%). We did not encounter any case of deformed nail of little finger. Two cases (4%) involved posttraumatic partial amputation of distal phalanx of great toe for which total nail reconstruction was done.

**Evidence of bony injuries**

Radiological evidence of bony injury to distal phalanx was present in 49% of the cases. This included healed fractures (20%), comminuted fractures (7%), absence of bone in distal phalanx (2%) and partial loss of distal phalanx (20%).

**Types of nail deformities**

**Intact nail bed**

Thirty-five patients (78%) had nail deformities with intact nail bed. Nonadherence (33%) and ridged nail (31%) accounted for the bulk of deformity in this group. Split nail (9%) and nail horn (4%) were the other deformities in this group. The deformities were treated by excision of the scar and nail matrix grafting. This included only STSM, only STGM or both depending upon the location of the defect. Overall, a satisfactory result was seen in 87% of nonadherence, 71% of ridged nail and 50% of split nail deformities (Figures 3–5). The result was unsatisfactory in both cases of nail horns (Figure 6). The analysis of results on the basis of the type of nail matrix graft is as follows (Figure 7):

Only STSM graft. 'Only STSM' graft was used in 69% of cases of nail deformity with intact nail bed. This included 87% cases of nonadherence and 79% cases of ridged deformity. The overall result was satisfactory in 88% of cases (92% in nonadherence and 82% in ridged nail deformity).

Only STGM graft. 'Only STGM' graft was used just once (3%), in a case of proximal nail splitting due to a linear scar in the germinal matrix and normal sterile matrix. The result was unsatisfactory and the splitting recurred on the eruption of new nail.

Both (STSM + STGM) grafts. 'STSM + STGM' grafts were used in 29% of cases. This included 13% cases of

![Figure 1](image1.png) An algorithmic approach to post traumatic nail deformities.

![Figure 2](image2.png) Schematic overview of the technique for correction of hooked nail deformity. (Upper left) Hooked nail deformity. (Upper right) Excision of scar and release of hooked nail bed. (Below left) Volar V-Y advancement flap. The distal part of the flap is de-epithelialized for STSM grafting. (Below right) Correction of hooking with lengthening of nail bed.
Figure 3  Nonadherence. (Left) Preoperative. (Right) 8 1/2 months postoperative following excision of scar and only STSM grafting. Picture also shows donor toe nail healed uneventfully.

Figure 4  Ridged nail. (Left) Preoperative view. (Right) 15 months postoperative following scar excision and both (STSM + STGM) grafting.

Figure 5  Split nail (Left) Preoperative, (Right) 5 1/2 months postoperative. Note, split is corrected after excision of scarred nail bed and only STSM grafting.
nonadherence, 21% of ridged nail, 75% of split nail and 100% of nail horn deformities. Overall, a satisfactory result was seen in only 40% of the cases (50% in nonadherence, 33% in ridged nail, 67% in split nail and none in nail horn deformity).

Partially amputated nail bed

Partially amputated nail bed was present in 16% of cases. All of these patients also had partial amputation of distal phalanx leading to hooked nail deformity. Four patients (57%) had satisfactory results in terms of improvement of curvature and deformity becoming less severe (Figure 8). In the other three patients, the deformity recurred due to receding of volar V–Y advancement flaps.

Completely amputated nail bed

Three patients (7%) presented with a total loss of nail bed. In this group, two patients had a partial loss of terminal phalanx of great toe, while in one patient there was a loss of nail and bone of distal phalanx of index finger with intact soft-tissue pulp. Total nail reconstruction was done in this group. In the patients with partial loss of great toe, the nail was reconstructed on the remaining stump of great toe. The result was unsatisfactory in all three with no nail formation and only patchy areas of keratinisation over nail bed grafts (Figure 9). The recreated proximal nail fold also ‘disappeared’ in the course of time.

Donor site

There was no donor site morbidity and all donor areas healed well with an eruption of normal-looking nails.

Follow-up

The follow-up period ranged from 6 to 19 months with a mean follow-up period of 11 months.

Figure 6  Nail horn (Left) preoperative view. (Right) 9 months postoperative view following nail bed excision and both (STSM + STGM) grafting. Note, no nail formation, only areas of focal keratinisation are seen. Also in picture, donor toe nail.

Figure 7  Satisfactory result (%) in relation to type of graft used in deformities with intact nail bed.

Figure 8  Hooked nail deformity (Left) Preoperative view. (Right) Postoperative (8½ months) showing reasonable correction. Also note the lengthening of the nail bed.
Discussion

Injury to fingertip and nail bed is the most common type of hand injury. Non-adherence of nail bed is usually low in the list of patient’s priority unless it is painful or incompletely attached. Good functional and cosmetic outcome in acute nail bed avulsion injuries treated by nail bed grafts encouraged us to use split-thickness toe nail graft for treating chronic nail deformities. The procedure included meticulous excision of scar, good haemostasis, replacement of nail bed by 'like tissue', proper splintage of recipient area, use of various flaps and bone graft for fingertip reconstruction and use of loupe magnification during surgery.

Nail deformities were common in all age groups and there was no statistical correlation between age and sex of patient with the type of deformity or the outcome following surgery. Crush injury by doors and heavy objects accounted for 85% of the cases. The evidence of fracture of distal phalanx was present in 45% of patients which was similar to that of Zook et al. (50%). Contrary to the findings of Zook, in our study, right hand was involved in 76% of cases and index was the commonest finger to get injured (33%).

The deformities were divided into three groups according to the increasing level of complexity involved in the reconstructive process. In the intact nail bed group, as the length of nail bed and underlying bone was normal or near normal, only nail bed scarring was addressed. However, in the partially amputated group, additional flaps for lengthening of nail bed were also used. In the totally amputated group, turnover flaps for proximal nail fold reconstruction and bone grafting for distal phalanx reconstruction added to the complexity of the surgical procedure.

In our study, 78% of patients belonged to the intact nail bed group. The deformities in this group were non-adherence (33%), ridged nails (31%), split nails (9%) and nail horns (4%). Shepard described longitudinal ridging as the most common anomaly (40%) followed by non-adherence of distal nail (21%) and central nail (8%). Zook et al. described non-adherence as the commonest nail deformity after trauma. The aetiology of non-adherence, ridge nail and split nail is 'somewhat' similar, with the nature of deformity depending upon the location of scar over the nail bed.

Shepard showed that in the cases of non-adherence, there is thickening of superficial sterile matrix with hyperkeratinisation across the entire width of the scar. Thus, although nail is being produced normally by the germinal matrix, it is unable to adhere to the distal scarred nail bed. As a consequence, a 'diffuse and wide' scar in sterile matrix produces non-adherence and a longitudinal scar in germinal matrix produces split nail. Ridging of the nail can be a result of matrix hyperplasia or irregularly healed distal phalanx fracture. Reconstruction involved complete excision of scarred tissue and replacement with 'like' tissue, that is, 'only STSM' or 'only STGM' or both ('STSM + STGM'). We used 'only STSM' graft in 69%, 'only STGM' in 3% and 'STSM + STGM' grafts in 29% of cases. The percentage of patients with satisfactory results was much higher when 'only STSM' was used (87%) as compared to 'only STGM' (0%) or 'STSM + STGM' (40%). This shows that STSM graft is far more consistent in providing satisfactory outcome as compared to STGM graft. The review of the literature revealed that STGM grafts fail to produce nail due to the absence of basilar layer of germinal cells. Therefore, in the case of replacement of germinal matrix, unlike sterile matrix, a full-thickness graft of germinal matrix is the appropriate option.

An interesting technique of nail bed regeneration by serial excision of a transverse strip of scarred nail bed and allowing it to heal by secondary intention has been described by Lemperle et al. The authors opine that the excision of the scarred nail strip stimulates the proximal healthy matrix cell to grow much faster than the distal wound margin and approximately 75% of the resected scar is replaced by healthy proximal matrix. This process, when repeated serially, causes lengthening of the nail bed. Zook in the discussion on the Lemperle et al. technique states that repeated ressection of the scarred tissue is akin to tension wound approximation or tissue expansion whereupon due to wound contraction, proximal, unscarred, mobile matrix is pulled distally with every resection and healing cycle, thus lengthening the nail bed. We have not used this technique and it is our strong belief that STSM graft should be applied after excision of the scar rather than allowing secondary intention healing. Zook has also expressed the same line of management in the discussion on Lemperle's technique.

Hooked nail is a deformity in which the nail curves voluntarily during distal growth. This occurs commonly after fingertip amputation, when either the remaining nail bed
is tightly sutured to the volar skin or secondary intention healing is allowed, thereby pulling the nail bed volarily. Hooked nail deformity is also seen following fracture and malunion of distal phalanx in a volar angulated position. Anatomically, in hooked nail deformity, there are three component losses: distal soft-tissue pulp, segment of distal phalanx and portion of distal sterile matrix. Correction of hooked nail deformity requires re-creation of the defect and bringing in various tissues to reconstruct the lost components. All of our seven patients with hooked nail deformities had bony loss. Sub-periosteal release of the curved nail bed along with local flaps to reconstruct the deficiency of volar pulp was performed. No added bony support was given. Fifty-seven percent of our patients had a satisfactory result in terms of improvement in curvature and thus alleviation of pain and discomfort (Figure 8). In the remaining patients, the volar advancement flap gradually receded back with recurrence of curvature. Hooked nail is a difficult deformity to correct satisfactorily and is exemplified by the fact that there are numerous techniques described in the literature for its correction: distraction osteogenesis of distal phalanx, free vascularised composite graft of nail bed and bone, composite graft from toe pad, ‘antenna’ procedure, etc. Shepard achieved consistently satisfactory results in seven patients of hooked nail deformities by using extended advancement lateral V–Y flaps. The reason for recurrence of deformity in three of our patients was receding back of the volar V–Y advancement flaps. The concept of lateral flaps appears much more prudent in this situation and therefore it will be our preferred technique in future cases. The role of bone grafts in the correction of hooked nail deformity remains controversial. Although Verdan (1981) and Lee et al. have successfully achieved improvement in convexity and length of distal phalanx by using bone grafts with local flaps, according to Zook & Russel (1990), the rate of bone graft resorption is fairly high as there is bony opposition at one end only.

Our experience of total nail reconstruction using STSM and STGM grafts with turnover flap for proximal nail fold creation was a complete failure. This finding is congruent to that of Shepard whose earlier attempts of total nail reconstruction with split-thickness nail bed grafts were a failure. Shepard recommends composite perionychial graft from second or third toe along with STSM graft from the great toe for total nail reconstruction. However, there is no predictable pattern of successful outcome of composite graft. In an excellent article on reconstructive procedure of nail transfer by Takashi et al., the authors describe their ‘surgical evolution’ from free nail graft transfer to short-pedicle vascularised nail flap as their present-day procedure of choice for nail reconstruction. Zook and Lillé also opined that microvascular nail transfer is the most reliable method of total nail reconstruction. Unfortunately, significant scarring of recipient finger, long operative time and steep learning curve required for vascular anastomoses at the level of fingertip are its noteworthy pitfalls and is therefore, not always a practical option. Hence, a relatively simple procedure of composite nail transfer as described by Shepard has equal relevance in the present scenario.

Conclusions

Patients with scarred but intact length of nail bed are consistently benefited when the treatment option is ‘only STSM’ graft transfer. In the cases requiring STGM grafts, satisfactory results are inconsistent. It is difficult to obtain superlative results in hooked nail deformities but respectable correction with elimination of pain and discomfort can be achieved by reconstruction of the component losses. There is no role of STG and STSM graft transfer for total nail reconstruction. The algorithm proposed in the study will aid in approaching a case of PTND in a standardised and logical manner.

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Conflict of interest

None.

References