Original Article

# Minimalistic Reconstruction Of Fingertip Injuries Using Artificial Dermal Substitutes: Analysis Of Early Clinical Outcomes

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## Abstract

**Background**: Fingertip injuries, common yet complex, pose significant challenges in resource-limited settings where advanced surgical interventions are scarce. This study evaluates the use of artificial dermal substitutes for minimalistic reconstruction of fingertip injury. We have used Novosorb® Biodegradable Temporizing Matrix (BTM) combined with chlorhexidine-impregnated paraffin gauze for single-stage fingertip reconstruction in Nepal, emphasizing functional, sensory, and cosmetic outcomes.

**Methods**: A retrospective single-centre study included 9 patients (13 digits) with fingertip injuries (Allen's I–IV) treated between January 2022 and December 2024. Under digital nerve block, wounds were debrided, and BTM was applied, followed by daily home dressings. Outcomes included healing time, fingerprint regeneration (0–3 scale), sensory recovery (0–5 scale), pain (VAS 0–5), patient satisfaction (1–5 scale), and complications.

**Results**: Mean healing time was 76 ± 12.51 days, correlating with injury severity (Allen's I: 70 days; IV: 95 ± 4.24 days). Fingerprint regeneration was robust (mean score: 2.69 ± 0.48), with near-complete recovery in Allen's I–II injuries. Patient satisfaction was high (overall: 4.31 ± 0.63; cosmetic: 4.08 ± 0.76), and sensory impairment (1.23 ± 0.43) and pain (1.30 ± 0.48) were minimal. Complications included hook nail (30.8%) and nail splitting (15.4%), primarily in Allen's III–IV injuries.

**Conclusion**: Artificial dermal substitutes like Novosorb® BTM offers a practical, minimally invasive solution for fingertip injuries in resource-constrained settings, preserving finger length, sensation, and function while avoiding donor-site morbidity. High patient satisfaction and functional outcomes underscore its viability as a first-line treatment specially for patient's preferring single stage surgery. Larger prospective studies are warranted to validate long-term efficacy and refine protocols for complex cases.

**Keywords**: Artificial dermal substitute; Fingertip injury; Novosorb® BTM; regenerative outcomes; resource-limited settings.

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## Introduction

Fingertip injuries are among the most common hand injuries worldwide, often presenting as emergencies in clinical settings. Fingertip injuries are described as any injury distal to the insertion of the flexor and extensor tendons.[1] The fingertip consists of volar pulp which is crucial for fine-touch sensation, grip stability, and precise manipulation due to its rich neurovascular network and specialized sensory receptors. Fingertip injury can result in functional impairment, sensory disturbances, and cosmetic disfigurement, ultimately affecting the patient's quality of life.[2]

The main goals of treating such injuries are to maintain functional length, adequate sensation, durable skin cover, and early finger mobilisation.[3] Despite numerous advances in treatment strategies, there is no consensus on the optimal management approach for fingertip injuries.[4] The choice of treatment depends on factors such as the degree of tissue loss, the site of injury, the patient's age, comorbidities, cultural diversity and surgeon's preference. Traditionally, fingertip injuries were reconstructed with grafts, flaps (local, regional, or free) as well as reimplantation and composite grafting. Recently, tissue engineered or artificial dermal templates combined with skin grafts or along with occlusive dressings for management of fingertip injuries are also being used.[4–7]

Surgical interventions often restore the soft tissue envelope and preserve finger length but are associated with donor site morbidity, prolonged immobilization, need for multiple surgeries, along with flap complications like necrosis, infection, finger stiffness, reduced sensation, wound healing sequelae, and fingertip instability.[7] Moreover, surgical interventions may not adequately restore the intricate sensory and biomechanical properties of the native pulp tissue, leading to suboptimal functional outcomes.[2] The use of artificial dermal substitutes like Biodegradable temporizing matrix (BTM) in management of complex wounds have shown promising results in Asian population.[9–12] In pursuit of more effective and less invasive treatment options for reconstruction of fingertip injuries, there has been a growing interest in conservative approaches that harness the body's inherent regenerative potential. Recent studies have highlighted the potential benefits of combining artificial dermis with semi-occlusive dressing or skin grafts after four weeks. Also, a few reports show promising results in one stage reconstruction using dermal regeneration templates.[2,3,8] Most of the studies have used Artificial dermal substitutes, such as Pelnac® or Integra which is unavailable in Nepal. Among various dermal regeneration templates biodegradable temporizing matrix (BTM; NovoSorb, PolyNovo Ltd., Port Melbourne, Australia) is a synthetic skin substitute that has recently gained its clinical application. Compared to other dermal templates, BTM is equally effective and feasible in treating various wounds, with relatively low complication rates.[9–12] The efficacy of skin substitutes including BTM for management of fingertip injuries hasn't been studied in sub-continent population. In resource-limited settings like Nepal, where microsurgical expertise is scarce and patients prioritize minimal hospitalization, tissue-engineered alternatives like artificial dermal substitutes offer a promising solution.

In this study, our aim is to evaluate the outcome of dermal substitute Novosorb® Biodegradable Temporizing matrix along with chlorhexidine impregnated paraffin gauze dressing for one stage minimalistic reconstruction of fingertip injuries. Novosorb® BTM, a biodegradable collagen scaffold, has shown success in Western and East Asian populations for soft-tissue regeneration.[9–12] However, its application in South Asian contexts remains understudied. This study evaluates the early clinical outcomes of Novosorb® BTM combined with chlorhexidine gauze for fingertip reconstruction in Nepal, addressing a critical gap in regional surgical literature.

The advantages of using this protocol is multifaceted. Firstly, a single operative procedure was required and patient was discharged on the same day. Simple dressings were used which could be done at home by the patient themselves. Finally, despite the higher initial cost, this approach may prove to be cost-effective, in the long run by achieving superior clinical outcomes and reducing the need for additional interventions.[3] To test this hypothesis and evaluate the effectiveness of this new combination protocol, a retrospective study was conducted with the following primary objectives:

1. To evaluate the early outcome of single stage reconstruction of fingertip injury using artificial dermal substitute.
2. To record the time taken for complete healing in different types of fingertip injuries.
3. To record overall patient satisfaction, cosmetic satisfaction, fingertip regeneration, sensory impairment, pain after complete healing.
4. Assess the short-term complications.

## Methods

### Study Design and Participants

A single-centre, retrospective study was conducted at Patan Academy of Health Sciences, which was approved by the Institutional Review Board (IRB) of Patan Academy of Health Sciences. This study was performed in strict adherence to ethical guidelines. The sample included all patients with fingertip injuries who underwent minimalistic reconstruction using BTM from January 2022 to December 2024. Written informed consent were obtained from the patient who were willing to participate in the study. Nine patients (8 males, 1 female) with fingertip injuries (Allen's I–IV) were included. Inclusion criteria consisted of patient's aged 1

year or above with fingertip injuries with single or multiple digits who underwent one stage reconstruction using artificial dermal substitute and willing to provide informed consent if above 16 years of age or assent if 1-16 years of age. The exclusion criteria included patient's who had fingertip injuries along with tendon injuries, neurovascular injuries or had additional wounds over dorsum or palmer aspect of hand. Patient's with previous injury over the same digit or injuries at different levels of the injured digits were also excluded. Also, patient's with known cause of impaired wound healing eg. Diabetes mellitus, patients taking immunosuppressive drugs etc were also excluded from the study along with patient's presenting late after 24 hours of injury or patient's with grossly infected wounds.

**Treatment Protocol**

Patients were taken to operation theatre. Under digital nerve block, wound was irrigated and cleaned with povidone iodine solution and in dirty wounds hydrogen peroxide was also used. Then, wound was debrided to remove all devitalised tissues along with exposed bone more than five mm which was devoid of periosteum. Haemostasis was secured with bipolar coagulation to avoid extensive tissue damage. Then, the artificial dermis (BTM, Novosorb®) procured from local vendor by the patient was mounted on the wound following the protocol provided by company. The artificial substitute was trimmed deliberately to fit the size and the shape of the wound. When the tissue defect was uneven, the collagen sponge of the artificial dermis was collected and filled into the wound. The artificial dermis was fixed on the wound with sutures (5–0 polypropylene). If the size of template was greater than 2 x 2 cm, then drainage holes were cut in the silicon film to facilitate exudation. The finger was dressed with chlorhexidine impregnated paraffin gauze as routine with normal pressure. The hand was covered in regular dressing and splinted in neutral position. Patient was discharged on the same day and followed up after five days. On 5$^{th}$ Post-operative day, splint was removed and dressing was changed with same chlorhexidine impregnated paraffin gauze and topical two percent Mupirocin. Patient was taught to perform regular dressing at home. The instructions were to soak the finger in normal saline for 10 minutes, dry and apply paraffin gauze with topical mupirocin twice every day. Weekly follow-up was done to check for vascularization of the BTM matrix and when it was visible, delamination was performed according to the manufacturer's instructions. Routine dressing changes was continued as previously mentioned. Patient were followed up weekly in the outpatient department until wound healed completely then at 3 months and 6 months.

**Outcome Measures**

After complete wound healing, patients were asked to complete a subjective questionnaire assessing the following outcomes:

I. Cosmetic satisfaction: rated on a scale from 1 to 5, with higher scores indicating greater satisfaction with the appearance of the treated finger.

II. Sensory impairment: rated on a scale from 0 to 5, with lower scores indicating less sensory loss.

III. Sensory hypersensitivity: rated on a scale from 0 to 5, with lower scores indicating less discomfort or abnormal sensations.

IV. Pain: assessed using a visual analogue scale (VAS) ranging from 0 to 5, with lower scores indicating less or no pain.

V. Overall satisfaction: rated on a scale from 1 to 5, with higher scores indicating greater satisfaction with all aspects of the treatment and recovery process.

To objectively evaluate the pulp tissue reconstruction, the degree of fingerprint regeneration was assessed on a scale from 0 to 3, with higher scores indicating better regeneration.

This scoring system was based on Kang et al developed scoring system to quantify the extent of fingerprint recovery: 0 indicating no regeneration, 1 indicating partial regeneration, 2 indicating significant regeneration with some irregularities, and 3 indicating nearly complete regeneration with clear fingerprint patterns.[2]

**Data collection, processing and analysis**

Following IRB clearance, data was collected, reviewed and analysed. Patients were followed up regularly as per our standard practice i.e twice per week until delamination, then once per week until complete healing, then every two weeks till 3 months and then every month till 6 months from time of injury.. Patient were grouped based on the level of injury using Allen's fingertip injury levels.

- Type I- loss of only the pulp of the finger
- Type II- pulp and nail loss without bone fragment in the distal amputated fingertip
- Type III- partial loss of the distal phalanx plus corresponding loss of the pulp and nail;
- Type IV- loss proximal to the germinal matrix

Data was collected using questionnaire and filled by the assessor on the basis of patient's response. In the subsequent follow-up after complete healing, outcome variables were assessed. The data was collected using a pre-formed questionnaire which was filled by the assessors on the basis of patient's response. Collected data was entered in Microsoft Excel Office 16 version and analysed using JASP software version 0.18.3.0. Continuous variables are reported as mean±SD; categorical variables as frequencies.

## Results

**Participant Demographics and Injury Characteristics**

The study enrolled 9 participants with 13 injured digits, predominantly male (88.8%,n=8) with a mean age of 32.92±11.32 years reflecting a diverse demographic

representation. Fingertip injuries were common in the digits of non-dominant hand (77.78%, n=7/9), with the right middle and index finger were the most frequently injured digits (23.07%, n=3/13). Crush injuries constituted nearly half of all cases (53.85%%, n=7), followed by clean transected (30.77, n=4) and mutilated injuries (15.4%, n=2).

The individual injured digits were classified according to Allen's classification of fingertip injuries. Most common were Allen's III (53.9%, n=7) followed by Allen's II (23.07%, n=3)., Allen's IV (15.4%, n=2) and Allen's I (7.7%,n=1). The mean size of defect was 500±205.14mm².

**Table1. Participant demographics**

| Characteristics | Total |
|---|---|
| Gender | |
| Male | 8 |
| Female | 1 |
| Age in years; Median ( range) | 40( 13-46) |
| Dominance | |
| Right | 5 |
| Left | 4 |
| Affected Hand | |
| Right | 6 |
| Left | 3 |
| Mechanism of injury | |
| Clean transected | 4 |
| Crush | 7 |
| Mutilated | 2 |

**Treatment protocol and healing duration**

The mean time for complete healing was 76±12.51 days and correlated with the severity of the injury.

**Clinical Outcomes and complications**

Fingerprint regeneration, assessed on a 0–3 scale, demonstrated high efficacy across all injury severities. The overall mean score was 2.69±0.48, with near-complete regeneration (3.00±0.00) observed in Allen's Level I injuries (n=1) and Level II (n=3) injuries achieved near-complete regeneration (3.00±0.49), while Level III (n=7) and IV injuries (n=2) showed significant (2.72 ± 0.49) and partial-to-significant regeneration (2.00 ± 0.00), respectively.

Patient satisfaction, rated on a 1-5 scale, yielded an overall mean of 4.31 ± 0.63, reflecting high approval across all groups (Level I: 5.00 ± 0.00; Level IV: 3.50 ± 0.70). The outcomes were notably positive. Cosmetic satisfaction mirrored this trend, with overall mean of 4.08 ± 0.76, with perfect scores (5.00 ± 0.00) for Level I injuries. Satisfaction decreased modestly with injury severity, yet remained clinically acceptable even for Level IV injuries (3.50 ± 0.70).

**Table 2. Injury Characteristics and time of delamination based on severity of the injury**

| | | Allen's type | | | | |
|---|---|---|---|---|---|---|
| | | I (n=1) | II (n=3) | III (n=7) | IV (n=2) | Total (N=13) |
| Affected Fingers | | | | | | |
| | Thumb | | | 1 | 1 | 2 |
| | Index | | 3 | 1 | | 4 |
| | Middle | 1 | | 3 | | 4 |
| | Ring | | | 2 | 1 | 3 |
| | Little | | | | | 0 |
| Time for delamination (Total mean=6.23±0.59 weeks) | | | | | | |
| | weeks | 6 | 6 | 6.14 ±0.38 | 7 ±1.41 | |
| Size of defect (Total mean: 500±205.14 mm²) | | | | | | |
| | mm² | 150 | 400 ±100 | 585 ±172 | 525 ±318 | |

**Table 3. Outcomes following treatment by using BTM**

| Outcome Measure | Allen's Type | | | | Mean |
|---|---|---|---|---|---|
| | I | II | III | IV | |
| Treatment duration (days) | 70 | 66.67 ±4.04 | 76 ±11.93 | 95 ±4.24 | 76 ±12.51 |
| Fingerprint regeneration score | 3 | 3 | 2.72 ±0.49 | 2 | 2.69 ±0.48 |
| Sensory impairment | 1 | 1 | 1.29 ±0.49 | 1.5 ±0.7 | 1.23 ±0.43 |
| Sensory hypersensitivity | 1 | 1.33 ±0.58 | 1.14 ±0.39 | 1.5 ±0.7 | 1.23 ±0.43 |
| Pain score (VAS) | 1 | 1.67 ±0.58 | 1.29 ±0.49 | 1 | 1.3 ±0.48 |
| Cosmetic satisfaction score | 5 | 4.33 ±0.58 | 4 ±0.82 | 3.5 ±0.70 | 4.08 ±0.76 |
| Overall satisfaction score | 5 | 4.67 ±0.58 | 4.29 ±0.49 | 3.5 ±0.7. | 4.3 ±0.63 |

Pain levels, measured via a 0–5 visual analogue scale, were consistently low (overall mean: 1.3 ± 0.48). Level I injuries reported minimal pain (1.00 ± 0.00), while Level II and III injuries exhibited mild pain with scores of 1.67±0.58 and 1.29±0.49 respectively.

Sensory outcomes revealed minimal impairment (overall mean: 1.23 ± 0.43) and low hypersensitivity (1.23 ± 0.43), with maximum hypersensitivity and impairment for Level IV injuries (1.5±0.7) each. These findings are summarised in **Table 3**.

**Stratification by Allen's Classification**

Higher Allen's levels correlated with incremental

**Table 4. Complications**

| Complication | Frequency |
|---|---|
| Hook nail | 4(30.76%) |
| Nail splitting | 2(15.38%) |

reductions in fingerprint regeneration and satisfaction scores. Level III and IV injuries, despite their severity, maintained clinically meaningful outcomes: Level III achieved significant regeneration (2.72/3.0) and high satisfaction (4.3/5.0), while Level IV injuries demonstrated partial regeneration (2.0/3.0) and moderate satisfaction (3.5/5.0). These findings are summarised in **Table 3**. Pain and sensory disturbances remained mild across all groups, underscoring the procedure's safety. Minor complications, hook nail (n=4) and nail splitting (n=2) was seen in 46% of digits specially Allen's III and IV.

## Discussion

The findings of this study demonstrate that Novosorb® Biodegradable Temporizing Matrix (BTM) combined with chlorhexidine-impregnated paraffin gauze offers a promising, minimally invasive approach for fingertip reconstruction, even in complex injuries (Allen's III–IV). This protocol achieved high functional and cosmetic outcomes while minimizing surgical morbidity—a critical advantage in resource-limited settings like Nepal, where access to microsurgical expertise is limited.

**Regenerative Capacity and Functional Outcomes:**

The robust fingerprint regeneration observed (mean score: 2.69 ± 0.48) aligns with studies using alternative dermal substitutes. Kang et al reported comparable regeneration (2.58±0.67) with Pelnac® artificial dermis, attributing success to scaffold-guided tissue regeneration.[2] Similarly, Saha demonstrated near-complete soft-tissue regeneration using stacked BTM layers, emphasizing its role in supporting neurovascular ingrowth.[13] Notably, even Allen's IV injuries achieved partial regeneration (2.00 ± 0.00), suggesting BTM's potential to salvage digits that might otherwise require terminalization or complex

**Figure 1. a at the time of presentation in the ER b. after immediate application of BTM c and d. shows after complete healing following use of BTM**

flaps. This contrasts with traditional methods, which often sacrifice length or incur donor-site morbidity.[14,15] The study cohort exhibited substantial fingerprint regeneration similar to Kang et al even in patients with injuries. This improvement could be attributed to the regenerative capabilities of the periosteum and bone marrow cells, as well as the inflammatory response triggering the recruitment of mesenchymal stem cells and growth factors.[2] These findings suggest that the conservative treatment protocol, which harnesses the body's inherent regenerative mechanisms is equally effective in all fingertip injuries.

**Patient Satisfaction and Cosmetic Outcomes**

High patient satisfaction (overall: 4.31 ± 0.63; cosmetic: 4.08 ± 0.76) reflects the protocol's ability to preserve finger length and avoid donor-site complications.

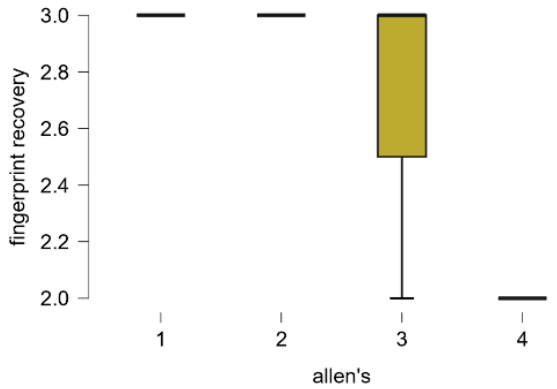


**Figure 2. Fingerprint recovery according to the severity of fingertip injury**

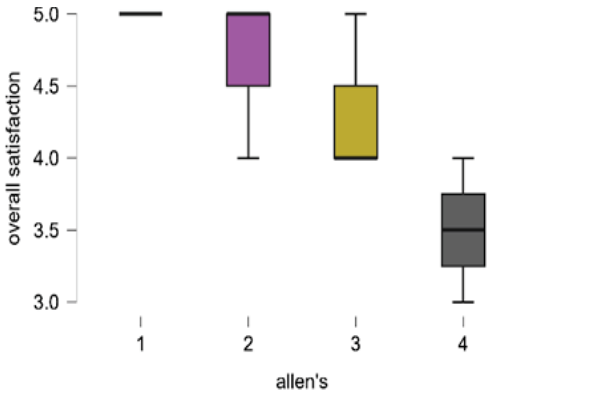


**Figure 3. Overall satisfaction after healing according to the injury severity**

These results parallel Lou et al, who reported 7.6/10 satisfaction using semi-occlusive dressings.[3] However, nail complications (46% hook nail, 15.4% splitting) were more frequent than in prior studies, likely due to the predominance of Allen's III/IV injuries (69.2%) with bone exposure and germinal matrix involvement. Such complications, while manageable, highlight the need for preoperative counselling, particularly in severe injuries where distal phalanx instability may predispose to deformities.[6]

**Pain and Sensory Recovery:**
The low pain scores (1.30 ± 0.48) and minimal sensory impairment (1.23 ± 0.43) mirror findings from Kang et al and Lou et al, who attributed these outcomes to the moist wound environment maintained by semi-occlusive dressings, which reduce neuropathic pain and enhance nerve regeneration.[2,3,5] However, the absence of objective sensory testing (e.g., two-point discrimination) limits direct comparison with studies reporting quantifiable sensory recovery.[3] Future work should incorporate standardized sensory assessments to validate subjective reports. Also, these are early results so, detailed sensory assessment in future is warranted to note long term sensory recovery and nerve regeneration.

**Healing Duration and Practical Implications:**
The mean healing time (76 ± 12.51 days) exceeded durations reported in Asian studies (45–56 days).[2,3] It was potentially because they were using expensive occlusive dressings along with dermal substitutes Integra® or Pelnac® which helped in faster healing, whereas in our cohort we are using BTM along with cheaper, simple to use daily dressings with chlorhexidine impregnated paraffin gauze. Despite this, the protocol's simplicity—single-stage surgery, home-based dressings, and early mobilization—aligns with the priorities of Nepal's resource-constrained healthcare system. The avoidance of prolonged hospitalization and multiple surgical or microsurgical interventions reduces costs and aligns with patient preferences for minimal disruption.[4,9] Our study achieved high patient satisfaction, good sensory recovery, and favourable cosmetic outcomes, consistent with the key outcomes reported in other studies despite the longer duration of treatment.[2,3,13]

**Limitations and Future Directions**
This study's retrospective design, small sample size (n=9), and lack of a control group limit generalizability. The ideal control group would be toe to thumb transfer but the absence of control group was guided by multiple factors: the inherent drawbacks of surgical interventions, encouraging outcomes from conservative approaches in prior studies, and significant recruitment challenges due to patients' strong preferences for minimally invasive procedures.

The high complication rate in severe injuries underscores the need for larger prospective trials comparing BTM with traditional flaps or other substitutes (e.g., Integra®). Additionally, long-term follow-up is warranted to assess durability, tactile sensitivity, and nail growth stability as the absence of objective assessments like the two-point discrimination test, impacts the thorough evaluation of sensory outcomes and the ability to determine the treatment's long-term durability and efficacy. Mechanistic studies could optimize protocols—for instance, combining BTM with platelet-rich fibrin (PRF) to accelerate vascularization, as proposed by Saha.[13]

To overcome these limitations and further advanced minimalistic reconstruction of fingertip injuries using artificial dermis and other conservative measures, future research needs to be done focusing on conducting well-designed, randomized controlled trials comparing conservative treatments with surgical interventions. It should include standardized outcome measures and longer follow-up periods to assess various aspects such as long-term efficacy, durability, pain levels, and nerve recovery. Also, future research should also focus on comparing different dermal substitutes and dressing materials to determine the most effective combinations that can reduce treatment time while optimizing regenerative outcomes.

## Conclusion

In summary, the artificial dermal substitute (Novosorb® BTM) demonstrated robust efficacy in fingertip

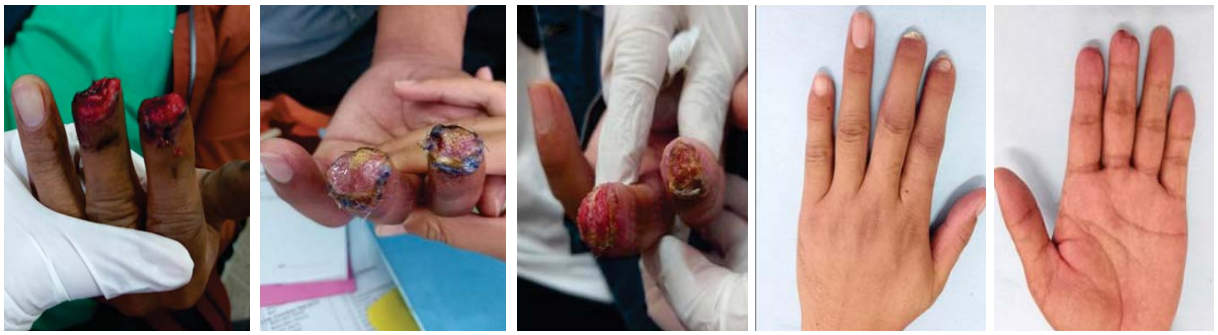

**Figure 4. sequences of events till the final outcome from the time of injury. a. time of injury b. after application of BTM c. after delamination d. and e. after complete healing**

reconstruction, with high patient satisfaction and functional recovery even in severe injuries. These findings advocate for its broader clinical adoption, particularly in resource-limited settings where complex surgical interventions are less feasible.

**Declarations**: Author has no financial interest or any other relationship with the manufacturer of any commercial product or providers of commercial services discussed in this study. Artificial dermal template, Biodegradable temporizing matrix (BTM) was procured by the patient from the vendor.

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