



Case report

Integrated management of diabetic foot ulcers (DFU) using a smartphone – A case report

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ABSTRACT

Introduction and importance: DFU care in India is expensive. Cost-effective integrated care approaches for diabetic wounds are a necessity.

Case presentation: A 54-year-old, type 2 diabetic male patient presented with bilateral Grade Four compound DFUs. He also had a peculiar pattern of progressive gangrenous lesions on both toes of his limbs. He was on medication for schizophrenia for 20 years. Doppler studies of both limbs revealed extensive atherosclerotic changes with no flow in the mid and very low flow in the distal left anterior tibial artery.

Clinical discussion: Along with Ayurvedic internal medication, in-home wound care was advised. Wound cleaning (shodhana) was done with Triphala decoction, gauze packing (ropana) with Gandhak druti, and application of Jatyadi oil (snehana) was done daily. The wound inspection was done using a smartphone. Out of six wounds, one infected wound measuring (8 cm–3 cm), one tunnelling wound measuring (9 cm–3 cm), one neuro-ischemic, Grade 4 planter wound, and other non-infected wounds healed within four to ten weeks. It has been observed that all the toes with progressive ischemic black spot on the proximal interphalangeal joint had deteriorated within 20–35 days.

Conclusion: Gandhak druti may be effective for progressive wounds. Jatyadi oil application to enhance micro-circulation as a preventive therapy should be investigated. Wound dressing guidelines recommended in Ayurveda classics can be followed at diabetic wound in-home care using a smartphone. Correlative timeframe of pathophysiological signs and anatomical site of dermatopathy patches can add value to the non-invasive micro-circulation detection tests.

1. Introduction

Diabetic foot ulcer (DFU) care in India is expensive. On average, a patient would require 5.7 years' worth of income to afford the cost of it [1]. Many times, lower- and middle-class people visit alternately the government and the private healthcare facilities, to curtail the cost of the treatment. Crowded outpatient departments in private hospitals do not welcome laborious wound care patients and long waits at overworked public hospitals discourage them from seeking hospital visits.

Neuro-ischemic wounds are at high risk for procedural-related complications. Around 20–25 % of critical limb ischemic diabetic patients die within one year. Schizophrenic diabetics on antipsychotic medication, have reduced lifespan by two decades [2]. Distal micro-vascular dysfunction impairs thermoregulation in diabetes.

Ayurvedic management for diabetes comprises thermoregulation and thermogenesis [3]. Ayurvedic pharmacopoeia comprises plant, animal, and mineral source documented formulations with preparation

instructions and dose recommendations. The effectiveness and safety of Ayurvedic medications for wound care have been confirmed by studies conducted at several Indian research institutes [4]. Additionally, the diabetic wound healing ability of many herbs when administered alone or in conjunction with antibiotics against multidrug-resistant bacteria was verified in clinical trials and animal-based investigations [5].

Multi-drug resistant infections, little use of systemic antibiotics on chronic wounds, and limited choice of topical medications intensify the challenge faced by clinicians. In chronic wounds, topical applications have greater bioavailability and better results than systemic medicines.

Cost-effective integrated models and effective preventive methods are essential for the management of diabetic wound care [6].

This case has been reported in line with the SCARE criteria [7].

2. Patient information

The family of a 53-year-old unemployed, uninsured, schizophrenic

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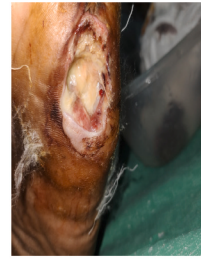
Left planter wound: three courses of antibiotics, two surgical debridement, saline wash and betadine application



A. 30/08/2022 (2nd week)



B. 19/09/2022 (3rd week)



C. 23/09/2022 (4th week)



D. 21/10/2022 (8th week)

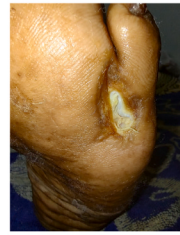
Along ayurvedic medication, Triphala decoction wash, Gandhak driti application and jatyadi oil massage



E. 21/10/2022 (day 1)



F. 7/11/2022 (3rd week)



G. 23/12/2022 (8th week)



H. 31/12/2022 (9th week)

Fig. 1. Left planter wound.

Right amputated toe wounds: four courses of antibiotics, saline wash and betadine application



A. 30/08/2022 (2nd week)



B. 17/09/2022 (3rd week)



C. 20/09/2022 (4th week)



D. 3/10/2022 (6th week)



E. 19/10/2022 (8th week)

Along ayurvedic medication, Triphala decoction wash, Gandhak driti application and Jatyadi oil massage



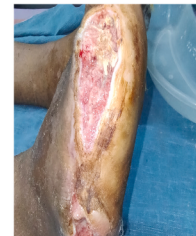
F. 1/11/2022 (2nd week)



G. 7/11/2022 (3rd week)



H. 16/11/2022 (4th week)



I. 29/12/2022 (9th week)



J. 4/01/2023 (10th week)

Fig. 2. Right amputated toe wounds.

male patient visited for unhealing diabetic wounds and fluctuating blood sugar levels with the hope of reducing the levels of amputation. The patient was adamant about hospitalization.

The patient had developed bilateral sores due to ill-fitted footwear that progressed into ischemic and neuro-ischemic ulcers in eight weeks (Figs. 1-A and 2-A). The family opted to amputate the 5th right toe at the government hospital (Fig. 2-B-C). Travelling and waiting at the government hospital was not cheap due to the work leaves of family

members. Eventually, the patient visited the private hospital whenever needed to amputate the gangrenous toes.

He had a sedentary lifestyle with a history of smoking for 30 years. He was susceptible to cool weather and had pins and needle sensations for 3–4 years. After each hospital dressing, he complained of a fungal infection in the interdigital areas of his foot (Fig. 5-B-1). He used to be drowsy until midday due to antipsychotic medication; otherwise, he was active and cooperative. His mother was diabetic and passed away from a

Table 1
Timeline.

Date	Clinical events	Intervention and outcomes
Before Ayurvedic intervention		
30/08/22	Bilateral plantar sores were noticed. The patient was asked not to walk around in the house.	Betadine application.
3/09/22	Bilateral sole debridement.	Augmentin (625 mg) BD 5 days
12/09/22	Bilateral surgical wound debridement was done in the private hospital, right 5th toe discolouration.	Taxim-O (200 mg) BD 5 days
14/09/22	Admitted to the public hospital for amputation.	Inj. Piptaz 4.5 g TDS 4 days
17/09/22	Discharged due to the unavailability of the anaesthetist.	
17/09/22–18/09/22	Admitted to the private hospital at night and discharged in the morning due to high cost.	Inj. Piptaz 4.5 g TDS, Inj. Dalacin 600 mg BD, Chymoral forte TDS
20/09/22	Right 5th toe was amputated in the OPD of the public hospital.	Augmentin (625 mg) TDS, PCM 500 mg for 7 days.
13/10/22	Right 4th toe amputated	Faropem 1 BD for 5 days, Celin 500 BD for 15 days, Silvrex gel
After Ayurvedic intervention		
22/10/22	Day 1 of Ayurvedic dressing.	Madhumeha kusumakar 250 mg OD, Triphala Guggul 500 mg BD, Jatyadi oil for dressing.
1/11/22	Frequent chills, intolerance to cold.	Asthimajjapachak 500 mg BD ^a
5/11/22	Gandhak druti consumption started with two drops and increased to five drops.	Gandhak druti 5 drops OD. And for wound dressing ^a
8/11/22	Right 3rd toe amputated	Bactrim DS 1 BD, Celin 500 BD for 10 days
	Arterial colour Doppler-Extensive atherosclerotic changes throughout both lower limbs.	No flow in mid-left ATA, and very low flow in distal left ATA.
19/11/22	Left 4th toe amputated	Faropem ER 300 mg 1 BD for 5 days, betadine application.
21/11/22	Fungal infection - interdigital spaces of feet	Gandhak druti application ^a
30/11/22	right 2nd toe amputation	Bactrim DS 10 days
3/12/22	Drainage point made by the surgeon. Green pus after the hospital visit.	Kaishore Guggul 500 mg BD ^a
3rd–6th Dec.	Drainage inflammation, malodor–blackened skin, bitter taste in the mouth (katu asyata)	Gandhak druti ribbon gauze packing ^a
27/12/22	The lateral wound was surgically opened.	Bactrim Ds BD, Celin 500 mg for 10 days
3/01/23–15/01/23	Green colour pus, from the lateral wound	Ayu dressing ^a Pus stopped
19/01/23	Bleeding from all the wounds	The endocrinologist stopped Ecosprin for 5 days, Ayurvedic dressing ^a
20/01/23	The bleeding stopped, the wound colour changed to pink, but increased white exudation from the right big toe tunnel wound	Ayurvedic dressing ^a
9/02/22	The family was advised to admit the patient to the hospital.	Increased exudation from the right big toe.
13/02/22	Surgical debridement of the right big toe at the private hospital.	Ayurvedic medicines and dressing stopped.

^a Along with ayurvedic medication: Madhumeha Kusumakar, Gandhak druti, Kaishor guggul, Triphala guggul, and Asthi-majjapachak yoga.
Ayurvedic medication was discontinued during each course of antibiotics, due to the surgeon's disapproval.

myocardial infarction.

2.1. Clinical findings

On physical examination, the skin of both legs was dry, and scaly,

with loss of hair and multiple hyper and hypo-pigmented spots on both shins and soles. The toenails were brittle and yellowish. The right foot had an infected full-thickness wound at the 5th and 4th toe amputation site (Fig. 2-E). A deep, painless plantar ulcer (Wagner classification Grade 4) was present on the left 5th metatarsophalangeal joint (Fig. 1-E-F). Active lesions were observed on the lateral proximal interphalangeal joints of the 2nd and 3rd right toe (Fig. 2-F) and 5th, 4th and 3rd left toe (Fig. 5-A) The left 5th toe also has it on the medial aspect (Fig. 5-B). The brown spot at the Right deep planter transverse arch was painful. The toe with ischemic black spots on the lateral proximal interphalangeal joint was noticed to be deteriorated within 20–40 days (Fig. 2 D to H, Right 3rd toe).

Medication history: He was on regular medication: T Queliapine 100 mg HS, T Respiridone 4 mg HS, Benzhexol HS, Zincovit OD, Trental 200 BD, T Ecosprin 75 mg OD, T. Stiloz 50 BDS, and T. Livogen OD Table 1.

3. Diagnosis with clinical reasoning

Physical signs and Doppler studies confirmed multilevel peripheral artery disease with acute progressive distal ischemia. Medication history, dermatopathy, acute ischemia, leukocytosis, drug resistance, and advancing anaemia were the indicators of DFU severity.

Ayurveda diagnosis: dushta vrana, prameha, rasa, rakta, and mamsa dhatu dushti, pranabheeruta, bala and ojakshaya were the indicators of krichchhrasadyata (intractable condition) [8].

3.1. Dressing of the wound

Triphala decoction was used for wound cleaning (shodhana) followed by Gandhak druti gauze packing (ropana). Jatyadi oil was applied (snehana) to the rest foot. Gandhak druti was applied to the toe webs to treat fungal infection. Right foot infected wounds and left planter wound were dressed loosely. Tunnel wounds were gently packed with ribbon gauze soaked in Gandhak druti (Fig. 3-D-F, 2-J). Application of leeches was avoided as any trauma, including surgical drainage, resulted in rapid tissue loss (Fig. 1-D, 3-B-C, 4-D).

4. Outcomes

Except for the deep tunnel wound of the Right big toe, all other wounds were healed within six to ten weeks (Table 2) (Fig. 3-D-F). In comparison to only contemporary management, the improved wound healing can be observed with integrated medication and exclusively with an ayurvedic dressing (Figs. 1, 2, 4 and 6). The left 5th toe medial ischemic wound was healed (Fig. 5-B, B-1). The black spots of the left big and 2nd toe faded without recurrence in 60 days (Fig. 5-C, C-1, and D, D-1). Out of six toes, only 3rd left toe was auto-amputated at the proximal interphalangeal joint (Fig. 5-C-1). Despite the necrosis of the remaining foot, the Right lateral healed wound never deteriorated (Fig. 6-A-1, B, D-1). Without any internal or intravenous treatment, wound granulation was an unanticipated result of the Ayurvedic dressing for the end-of-life patient (Fig. 6- D-1-2-3).

4.1. Follow-up

As told by the relatives, after surgical debridement of the right big toe in the private hospital, trans metatarsal amputation was done in the public hospital. The patient was happy that his leg was saved. But cardiac arrest after the surgery elongated his hospital stay. A thyroid cyst was also found in the USG. The physicians recommended below the knee amputation, whenever he would be fit to undergo the procedure. As his health deteriorated, he wished to spend his end-of-life days at home. The family took on-demand discharge after 19 days of hospitalization. They continued Ayurvedic dressing at home (Fig. 6-D-1-2-3). The patient died at home after 10 days.

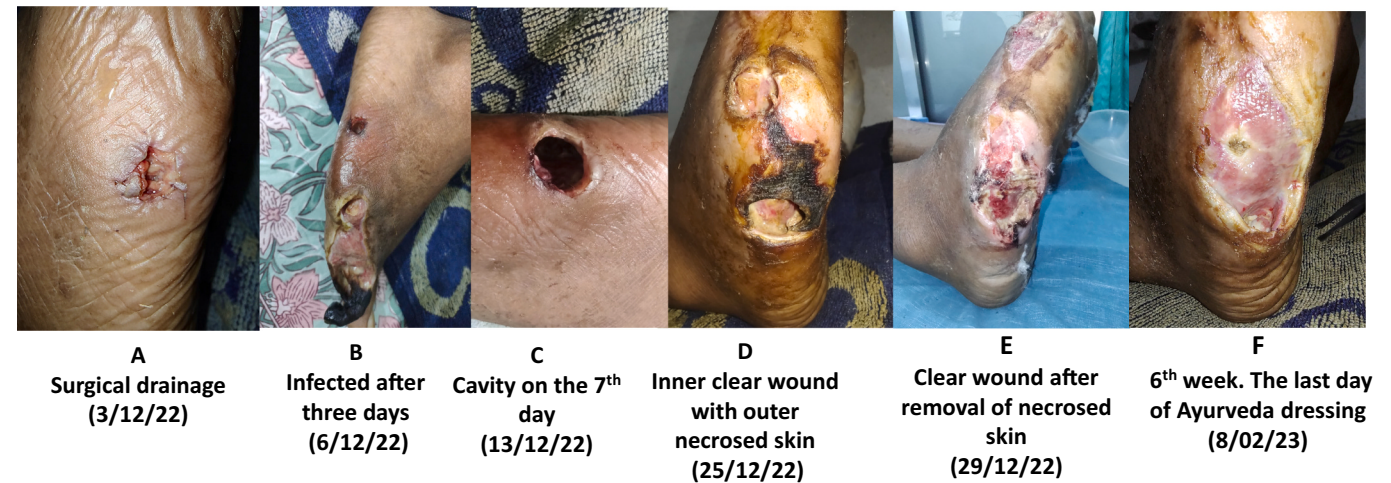


Fig. 3. Healing of right lateral surgical drainage wound (right big toe at 12 o'clock position).

Table 2
Characteristic and prognosis of diabetic foot ulcers.

Wound site	Left foot planter ulcer (Fig. 1)	Left 4th and 3rd toe amputation site. (Fig. 4)	Right 5th and 4th toe amputation site (Fig. 2)	Right 3rd and 2nd toe amputation site (Fig. 2)	Right big toe (Fig. 1)	Right lateral surgical sinus wound (Fig. 3)
Wound age (days) on the first day of the Ayurveda dressing	55	4 and 1	32 and 9	2 and 1	1	4
Grade (Wagner classification)	4	4	4	4	3	3
Edge of wound on first day of dressing	White, elevated Fig. 1-D-E	White and Elevated Fig. 4-A-D	Blackened, dry, hard Fig. 2-D-E	Pink Fig. 2-H-I	Elevated Fig. 2-J	Red, rolled Fig. 3-C
Exudate type and amount	Serous Moderate	Serous Mild	White bloody	Serous Mild	White High	Green High
Exudation start date	15/09/22	–	12/12/2022 From the cavity at 5th toe	–	9/01/2023	3/01/2023
Exudation end date	4/12/22	–	10/01/23	–	12/02/2023	15/01/2023
Pain on first day of dressing	No sensation	Mild pain	Painful	Mild pain	Deep pain	Very painful
Oedema on the first day of Ayurveda dressing	Absent	Mild	Peripheral tissue oedema at 5th toe amputation site Fig. 2-E	Mild	Mild	Peripheral tissue oedema Fig. 3-B
Odour	Odourless	Odourless	Malodour	Odourless	Malodour	Malodour
Start date	–	–	10/12/2022	–	9/01/2023	8/12/23
End date	–	–	23/12/2022	–	10/01/23	10/01/23
Slough on first day of dressing	Mild	Moderate	High	Moderate	Mild	High
Granulation (week)	2nd week Fig. 1-F	1st week	2nd week Fig. 2-F	1st week Fig. 2-H-I	Necrosed	3rd week Fig. 3-D
Epithelialization/shrinking	4th week Fig. 1-G	2nd week Fig. 5-B-C	4th week Fig. 2-H	3rd toe–5th week 4th toe–3rd week Fig. 2-J	Necrosed 12/12/23	5th week
Complete closure of wound day	9th week Fig. 1-H	4th toe:6th week Fig. 4-C and 3rd toe: 8th week	4th toe–8th week and 5th toe–9th week Fig. 2-I	3rd toe–7th week	–	Healed without epithelialization 8th week Fig. 3-F
Wound healing duration in weeks	8th week	6th and 7th week after amputation	7th and 8th week after amputation	3rd toe–5th week and 2nd toe–3rd week after amputation	–	5th week after opening of the wound

4.2. Discussion

The key elements of treating diabetic foot ulcers include offloading, frequent wound debridement, moisture control, wound dressing, glycemic control, and infection control. Herbo metallic formulation of Madhumeha Kusumakar formulation contains Swarna Bhasma that has a restorative effect in ischemia, Zinc-based Yashad Bhasma, Mamajjaka, *Curcuma longa* and *Tinospora cordifolia* effectively control blood sugar and reduce oxidative stress [4,5,9–11]. Wound cleaning with Thriphala decoction helps in natural debridement [12,13]. Oil bases of Gandhak druti and Jatyadi oil control the moisture and protects the skin from infections [4,14,15]. The bioactive compounds in the herbal formulation

of Asthimajjapachak control the infection. Commiphora mukul the main ingredient of Triphala and Kaishor Guggul has anti-lipidemic properties [13,16]. Both medicines have anti-infective and tissue regenerative properties.

In-home care reduces anxiety and encourages treatment adherence of the patient. The use of smartphones in wound care enables physicians close monitoring and assists them in making informed, personalized decisions [17]. Ayurveda classics recommend seasonally appropriate dressing frequency and timing of application for accelerated healing. Like, twice-a-day wound dressing is indicated in the autumn. Wound dressing Ayurveda guidelines can be easily followed with in-home diabetic wound care using a smartphone.

Healing of left 4th toe wound exclusively with ayurveda dressing.



Healing of left 3rd toe wound exclusively with ayurveda dressing.



Fig. 4. Healing of left 3rd and 4th toe wound exclusively with Ayurveda dressing.



Fig. 5. Blackish marks on the lateral aspect of proximal interphalangeal joints.

4.3. Observations

The diameter of the lateral proper digital arteries (0.66–0.99 mm) is half of the diameter of the medial proper digital arteries (1.2–1.26 mm), which might have been the apt reason for the initial emergence of an

ischemic brown spot on the lateral side of every proximal interphalangeal joint of bilateral toes. It has been observed that waiting for autoamputation accelerated tissue loss that led to complex tunnel wounds at the right 5th and 2nd toe (Fig. 2-H-J). Out of the two infected deep tunnel wounds, the right lateral tunnel wound was healed (Fig. 2-I-

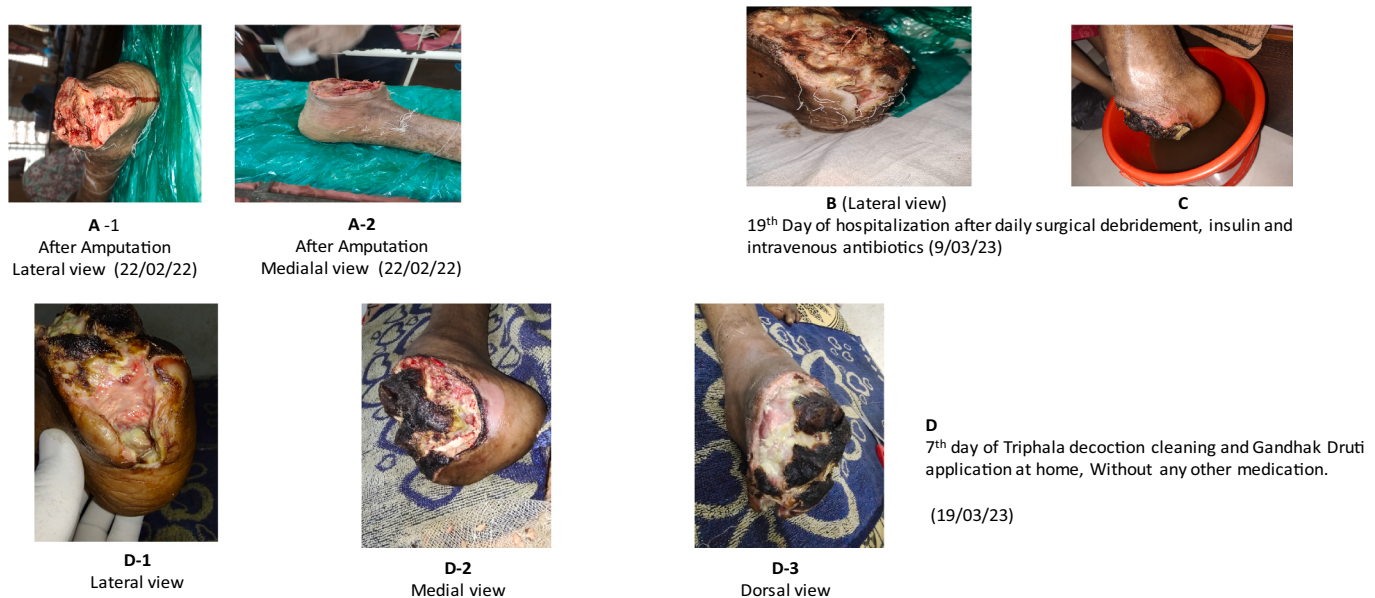


Fig. 6. Follow-up.

J). The other wound at the base of the right big toe was connected to the brown painful planter spots, signifying the deep ischemia (Fig. 2-B). The lateral right foot's soreness and inflammation did not go down after surgical drainage; instead, it created another necrosed wound to deal with (Fig. 3-A-B-C).

4.4. Conclusion

Gandhak druti application may be effective for progressive wounds. Jatyadi oil application as a preventive therapy to enhance microcirculation should be investigated. With smartphone-assisted diabetic wound at-home care, wound dressing recommendations found in classic Ayurvedic texts can be adhered to. Correlative timeframe of pathophysiological signs and anatomical site of dermopathy patches can add value to the non-invasive microcirculation detection tests.

Consent

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Ethical approval

In a private practice informed consent of the patient is an ethical and legal proof for a physician who is not attached to any institution. Hence, ethical approval was not obtained.

The family of this schizophrenic patient was already taking care of him. Hence, an informed consent from his son was taken.

Preparation of decoction at home for wound cleaning was the part of the consent suggesting that the family opted for the treatment by choice. The patient was also cooperative for the same. Please note that these points are mentioned in the manuscript.

Funding

None.

Author contribution

All portions of the work are my original creations for which I have obtained all necessary consents for the use, distribution, and publication of such materials.

Guarantor

Dr. Sangeeta Jadhav.

Conflict of interest statement

No conflicts of interest exist.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijscr.2024.110012>.

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