

Physical Rehabilitation in Leprosy

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Introduction

This chapter highlights the significance of and need for physical rehabilitation in the prevention and management of impairments caused by leprosy. The information provided will help health care workers identify and understand the vital components required to rehabilitate leprosy-affected patients. In addition, recent technological advances in the field of rehabilitation and their use in preventing impairments are discussed in detail, enabling readers to enhance the functionality of existing devices in a cost-effective manner.

The primary goal of physical rehabilitation is to restore an individual to maximal physical well-being. However, rehabilitation is not limited to the physical but rather extends to the whole individual. To achieve such holistic rehabilitation, the primary goal should be reversing the physical impairments caused by leprosy, while the secondary goal should be customizing lifestyle modifications for the individual patients, their families, and their communities. Rehabilitation of a leprosy-affected individual should start at diagnosis and continue until the patient is able to return to an active normal life.

The physical rehabilitation of the leprosy-affected can be classified into the following categories: (1) Identifying nerve function impairment (NFI), (2) Monitoring impairments, and (3) Preventing further deterioration of impairments.

Identifying Nerve Function Impairment

NEUROPATHY IN LEPROSY

The consensus report of the 2007 international workshop on neuropathology in leprosy (see Chapter 9.1) identifies three mechanisms of nerve damage (see Chapter 9.2). Nerve damage could be due to the direct effects of the bacilli, immune-mediated and inflammatory responses, or mechanical trauma and intercellular edema (1). The superficial nerve trunks are commonly affected in neuritis, as the lower temperature in proximal areas allows sustained growth of the leprosy bacilli (2). (See Chapter 2.5 for a detailed discussion of the neural manifestations of leprosy.)

Assessment of neuritis

Patients presenting with neuritis should be regularly monitored for nerve function impairment (NFI). For effective monitoring, assessments need to be carried out regularly on patients. Ideally, such assessments are done

1. Before the start of anti-leprosy treatment
2. During anti-leprosy treatment (every month when patient comes in for multi-drug therapy [MDT])
3. While on a steroid course for reversing the impairment (every fourteen days)
4. At the end of anti-leprosy treatment

Primary impairments in leprosy occur as a direct result of damage to the nerves. The various types of primary impairments may be defined as a loss or abnormality of a body part (structure), a body function (physiological function), or a mental function (psychological function). A list of the primary impairments that commonly occur in leprosy, along with the nerve that is damaged, is provided in Table 1.

Nerve palpation

Palpation of the nerves needs to be performed to examine the size and tenderness of the nerves. The pulp of the health worker's fingers is used to palpate the nerve along its course. While palpating, the health worker needs to look for signs of tenderness, thickening, and abscess. Nerves that are routinely palpated during diagnosis and follow up of the disease are the greater auricular, ulnar, median, radial, common peroneal, and posterior tibial nerves (1).

TABLE 1 Primary impairments in leprosy

Nerve Damaged	Primary Impairment
Face	
Facial Nerve	Lagophthalmos
Trigeminal nerve	Corneal anesthesia
Hand	
Ulnar nerve	Ulnar clawing
Median nerve	Ape thumb deformity
Ulnar and Median Nerve	Palmar anesthesia
Ulnar and Median Nerve	Total clawing
Radial nerve	Wrist drop / Finger drop
Feet	
Lateral popliteal nerve	Foot drop
Posterior tibial nerve	Claw toes
Posterior tibial nerve	Plantar anesthesia

Sensory testing

In leprosy, sensory loss can include all of the different modalities, including pain, temperature, light touch, and pressure (2). Sensory testing is commonly performed with Semmes-Weinstein graded monofilaments (3, 4, 5, 6), allowing health workers to diagnose and monitor the progress of the disease. The generally accepted monofilament for testing the threshold of protective sensation is 2 gm for the hand and 10 gm for the foot (7, 8). Sensory testing can be further refined at referral centers using graded monofilaments. Under field conditions, a ballpoint pen is sometimes used to test sensation. Studies have shown that testing with a ballpoint pen might be capable of detecting the deterioration of sensation but might not be able to detect minor changes in the deterioration of sensation (9, 10, 11).

Testing to determine the presence of sensation is performed on ten points in the hand (Figure 1A). The thenar eminence, thumb, and index fingers are tested to check the median nerve function. The little finger as well as the hypothenar eminence are tested to check the ulnar nerve function. Similarly, ten points in the foot are tested to diagnose damage to the posterior tibial nerve (Figure 1B). The test sites include the pressure-prone forefoot area, the lateral border of the foot, and the heel.

Motor testing

Motor testing is the grading of muscle power. Muscle power is graded using the Medical Research Council (MRC) scale used in research institutions and referral hospitals (see Table 2; Table 6).

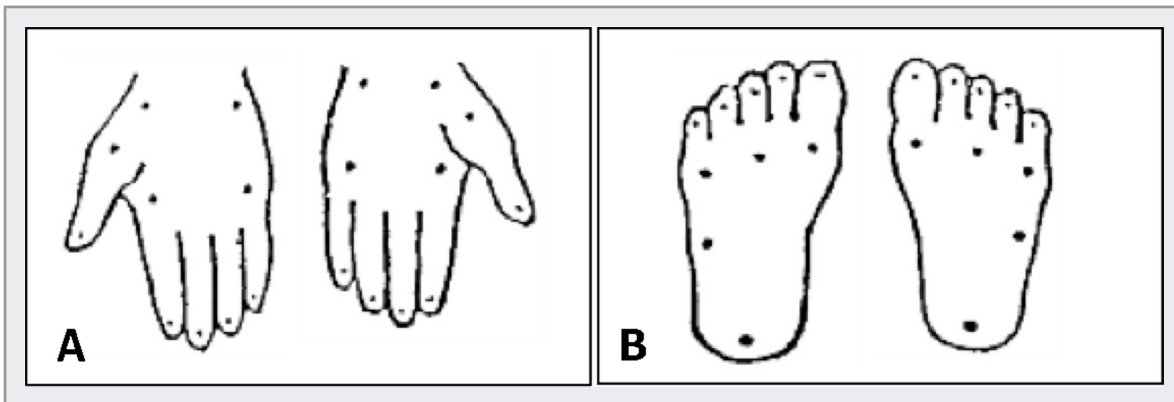


FIG 1 Points for Assessing Sensation in the Hands and Feet.

In a field setting, the health worker may categorize the muscle power using a simple scale based on whether the muscle is Strong 'S', Weak 'W', or Paralyzed 'P'. If the muscle is completely paralyzed, then it is graded as paralyzed 'P'. If the patient is able to perform minimal movement or function against minimal resistance, then the muscle is graded as weak 'W'. If the patient is able to perform full movement against gravity and is able to withstand maximal pressure, then the muscle is graded as strong 'S'.

TABLE 2 MRC grading scale grades muscles from 0–5

Grade 0 – No contraction
Grade 1 – Perceptible flicker of contraction over the muscle
Grade 2 – Visible movement at the joint but not full range
Grade 3 – Full range of movement against gravity
Grade 4 – Strong contraction against movement but not normal
Grade 5 – Normal

Facial nerve. The orbiculari oculi (see Chapter 3.1) are tested to diagnose NFI of the facial nerve. The patient is asked to close the eye as if asleep. If a gap is present, it is measured using a common ruler (scale) in millimeters. If a gap is not present, the patient is asked to close the eyes tightly. The examiner then gently exerts pressure and tries to separate the eyelid. The muscle power is graded as per the strength of the muscle. A demonstration of facial assessment is available at the following link: <https://www.youtube.com/watch?v=fVEu8LSKpEQ>

Ulnar nerve. The abductor digiti minimi muscle is tested to diagnose NFI of the ulnar nerve. This muscle is tested with the patient's hand placed flat and the palm facing up. When the little finger is moved out, resistance is applied from the medical aspect in the proximal segment of the finger. The muscle is graded based on the presence or absence of muscle power, according to the MRC scale.

Median nerve. The abductor pollicis brevis (APB) as well as the opponens pollicis muscle are tested to diagnose NFI of the median nerve. APB is tested with the patient's hand placed flat and the palm facing up. The patient is instructed to use the thumb to touch the opposing fingers. Resistance is applied over the first metacarpal area. The muscle is graded based on the presence or absence of muscle power, according to the MRC scale.

Radial nerve. The wrist extensors are tested together to diagnose NFI of the radial nerve. The patient is told to extend the wrist from the neutral position. Resistance can be applied over the dorsum, against the movement. The muscle is graded based on the presence or absence of muscle power, according to the MRC scale. A demonstration of hand assessment is available at the following link: <https://www.youtube.com/watch?v=GUnZnYM75Po>

Lateral popliteal nerve. The ankle dorsiflexors are tested together to diagnose NFI of the lateral popliteal nerve. The patient is seated with the foot held by the examiner. The patient is then told to dorsiflex the foot. Resistance can be applied over the dorsum of the foot, against the movement. The muscle is graded based on the presence or absence of muscle power, according to the MRC scale. A demonstration of foot assessment is available at the following link: <https://www.youtube.com/watch?v=6k0Qjv7gvLY>

If the muscles are paralyzed because of nerve damage, they can be exercised passively. If the muscles are only weak, not paralyzed, active exercises are recommended to strengthen the muscles. Electrical stimulation can also be applied to weak or paralyzed muscles to activate the neuromuscular junction. The muscle as well as the nerve can be stimulated to obtain the desired effect. Exercises and electrical stimulation of muscles can help in maintaining muscle tone and preventing atrophy.

PRIMARY IMPAIRMENTS

Lagophthalmos and corneal anesthesia. NFI of the facial nerve may lead to the paralysis of the orbicularis oculi muscle (see Chapter 3.1). The affected patient may lose the ability to close the eye, exposing the conjunctiva and cornea (Figure 2). The sensory branch of the trigeminal nerve supplies the conjunctiva, cornea, and part of the facial skin. Impairment of the trigeminal nerve can cause a loss of sensation over the cornea, and corneal anesthesia can lead to the loss of the blink reflex.

Clawing of fingers. NFI of the ulnar nerve leads to paralysis of the third and fourth lumbricals. All of the interossei muscles are also paralyzed. The paralysis causes the little and ring fingers to claw. Clawing of the medial two fingers is referred to as an "ulnar claw". Involvement of both the ulnar and median nerves causes total clawing (Figure 3), which happens when all four lumbricals and the interossei are paralyzed. The paralysis of muscles is accompanied by metacarpophalangeal (MCP) joints extension, which is caused by extensor digitorum communis and extensor indicis (the finger extensors). Passive insufficiency causes the interphalangeal joints to become flexed,



FIG 2 Lagophthalmus (Facial Nerve Paralysis).



FIG 3 Clawing of Fingers (Ulnar Nerve Paralysis).



FIG 4 Adducted Thumb (Median Nerve Paralysis).

leaving the fingers clawed. The loss of the hypothenar muscles in ulnar nerve paralysis reverses the distal palmar arch, leading to the loss of the grasp function.

Ape thumb deformity. NFI of the median nerve leads to thenar muscle paralysis. Opposition and abduction movement of the thumb are lost, leading to the characteristic 'ape thumb deformity' (Figure 4). In isolated median nerve palsy, the abductor brevis and the opponens are non-functional with flexor pollicis brevis partially supplied by the ulnar nerve. Thus, the pinch function is not affected in an isolated median nerve paralysis. However, pinching is affected in a combined ulnar-median paralysis and is commonly seen in leprosy-affected patients.

Wrist drop. NFI of the radial nerve rarely occurs in isolation. Instead, the radial nerve is usually damaged along with the median and ulnar nerves, leading to triple nerve paralysis. The clawing of fingers is not significantly visible in a triple nerve paralysis, as the extensors are not capable of hyperextending the MCP joints. The power grip is usually lost in radial nerve palsy. This loss occurs because the flexors of the fingers work in a shortened position and the grasp functions are restricted by the loss of the finger extensors.

Sensory loss over palm. When the sensory fibers of the ulnar nerve are damaged, loss of sensation over the palm is limited to the ring and little fingers. The loss of sensation could cover the lateral aspect of the hand, if the median nerve is affected. If both of these nerves are damaged, the palm usually loses sensation completely.

Foot drop. NFI of the deep branch of the lateral popliteal (common peroneal) nerve leads to paralysis of the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius muscles. The peroneus longus and brevis are affected if the superficial branch is affected, leading to the loss of ankle dorsiflexion, foot eversion, and toe extension. An inability to dorsiflex the foot leads to foot drop deformity (Figure 5A).

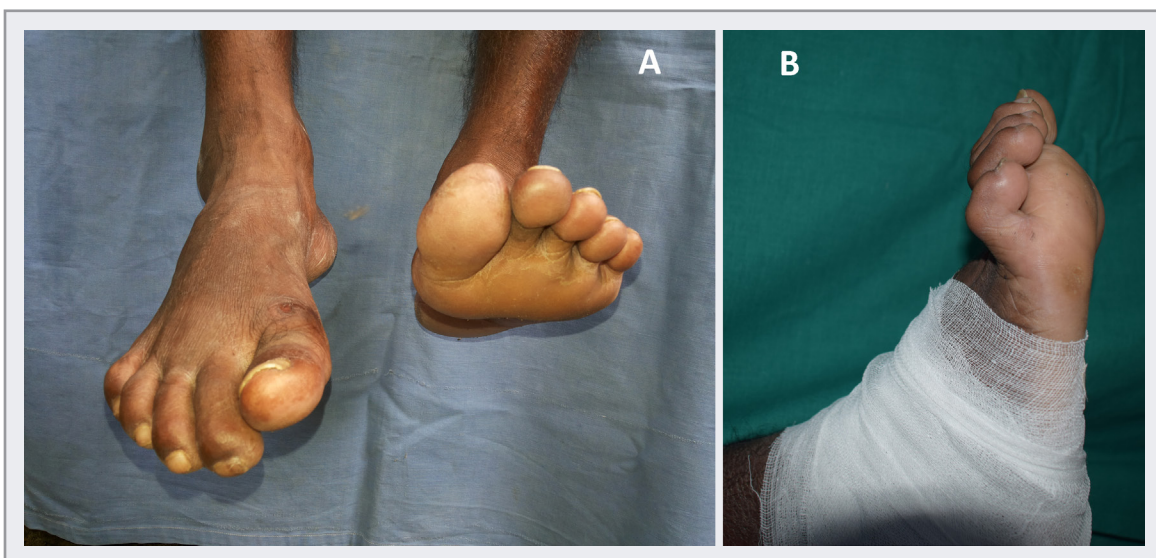


FIG 5 Foot Impairments.

- A. Foot drop (lateral popliteal nerve paralysis)**
- B. Claw toes (posterior tibial nerve paralysis)**

Claw toes. NFI of the posterior tibial nerve causes the intrinsic muscles of the foot to be paralyzed. The extensors of the metatarsophalangeal joint pull the joint into extension which, coupled with the flexion of the toes, leads to clawing of the toes (Figure 5B).

Plantar anesthesia. Loss of sensation over the plantar aspect of the foot occurs due to NFI of the posterior tibial nerve. Based on the extent of damage to the nerve, there could be a partial or complete loss of sensation.

Autonomic dysfunction. NFI of any of the nerves affected in leprosy may cause loss of sweating over the areas supplied by the nerve, leading to dry skin.

SECONDARY IMPAIRMENTS

Neglecting the primary impairments can result in secondary impairments. A list of the secondary impairments commonly occurring in leprosy is provided in Table 3.

TABLE 3 Secondary impairments in leprosy

Secondary Impairment
Stiff joints
Joint contractures
Ulcers
Shortening
Disintegration of the bones
Exposure keratitis, corneal ulcer, and corneal opacity

Stiff joints. An inability to move a joint through its full available range leads to stiff joints. Muscle paralysis, which is a primary impairment, prevents a patient from actively moving the joint. If the joints are not passively moved through the full range of motion available, the lack of movement can cause stiff joints.

Joint contractures. Stiff joints need to be stretched to improve mobility. If stiff joints are ignored, contractures can develop. Common contractures that occur in leprosy are interphalangeal joint contracture, which results when claw hands are ignored. Thumb web contracture develops when ape thumb deformity is ignored. Tendo-achilles contracture develops when foot drop is ignored and no exercises are performed.

Ulcers. Ulcers develop because of skin breakdown over the palm of the hand or plantar aspect of the foot. Sensory loss, deformity, and dryness of skin can be the underlying causes of ulceration. Skin breakdown may occur due to shearing stress, continuous pressure, thermal injuries, or sharp injuries.

Shortening. Shortening can occur due to the loss of soft tissue and bone. Repeated ulceration can lead to such shortening of the toes and fingers. Surgical removal of dead tissue, subsequent to an ulcer, may also cause shortening. (See Chapter 2.4 for additional information.)

Joint disintegration. In leprosy, hyperemia, in association with chronic ulceration and infection of the bone, leads to osteopenia of the bone. Osteopenia predisposes the bones to fractures, which further exacerbate hyperemia, which worsens the cycle of destruction. “Neurological Bone Disorganization” is usually accompanied by painlessness and warmth in the joint area. A boggy swelling in the joint can occur and crepitus can be felt when the joint is gently moved. Such swelling and instability in a joint is also termed neuroarthropathy. Patients with neuropathy should be taught to suspect and treat early joint disintegration by looking for “hot spots” in swollen joints. (See Chapter 4.2 for additional information.)

Exposure keratitis, corneal ulcer, and corneal opacity. In an eye with lagophthalmos or corneal anesthesia, the patient does not blink. Exposure of the eye to dust can cause exposure keratitis. A corneal ulcer can occur if a dry eye is rubbed, which, if left untreated, may lead to corneal opacity as well as blindness. (The consequences of these eye impairments have been further elaborated in Chapter 3.1.)

Other impairments. Impairments in lepromatous leprosy occur because of the direct infiltration of the bacteria into the skin. This infiltration can cause impairments such as leonine facies, pendulous earlobes, madarosis, gynecomastia, and nose collapse. The major consequences of these changes are cosmetic and often result in stigma. (See Chapter 4.5 for a discussion of the stigma experienced by leprosy patients.)

Monitoring Impairments

GRADING IMPAIRMENTS

WHO grading

The progression of an impairment over a period of time can be effectively monitored using the World Health Organization (WHO) disability grading system. The WHO system can also be utilized as an epidemiological indicator, which helps to effectively report on the impairment status in a specified geographical area. Studies have shown that the intra- and inter-observer reliability of the WHO grading system is good when performed by health workers with minimal training (12, 13). These operational guidelines have improved the understanding and definition of impairments, as they help health workers grade impairments effectively (14).

The WHO grading system has separate components for hands, feet, and eyes. Therefore, hands, feet, and eyes are graded separately based on the impairments present. The scale has a maximum score of two and a minimum score of zero, as shown in Tables 4A and 4B.

TABLE 4A WHO disability grading for hands and feet

WHO Grade for Hands and Feet	
0	Absence of anesthesia and absence of any visible impairments in the hands and feet
1	Presence of anesthesia and absence of visible impairments in the hands and feet
2	Presence of visible impairment in the hands and/or feet

TABLE 4B WHO disability grading for eyes

WHO Grade for Eyes	
0	No eye problems due to leprosy and no visual loss
1	Eye problems due to leprosy but vision not affected (Vision is 6/60 or better; can count finger at 6 meters)
2	Severe impairment to vision (Vision is worse than 6/60; cannot count fingers at 6 meters)

The WHO grading system has been a very effective and widely used tool in grading impairments and assessing the effectiveness of control programs for identifying patients earlier in the course of the disease. However, it has not been as useful in measuring improvements in individual patients. A recently conducted study using the Delphi technique has helped to clarify the WHO system and to develop simple guidelines for health workers based on the consensus of the panel of experts (15).

EHF scoring

The Eye, Hand, and Feet (EHF) scoring system was developed to more readily document the progression of impairments in individual patients. Studies have shown that the EHF score is very sensitive in identifying impairments from leprosy (16, 17). The EHF score calculates the sum of the individual WHO scores for each eye, hand, and foot. For example, the maximum EHF score in a patient with grade 2 disabilities in both eyes, both hands, and both feet would be 12, or the sum of the maximum score of 2 for each eye, hand, and foot.

The examples in Tables 5A and 5B demonstrate the sensitivity of the EHF tool in monitoring impairments in patients affected by leprosy. In the example, the improvement in the impairment status is well illustrated by the EHF scoring. The EHF score has improved from 9 in the pre-intervention phase to 6 in the post-intervention phase. However, the basic WHO score would not have been as informative, as the grade would have been “2” in both the pre- and post-intervention phases.

TABLE 5A Pre-intervention

	E		H		F		
	R	L	R	L	R	L	
0		0					
1			1				
2	2			2	2	2	EHF
	2	0	1	2	2	2	9
				WHO Score = 2			
				EHF Score = 9			

TABLE 5B Post-intervention

	E		H		F		
	R	L	R	L	R	L	
0		0	0				
1				1	1		
2	2					2	EHF
	2	0	0	1	1	2	6
				WHO Score = 2			
				EHF Score = 6			

ACTIVITY LIMITATIONS

Loss of manual dexterity. The paralysis of hand muscles causes a loss of manual dexterity. Multiple deformities, often seen in those affected by leprosy, will cause an extreme loss of manual dexterity (Figures 6A, 6B, 6C). Subjective and objective outcome measurement tools, such as the Michigan Outcome Questionnaire (18) and the Musculoskeletal Function Assessment (18, 19), have been developed to assess the functional outcomes of hand impairments. In leprosy, a tool with 20 questions, the SALSA (Screening of Activity Limitation and Safety Awareness Score), is commonly used to help identify patients' perceptions of their functional ability to use their hands, feet, and eyes (20, 21).

Locomotion limitations. The presence of foot deformities causes problems in locomotion. The patient may have gait abnormalities or may not be able to walk. Deformities such as foot drop can cause a high stepping gait, leading to postural abnormalities and imbalance. Foot drop and anesthesia further increase the risk of developing plantar ulcers.

Visual impairments. Visual impairments can lead to an inability to perform self-care, personally groom, or maintain good hygiene, as well as interfere with employment and many daily activities.

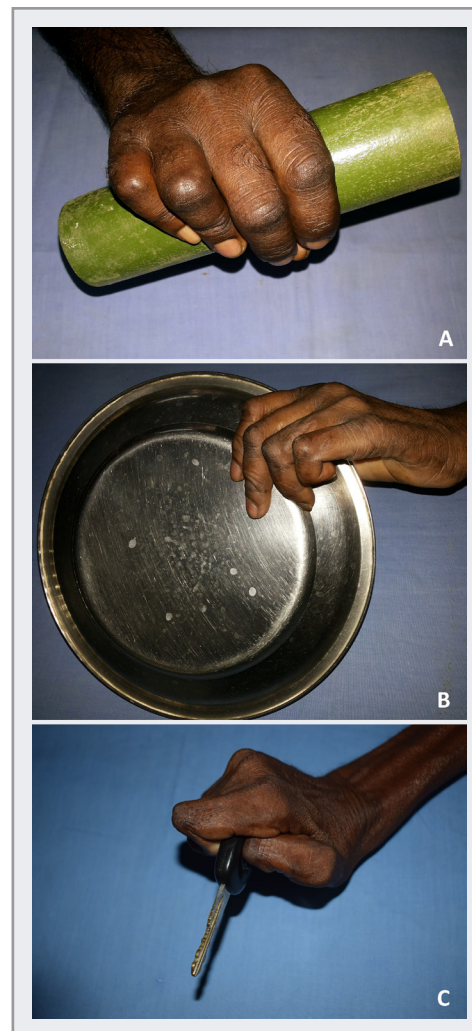


FIG 6 Loss of Manual Dexterity.

A & B Grasp functions

C Pinch functions

OCCUPATIONAL THERAPY

Leprosy may affect an individual's performance of the activities of daily living (ADL) as well as of work- and leisure-related activities. For example, an affected person may have trouble carrying out essential ADL tasks required for self-care and self-maintenance, such as personal hygiene, brushing, bathing, feeding, and dressing. The limitations experienced when performing these activities lead the person to depend on others and restrict his or her social participation. The goal of occupational therapy is to enhance or enable meaningful participation in the ADL and work- and leisure-related activities that are important to the clients served.

In the process of rehabilitation, an occupational therapist uses assistive technology/devices to compensate for the leprosy-affected person's impairments, with the goal of increasing, maintaining, or improving functional skills. Adaptive devices have been found to increase the affected person's sense of satisfaction and independence in carrying out routine activities and participating in social activities (22).

Assistive technology/devices. Assistive devices should be adapted to a client's daily routine and context. For example, mittens can be provided (gloves made of soft cloth) to protect anesthetic hands from heat-related injuries during cooking. Often, the tools used or suggested by clients are padded with soft materials to protect hands from pressure injuries, such as utensils, sickles, spades, hammers, screw drivers, and so on. For ADL, padding spoons, forks, toothbrushes, shaving razors, combs, etc., enhances the self-maintenance activity. Padding not only protects hands from pressure injuries but also enables better grip while using tools (23). Clients need to be trained on the use of adaptive devices in their daily routines to ensure that they use the tools.

Loss of digits on hands due to repeated injuries and absorption is a common complication in leprosy-affected people with long-term impairments. As a result, their functional abilities to perform their daily activities are compromised. Grip aids are a kind of adaptive device that is customized to enhance the ability of the hands to hold objects such as pens, spoons, shaving razors, etc. Modulan® material is commonly used to make custom grip aids (24). Aids such as cosmetic prostheses that use latex rubber for absorbed digits are simple and cost effective (25). However the effects of cosmetic prostheses need to be scientifically studied to understand their role in reducing stigma due to leprosy.

The assistive devices most commonly used to compensate for impairments caused by leprosy are shown in Table A1 (Appendix 1). Each device is listed with a picture, indications, and a brief description. Although adaptive devices improve a client's functional ability, level of self-esteem, sense of independence, and degree of social participation, they may invoke stigma when used outside the home environment (23). Therefore, appropriate counseling should be given in conjunction with the devices.

Special training. Along with the adaptive devices, special training can be offered to leprosy-affected individuals. For example, they can be taught compensation techniques for using anesthetic

hands in their daily routines. This training can be provided effectively in a group session. For cooking activities, clients can be taught how to cook while protecting their affected limbs. Initially, the therapist demonstrates the technique and then supervises as the client practices an actual cooking activity over multiple sessions. Special training can also be provided for different occupational groups, such as farmers, carpenters, mechanics, tailors, and so on.

Tendon transfer surgery. Motor impairments may lead to paralysis and compromise hand functions such as grasp, pinch, and prehension. The lost movements can be restored to some extent with tendon transfer surgeries. Unfortunately, not all paralyzed hands will benefit from tendon transfer procedures due to contractures, absorption of digits, availability of tendons to transfer, the client's ability to undergo a re-education process, and various other reasons. In these circumstances, the use of adaptive devices can facilitate the functional ability of the hand. As described above, padding tools used by the clients will enhance the grasp and, thereby, the functional ability of the hand.

Vocational and diversional activities. The occupational therapist uses vocational activities to divert as well as to enhance the skill level of clients. Individuals affected by leprosy often stay in hospitals for long periods of time to care for complications such as wounds, deformity corrections, and reactions. Activities such as greeting card making, candle making, carpentry, and tailoring can be used as diversional activities. These activities not only keep patients engaged during their hospital stays but also enhance the skills needed for their livelihoods (26).

COMMUNITY-BASED REHABILITATION

Institutionally based rehabilitation is an integral, key component in providing the holistic rehabilitation of a patient. However, health workers need to make a conscious effort to focus on the aspects of rehabilitation that will effectively integrate a leprosy-affected patient back into the community. (Chapter 4.4 provides further details on community-based rehabilitation for leprosy-affected individuals.)

Preventing Further Deterioration of Impairments

Some of the impairments in leprosy are irreversible because of late diagnosis, late treatment, and the severity of causative factors, as in reactions. Such impairments will persist and cannot be completely reversed. The goal of the rehabilitation team should be to prevent any new impairment or the worsening of a primary impairment to a secondary impairment.

EXERCISES

Muscle weakness of lesser duration will recover with appropriate exercise and a course of steroids. For paralysis of a longer duration, exercises might only help in maintaining the muscle tone and bulk. Table 6 gives a guideline on the exercises recommended for various grades of muscle strength.

TABLE 6 Exercise guidelines

MRC Grading	'S' 'W' 'P' Score	Exercise Prescription
0	'P' – Paralyzed	Passive Exercise
1	'W' – Weak	Active and Active Assisted
2		
3		
4		
5	'S' – Strong	Active Resisted

There are different types of exercises. The most commonly recommended are listed in Table A2 (Appendix 2).

SPLINTING

Splints are supportive devices that are primarily used to immobilize a part of the body. Splints are classified into dynamic splints and static splints. Static splints immobilize a joint so as to prevent movement in the area that is immobilized. Dynamic splints allow specific movements that help in maintaining some functions, while other areas are immobilized.

Most of the materials used to make splints are low cost, but comfortable, materials. Metal, bamboo, and coconut shells were commonly used in the past. Thermoplastics and plaster of Paris are now commonly used to make different kinds of splints.

Splints for neuritis

Ulnar neuritis slab. This splint is indicated in the case of acute ulnar neuritis, or when there is ulnar nerve tenderness. The purpose of the splint is to relieve pain and to provide rest and warmth to the affected nerve. The splint also helps support the weak and paralyzed muscles supplied by the nerve. It can also help to prevent contractures. The ulnar neuritis slab extends from the back of the elbow to the palmar crease, if the fingers are not included. The slab helps to maintain the elbow in flexion of about 60 degrees, providing adequate rest to the nerve.

Posterior slab / Functional foot slab. This splint is indicated for patients with posterior tibial neuritis or lateral popliteal neuritis, as well as for those with a swollen foot or leg caused by a reaction. Other indications include an infected or neuropathic foot. It is also used as a supportive device for patients with foot drop or tibialis anterior weakness. This splint is also indicated after reconstructive surgery to correct foot drop, helping to protect the transferred tendon, the tibialis posterior. The splint maintains the foot in the functional position, which allows damaged tissues to heal. The splint also helps to support the anterior foot muscles, prevents Tendo Achilles (TA) contracture, and enhances nerve healing. This splint extends from the mid-calf region to the tip of the toes.

Palmar slab / Anterior slab / Median neuritis slab. This splint is indicated for patients with median neuritis, whether or not muscle weakness exists. The purpose of the splint is to provide rest and warmth to the median nerve, allowing it to heal and regenerate. The splint also supports the weak muscles and helps prevent thumb web contracture (if the thumb is included). The splint extends from the upper 2/3rd of the forearm to the palmar crease. Usually the thumb is excluded from the splint, unless the thumb needs to be in a functional position or thumb web contracture needs to be prevented.

Cock up slab. This splint is indicated when there is radial nerve damage associated with paralysis or weakness of the wrist extensors. The purpose of the splint is to stretch and maintain the extensors in their optimal position, thus preventing wrist joint contracture from excessive wrist flexion. The splint extends from the upper 2/3rd of the forearm to the palmar crease. The wrist is maintained in extension. The fingers are included in the splint if they are paralyzed; if not, they are excluded.

Splints for deformity correction / maintenance of joints in optimal position

Cylindrical splint. This splint is indicated when there is interphalangeal joint stiffness or contracture, as well as if there are finger wounds and cracks. The purpose of the splint is to prevent contracture, correct existing contracture, and provide rest or encourage healing. The splint extends from the tip to the base of the finger. Wound healing cylindrical splints can have a window over the wound.

Thumb web spica / tuck-in splint. This splint is indicated when there is thumb web contracture. The purpose of the splint is to prevent and treat thumb web contracture, such as by maintaining the thumb in an abducted position. The splint is also used to protect the transferred tendon after reconstructive surgery to correct ape thumb deformity.

Functional slab for hand. This splint is indicated when a patient has a reaction or wound infection that causes swelling in the hand. The splint helps to rest the hand in a functional position, as well as relieves pain and assists in healing. The splint is applied with the metacarpophalangeal joint at 45 degrees, the proximal interphalangeal joints at 25 degrees, and the distal interphalangeal joint at 15 degrees.

Splints for pre- and post-operative phases of reconstructive surgery

Lumbrical slab. A lumbrical slab is indicated when there is a need to maintain the hand in the lumbrical position after surgery. The primary purpose of the splint is to protect the transferred tendons post-operatively. Finger loops are provided to maintain the position of the metacarpophalangeal joint in flexion. This splint is also useful in reducing swelling and promoting healing.

Non-weight bearing cast. A non-weight bearing cast is indicated after Tibialis Posterior Transfer (TPT) surgery. It is also used to heal simple ulcers. The patient is not allowed to bear weight on this cast, but instead must use crutches for locomotion. The cast extends from the neck of fibula to the tip of the toes, with the ankle joint maintained at 90 degrees of dorsiflexion.

Offloading measures for plantar ulcers

Below Knee (BK) cast with Bohler Iron. Most hospitals treating leprosy patients use a Bohler Iron in the walking cast. The Bohler Iron helps transmit weight and pressure to the calf area, preventing weight bearing on the foot. This technique helps ulcers heal more quickly. This cast is indicated in the presence of a simple heel ulcer in a foot, whether or not the foot is deformed. If an ulcer needs dressing, a window can be left in the cast over the ulcer area to enable dressings. This cast extends from the neck of the fibula to the tip of the toes.

Molded Double Rocker Shoe (MDRS) / Boot. This name is a misnomer, as there is no proper rocker, but the cast provides an effect similar to that of a rocker. This cast, which is shaped like a boot, can be used to heal plantar ulcers on the forefoot. An MDRS is contraindicated in the presence of foot drop, stiff claw toes, or heel ulcers. The cast is applied below the malleoli, but covers the entire foot, just like a boot.

TENDON TRANSFER SURGERIES

Tendon transfer procedures are performed to regain near normal function and appearance due to existing impairments. Effective pre-counseling and strict adherence to rehabilitation protocols are key for patients to have a satisfactory post-operative result (22). The tendon transfer procedures are well elaborated in Chapter 4.2.

The balancing of forces which is re-established through reconstructive surgery depends on the selection of an appropriate tendon for the transfer procedure. Pre-existing secondary impairments and their multifactorial dimensions need to be considered when selecting and re-educating an appropriate muscle for transfer (27). The selection and modification of the appropriate rehabilitation protocol for pre- and post-tendon transfer surgery determines, in a major way, the patient's adaptability to functional activities after the surgery.

Pre-operative plan

Patient profile. The profile of a patient, including age, sex, occupation, and functional dominance of the extremities, establishes some of the key parameters in determining post-operative results. The patient's expectations, apart from the motivation or need for surgery, are vital in selecting and isolating an appropriate muscle for the tendon transfer.

Assessments. The status of muscle power before surgery plays a vital role in determining the effective post-operative functioning of the graft. An assessment of the muscle to be transferred using MRC grading (Table 2) provides surgeons and therapists with information necessary to plan for the surgery. Individual muscle assessments of the hands and feet supplied by the affected nerves, and their joint angles, are essential for understanding and maintaining their normal mechanics during tendon transfer surgery.

The identification of an appropriate muscle, with good muscle power, suitable for the transfer is vital for a successful surgery. The rehabilitation team should also be conscious of whether the transferred muscle acts in cohesion with other muscles to perform specific movements. The individual muscle tests should always be complemented by other assessments. The Rotterdam Intrinsic Hand Myometer (RIHM) is one of the devices that can help test the intrinsic muscles of the hand (28). Furthermore, the matrix recently developed by Govindasamy et al. in India can help the rehabilitation team make better decisions when selecting tendon transfer procedures for ulnar and median nerve paralysis. The matrix can also help decide the ideal tendons that can be transferred for the correction of these long-standing deformities (29).

Post-operative plan

Post-operatively, the effectiveness of the surgery is assessed based on improvements in the joint contracture angles and in the functionality of the hands and feet (30). Thus, the patient's daily functions and post-operative expectations need to be considered when selecting the donor muscle. The assessment will also motivate the patient to set post-operative targets for ADL, even before the surgery. Appendix 3 provides detailed pre- and post-operative assessments for the hands, feet, and eyes (Tables A3A, A3B, A3C, respectively) that are necessary for the continuous and effective monitoring of a patient's progress.

Pre- and post-operative rehabilitation

The rehabilitation team should involve the patient in the surgical planning sessions, which will have a positive effect on the post-operative results. Group therapy sessions for patients waiting to undergo reconstructive surgery can help motivate the patient and facilitate a positive outcome. Appendix 4 overviews pre- and post-operative physical rehabilitation protocols for patients undergoing tendon transfer surgeries (Table 4A). An emphasis on a customized functional reorientation protocol in accordance with the patient's profession would be an ideal and effective

approach to post-operative rehabilitation. However, due to a paucity of time and funds, many functional rehabilitation protocols are limited to those given in the appendix. An improvement in the SALSA scale score would help determine an improvement in functions after the surgery.

SELF-CARE

Principles of self-care for eyes, hands, and feet

Every patient with a leprosy-related impairment needs to be educated about self-care. The education needs to be participatory and problem based. Each patient will have a different lifestyle, and self care needs to be modified to suit that lifestyle. Effective self-care interventions or lifestyle modifications adopted by the patients will help reduce their impairments (31, 32).

Self-care of eyes

Impaired corneal sensation. Corneal sensory loss is caused by damage of the trigeminal nerve. If care is not taken, red eye can occur, which will further decrease vision. ‘Think Blink’ is one of the best methods of preventing such complications. The patient is taught to deliberately close the eye at regular intervals. If the patient remembers to blink every few minutes, the risk of corneal damage can be reduced.

The following list provides guidance on the self-care of lagophthalmos (see Chapter 3.1):

- Wear protective eyeglasses to help prevent dust and insects from damaging the eye and to prevent dryness on the surface of the eye.
- Cover the head during sleep with a clean bed sheet or towel, and wear a wide-brimmed hat (Figure 7) or cover the eye with any available cloth during the day, to prevent damage to the eye from foreign particles and insects.



FIG 7 Covering the Eye.

- Perform passive eye exercises to maintain muscle tone and prevent atrophy.
- Wash the eye with clean water at least twice a day to flush out dirt and to prevent dryness.
- Inspect the eye in a mirror to help the early detection of redness or injury (Figure 8).
- Avoid rubbing the eye at all costs, as it can compound damage.



FIG 8 Daily Inspection of the Eye.

In addition, the affected person can be taught a simple test for visual acuity, counting fingers at a distance of 6 meters, so that refractive issues can be addressed in a timely manner.

Self-care of hands and feet

The following list provides guidance on the self-care of hands and feet:

- Use thick cloth or gloves for insulation when handling hot objects to protect insensate hands. Use tools with wooden or rubber-covered handles to help prevent injury.
- Use grip aids and splints to protect hands.
- Wear appropriate footwear to protect insensate feet.
- Use appropriate footwear to help prevent plantar ulcers.
- Soak a palm or sole with sensory loss for 20 minutes in cool clean water to make the skin supple. Then rub off the hard skin with a scrapper stone, which keeps the skin soft. Oil the wet skin to help retain moisture and prevent dryness.
- Include inspecting as well as soaking, scraping, and oiling in the self-care routine to help the early detection of issues.
- Inspect the anaesthetic area for injuries, or even red spots, swelling, and cracks and take adequate precautions to prevent the wound from becoming bigger.

- Treat simple wounds at home by bandaging with a clean cloth. A wound area on the hand should be rested; one on the foot should be offloaded. Immediately report any signs of infection to the physician for further management.
- Make lifestyle modifications to protect the hands and feet from being injured.

Self-care groups

A self-care group is a group of leprosy-affected patients, and even their family members, who meet to discuss various aspects of self-care. Often the group practices self-care as a team, helping each other out. The problems faced by individuals in self-care are discussed and solutions found. The group is usually a cohesive unit and the discussions help the patients broaden their knowledge about self-care. The expected outcome of self-care groups is to obtain feedback from various group members and change attitudes regarding self-care. The goal is to reduce existing impairments and prevent new ones from occurring.

Footwear

Feet that have sensory loss are at a high risk of thermal and repetitive pressure injuries, as well as injuries from sharp objects. Therefore, the care and protection of the foot should be accorded the highest priority. Patients with existing secondary impairments, such as shortening, plantar ulcers, or deformed feet, require specialized footwear. Specialized footwear provides a rocker effect while walking and redistributes pressure over a large surface area during weight bearing, thus reducing the risk of further impairments.

The use of appropriate footwear helps protect the foot, but the footwear needs to be affordable and acceptable to the client. Footwear for leprosy-affected individuals needs to cover the foot and protect it from external pressure. It should have adequate padding on the sole, which helps redistribute weight and increase the surface area for weight bearing. The footwear should be rigid, to avoid shearing stress on the foot, but molded to the contours of the foot. Footwear made of Micro Cellular Rubber (MCR) is considered to be the most appropriate because the micro cells in the rubber cushion the feet. MCR also helps redistribute pressure and provides adequate protection from external pressure. If special footwear is not available, any appropriate local footwear that can adequately protect feet can be used. Footwear should be changed at least once a year to maintain its quality and effectiveness in protecting the feet.

Patient resistance to wearing protective footwear is a common issue faced by many health workers. Also, protective footwear usually does not suit the cosmetic desires of patients. Health education plays an important role in improving patient compliance. A recently conducted study in an urban leprosy center demonstrated the need for more footwear designs (33). In any leprosy control program, if the footwear is customized to locally accepted designs and fashion, the rate of compliance will improve.

Ideal footwear. Simple footwear consists of a soft insole, hard outer sole, a heel counter, adjustable uppers, and a back strap. Molded footwear is prescribed for those with deformed feet. Footwear should fit correctly because loose or tight shoes can cause ulcers. The shoes should not contain any nails; rather, they should be panted. A heel counter in the shoes benefits the patient as it helps keep the foot in position.

An assessment of the foot is necessary before footwear is prescribed. The size and type of the foot need to be noted. The presence or absence of deformities plays a major role in the decision to provide a specific type of footwear. Table 7 lists the common types of footwear and orthoses that can be prescribed to patients with anesthetic feet.

TABLE 7 Recommended footwear for patients with anesthetic feet

Foot Assessment	Prescribe Footwear and Orthoses
No deformities	MCR footwear or any appropriate footwear
Claw toes and forefoot scarring	MCR footwear with a metatarsal pad
Pronated subtalar joint	MCR footwear with a tarsal cradle
Hyper pronated subtalar joint	MCR footwear with a hatti pad
Supinated subtalar joint	MCR footwear with a heel cup or tarsal platform
Ulcer on the metatarsal head on a supinated foot	MCR footwear with a plantar metatarsal pad
Ulcer on the metatarsal head on a pronated subtalar joint	MCR footwear with a plantar metatarsal pad and a tarsal cradle
Neuro arthropathy	Fixed Ankle Brace
Shortened and scarred foot	Patellar Tendon Bearing Brace

Functional and accommodative orthoses should not be fabricated or provided until after a detailed foot biomechanical assessment. The position of the subtalar joint and the functions of other joints in the foot allow the identification of normal and abnormal foot functions (34). The fabrication of an appropriate foot orthosis will complement the management of plantar ulcers (35). The efficacy of using an orthosis for leprosy patients has been well established by Cross et al. (35).

TECHNOLOGICAL ADVANCES

Changing scenario and challenges in leprosy rehabilitation

Though technology has aided in the rehabilitation of people with impairments across the globe, leprosy-affected patients have not received a great deal of benefit from the technological boom. The translation of technological advances to rehabilitation in leprosy-affected persons has faced

several challenges over the years. A lack of funding and a surfeit of complacency in adapting the technology to benefit leprosy-affected patients are two of the challenges that leprosy programs face in implementing these technologies. Given the technological advancements and the availability of low-cost technology, leprosy health workers need to adapt these advancements and adopt them in their health programs. In a rapidly growing economy, leprosy-affected patients also should be provided with rehabilitation plans customized to their needs within a shorter span of time.

Technological advancements

The advancements in technology have provided health workers with an array of options for rehabilitating physically challenged people using assistive devices. Technologically driven methods for fabricating assistive devices have helped the physically challenged lead independent and emancipated lives, allowing them to overcome the challenges initially caused by their impairments. Technology has also brought a paradigm shift, making health care more appropriate and more affordable. The widespread availability of and easy accessibility to technology has greatly contributed to breaking the physical barriers faced by the physically challenged, helping them become functionally independent and productive over a short span of time (36, 37, 38). Technology has also enabled the customization of assistive devices and reduced the time required for their fabrication.

Numerous studies have found that involving users in the fabrication of technologically advanced devices would help improve user adherence to those devices. In one study, Phillips established that user adherence to devices would improve if those devices supported psychological and social independence as well as improved physical functioning (39). In another study, Bradley and Dunlop emphasized that users need to be involved in the design process so that devices can be more effective, especially if a human-computer interface is included (40).

In addition to the lacunae in considering the user's opinion in the design process, the stigma of using assistive devices is considered to be one of the key factors in users' abandonment of those devices (41, 42). This issue is particularly applicable to patients with leprosy, who use assistive devices to protect themselves and to facilitate their self-care and other daily activities (43, 44). In their work, Fatima et al. have highlighted the need to design assistive devices that facilitate inclusiveness and thereby reduce stigma (45). (See Chapter 4.5 for additional information on overcoming the stigma of leprosy.)

New technology has also helped develop models and simulation techniques for understanding the effects of plantar stresses in causing foot impairments (Figure 9A) (46, 47, 48, 49, 50, 51). Analysis of the peak plantar pressures have facilitated the computer-aided design and fabrication techniques for foot orthosis. Techniques have been developed and adopted to design and correct foot impairments for patients living in remote places (52, 53, 54).

Cost-effective tactile sensors have also been used to design and develop bio-feedback systems that can help prevent peak palmar and plantar pressures (Figure 9B) (55). The use of advanced computer technologies has helped to identify and provide feedback on the progression of ulcer care in leprosy (56). Furthermore, mobile-based technology has helped patients in a resource-limited setting access health care from the comfort of their homes. For example, the Leprosy Alert and Response Network System (LEARNS) in the Philippines and an urban leprosy project in Kolkata have utilized mobile-based technology for the early detection of leprosy and the prevention and management of impairments from leprosy (57).

Developing newer designs through reverse engineering would further help to retain and refine the functionality of devices. A framework that involves caregivers and patients affected by leprosy in the design and development process would help improve their adherence to and use of assistive devices. In the near future, advanced technologies such as virtual reality and artificial intelligence could also be integrated into the fabrication of assistive devices.

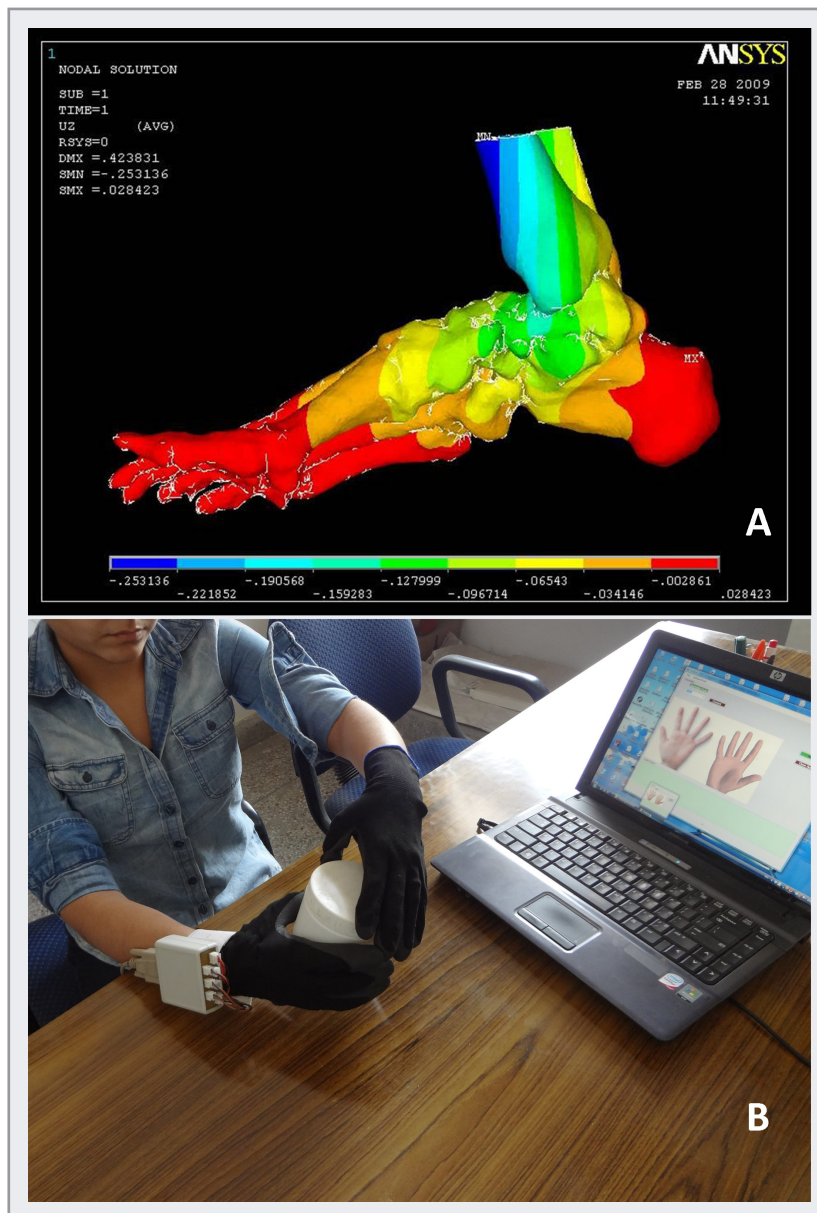


FIG 9 Foot Assessment.

A Plantar stress assessment

B Palmar pressure assessment

Appendix 1

TABLE A1 Common adaptive / assistive devices used in leprosy





Name of the device	Indication	Brief description
<p>Adapted spoon</p> 	<p>Those with no grasp due to absorbed digits or complete paralysis of hand muscles</p>	<p>Device is made of a spoon attached to an aluminum cuff to facilitate the retention of the spoon in the hand while eating. This device can be adopted for a toothbrush and a comb.</p>
<p>Built-up spoon</p> 	<p>Those with some grasp but inability to hold thin items such as a spoon or toothbrush during function movement</p>	<p>Soft material is padded around the spoon handle to facilitate grip for those with poor hand grasp. The same modifications can be done for a toothbrush, pen, shaving razors, and comb.</p>
<p>Nail cutting device</p> 	<p>Those with deformities; clawed fingers and thumb paralysis</p>	<p>Nail cutter is attached to stable base and cutter handle is broadened to facilitate easy cutting of nail.</p>
<p>Soap holder</p> 	<p>Those with paralyzed fingers and thumb or absorbed digits with difficulty in grasp</p>	<p>Soap is fixed into an aluminum holder, which is attached to a stable cuff around the palm to facilitate the retention of the soap in the hand. This device is rarely used.</p>

TABLE A1 (cont'd)

<p>Button hook</p> 	<p>Those with difficulty in fine motor activity due to paralysis and/or loss of sensation</p>	<p>A hook is fixed to a soft handle to facilitate buttoning, which is very challenging for those with thumb paralysis.</p>
<p>Writing aid</p> 	<p>Those with poor prehension (tripod) function with some pinch power</p>	<p>A soft rubber grip slips onto a pen or pencil to facilitate grip while writing.</p>
<p>Grip aids</p> 	<p>Those with absorbed digits with some grasp/prehension function</p>	<p>Made of a special material that takes the shape of the contact surface of the fingers to facilitate easy grasp.</p>
<p>Universal cuff</p> 	<p>Those with poor or no grasp due to absorbed digits or paralysis of muscles of the hand</p> <p>Those without fingers or loss of grasp</p>	<p>This device consists of a nylon or leather cuff around the palm with a pocket to insert a spoon, toothbrush, comb, etc.</p>
<p>Zipper puller</p> 	<p>Those with poor prehension function</p>	<p>This device consists of a hook with a ring at one end to facilitate pulling a zipper.</p>

Appendix 2

TABLE A2 Exercises recommended for peripheral nerve injuries*

Nerve	Major Muscle(s) affected	Active Exercise	Active Assisted Exercise	Passive Exercise
Facial	Orbicularis Occuli	Patient should try to tightly close eye, hold it for 10–20 counts, and then open it. Repeat 5 to 10 times hourly.		Patient should place index finger at lateral side of eye and gently pull eyelid laterally so that it closes.
Ulnar	Abductor digiti Minimi Interossei Lumbricals 4th & 5th Flexor Digitorum Profundus 4th & 5th Flexor Carpi Ulnaris	Patient is asked to adduct and abduct fingers as much as possible with palm placed on flat surface (thigh / table). IP joints are flexed and extended while MCP joints are kept in flexion, wrist in neutral, and elbow in extension on soft padded surface.	MCP joints of affected hand are supported at 90 degrees by other hand, which is held in lumbrical position. From this position (MCP at 90 degrees flexion and wrist in neutral), interphalangeal joints of medial four fingers of affected hand need to be flexed and extended completely.	Hand is placed on thigh or soft flat surface, with palm facing up. Palm or hypothenar area of unaffected hand is used to gently straighten fingers. Once one cycle of exercise is over, other hand is lifted up and then exercise is done again. Repeat exercise at least 10 times every 2–3 hours. Oil or Vaseline can be used to soften hand.
Median	Abductor Pollicis Brevis Extensor Digitorum Profundus 2 & 3rd Oppones Pollicis Longus Lumbricals 2nd & 3rd	Extended thumb of affected hand is moved into abducted position; position needs to be maintained for some time.	Support MCP joint of affected thumb with thumb and fingers of other hand: With thumb fixed in above position, interphalangeal joint of thumb should be flexed and extended. Exercise will prevent contracture of IP joints of thumb.	Hand is placed on soft flat surface with palm facing up. Extended thumb of affected hand is moved into opposition with other four fingers. Thumb is also actively moved into abduction position and this position is maintained for about 5 seconds. Repeat exercise at least 10 times every 2–3 hours.

TABLE A2 (cont'd)*

Nerve	Major Muscle(s) Affected	Active Exercise	Active Assisted Exercise	Passive Exercise
Radial	Extensor Carpi Ulnaris Extensor Carpi Radialis longus & Brevis Extensor Digitorum Communis & Indicis	Keep wrist on edge of table, palm facing down. Ask patient to extend wrist and hold it for 30 seconds. Repeat exercise at least 10 times every 2–3 hours.	Two palms are placed in approximation with each other. From this position, wrist of normal hand is flexed to make affected wrist move into extension. Extension of paralyzed wrist should make it move to end ranges. Other method of exercising wrist is to place it flat on surface and lift elbow perpendicular to wrist joint.	
Lateral Popliteal	Tibialis Anterior Extensor Digitorum Longus Extensor Hallusis Longus	Patient sits high with legs not supported by ground. Foot is dorsiflexed and position is maintained for about 15 to 20 seconds. Repeat exercise at least 10 times every 2–3 hours.	Leg with paralyzed foot is placed over other leg and patient actively tries to dorsiflex foot on this gravity-eliminated plane.	Patient is positioned in long sitting (leg in extended position). Towel is placed over plantar surface over forefoot and patient holds edges of towel. When towel is pulled towards patient, foot is dorsiflexed and held in this position for about 10 seconds and then released. Another exercise can be performed by standing about a foot in front of a wall, facing wall. Patient can lean forward with hands placed on wall for support. Position causes foot to dorsiflex. Repeat exercise at least 10 times every 2–3 hours.
Posterior Tibial			Patient is positioned with affected leg resting on other thigh. Patient can use hand to stretch toes passively and hold for 20 seconds.	

* IP = Interphalangeal; MCP = Metacarpophalangeal

Appendix 3

TABLE A3A Pre- and post-operative assessment protocol of tendon transfer surgeries of hand*

	Pre-Operative Assessment			Post-Operative Assessment
	Ulnar Nerve	Median Nerve	Radial Nerve	
Muscle Assessment	<ul style="list-style-type: none"> • Abductors of little and index fingers • Intrinsic muscles • Flexor Digitorum Profundus – Ring and Little finger • Flexor carpi Ulnaris 	<ul style="list-style-type: none"> • Abductors and the opposers of thumb • Flexor Carpi Radialis • Intrinsic muscles • Flexor Digitorum Profundus – Index and middle finger • Pronator Teres • Palmaris Longus • Flexor Pollicis longus 	<ul style="list-style-type: none"> • Extensor carpi Radialis longus and brevis • Extensor carpi ulnaris • Extensor digitorum communis • Extensor pollicis longus • Extensor digiti minimi 	<ul style="list-style-type: none"> • Infection • Stitch abscess • Swelling • Adhesion • Loose tension • Tendon slipping • Pain • Sublimus Minus • Check Rein
Sensation	Sensory areas supplied by ulnar nerve	Sensory areas supplied by median nerve	Sensory areas supplied by radial nerve	
Angle Measurements	Finger PIP angles in MCP flexion Thumb MP and IP angles	Thumb web measurement Thumb MP and IP angles	Wrist angles	
Secondary Impairments	Assess for <ul style="list-style-type: none"> • Skin Contracture • Capsular Contracture • Long flexor tightness • Hooding 	Assess for <ul style="list-style-type: none"> • Skin Contracture • Capsular Contracture 		

TABLE A3A (cont'd)*

	Pre-Operative Assessment		Post-Operative Assessment
	Ulnar Nerve	Median Nerve	
	<ul style="list-style-type: none"> • Guttering • Swan neck deformity • Extension Lag (DDE damage) 		
Functional Assessment	<p>Grasp contact</p> <p>Grasp strength</p> <p>Pinch Contact</p> <p>Pinch strength</p> <p>9-hole peg boards</p> <p>Other functional activities concerning the patients occupation:</p> <ul style="list-style-type: none"> • Opening and closing jar • Picking up pebbles • Picking up cooked rice • Opening and closing big and small buttons • Opening and fastening zip • Counting paper • Drawing small and big shapes • Screening of Activity Limitation and Safety Awareness (SALSA) scale score 		

* PIP = Proximal Interphalangeal; MCP = Metacarpophalangeal; IP = Interphalangeal; DDE = Dorsal Digital Expansion

TABLE A3B Pre- and post-operative assessment protocol of tendon transfer surgeries of feet

	Lateral Popliteal Nerve	
	Pre-Operative Assessment	Post-Operative Assessment
Muscle Assessment	Tibialis anterior Tibialis posterior Extensor Hallucis longus Extensor digitorum longus	Infection Stitch abscess Swelling Adhesion
Sensation	Sensory areas of the lateral popliteal and posterior tibial nerve	Loose tension Tendon slipping
Angle Measurements	Ankle at rest With Knee Extended <ul style="list-style-type: none"> • Active Dorsi / plantar flexion • Passive Dorsi / plantar flexion With Knee Flexed (90°) <ul style="list-style-type: none"> • Active Dorsi / plantar flexion • Passive Dorsi / plantar flexion Inversion and eversion at dorsiflexion Inversion and eversion at plantar flexion	Pain
Functional Assessment	Navicular Height Gait (123 pattern) Whether able to walk short / long distances, run, climb stairs, and squat SALSA Scale score	

TABLE A3C Pre- and post-operative assessment protocol of tendon transfer surgeries of eye

	Eye	
	Pre-Operative Assessment	Post-Operative Assessment
Muscle Assessment	Functioning of orbiculari oculi	Functioning of the transferred tendon “temporalis muscle”
Sensory assessment	Corneal Sensation – Blink Lid gap in light closure (in millimeters) Lid gap in tight closure (in millimeters) Vision (Snellen’s E-Chart)	Lid gap in light closure (in millimeters) Lid gap in tight closure (in millimeters) Vision (Snellen’s E-Chart)
Other assessments	Ectropion Entropion Watering of the eye Corneal Ulcer	Ectropion Entropion Watering of the eye Corneal Ulcer

Appendix 4

TABLE 4A Surgical rehabilitation protocols

Surgical Procedure	Pre-Operative Rehabilitation	Post-Operative Rehabilitation			
		1st Week	2nd Week	3rd Week	4th Week
Extensor to Flexor 4 Tail Transfer (EF4T)	To gain isolation and full strength of ECRL, support hand in pronation and practice wrist extension without allowing finger or thumb movement. To strengthen ECRL, do same action against resistance.	Isolate and do wrist extension with radial deviation, looking for MCP joint flexion and PIP extension in all fingers. Use cylindrical splints for finger extension and lumbrical slab to reduce swelling. Assess at end of 1st week.	MCP extension Assess at end of 2nd week.	Start MCP and PIP joint flexion. Assess at end of 3rd week.	Perform functional activities: <ul style="list-style-type: none"> Grasping large progressing to smaller objects Grasping light progressing to heavier objects Picking up beans with fingers and thumb in lumbrical position Assess at end of 4th week.
Extensor to Extensor 4 Tail transfer		Post-operative exercises are same as EF4T, except too much full wrist flexion should be avoided in post-operative period.			
Palmaris Longus 4 Tail Transfer	Isolate PL by wrist flexion and hand cupping.				
Sublimus Transfer	Ask patient to flex PIP joint of only long finger; all other fingers should be relaxed. MCP of long finger should	Post-operative exercises are same as above surgeries except care must be taken for “check-rein” and “sublimus-minus” deformities.			

TABLE 4A (cont'd)

Surgical Procedure	Pre-Operative Rehabilitation	Post-Operative Rehabilitation			
		1st week	2nd week	3rd week	4th week
Lasso Procedure	be flat and DIP joint must be relaxed. Ask patient to flex PIP joint of only long finger; all other fingers should be relaxed. MCP of long finger should be flat and DIP joint must be relaxed.	Perform isolation exercises of transfer (FDS of long finger). Flex and extend PIP and DIP joints while maintaining MCP joint in 55°. Use POP slab when not exercising. Assess at end of 1st week.	Flex and extend PIP and DIP joints while maintaining MCP joint in 55°. Assess at end of 2nd week.	Perform coordination exercises. Perform more extensions of MCP joints. Change slab to one with MCP joints in 30° extension. Assess at end of 3rd week.	Perform functional activities: <ul style="list-style-type: none"> Grasping large progressing to smaller objects Grasping light progressing to heavier objects Picking up beans with fingers and thumb in lumbrical position Assess at end of 4th week.
Sublimus Transfer	Ask patient to flex PIP joint of only long finger; all other fingers should be relaxed. MCP of long finger should be flat and DIP joint must be relaxed.	Perform isolation exercises of transfer (FDS of long finger). Look for MCP joint flexion and PIP extension in all fingers. Immobilize IP	Perform MCP extension. Assess at end of 2nd week.	Start MCP and PIP joint flexion. Assess at end of 3rd week.	Perform functional activities: <ul style="list-style-type: none"> Grasping large progressing to smaller objects Grasping light progressing to heavier objects Picking up

TABLE 4A (cont'd)

Surgical Procedure	Pre-Operative Rehabilitation	Post-Operative Rehabilitation			
		1st week	2nd week	3rd week	4th week
Opponens Replacement	To gain isolation and full strength of ring finger FDS, support hand in supination and practice PIP flexion of that finger. DIP joint and all other fingers must remain relaxed. Thumb web angle should be 40°.	<p>joints using POP cylindrical splints. Assess at end of 1st week.</p> <p>Try old action of PIP flexion of ring finger and watch for new action of thumb abduction / rotation. Make sure while doing exercises that:</p> <ul style="list-style-type: none"> • Other fingers and ring finger DIP joints are relaxed • There is no thumb tip flexion as transfer is used • MCP joint does not hyper extend 	<p>To strengthen transferred muscle:</p> <ul style="list-style-type: none"> • Increase amount of exercise. • Provide less support for hand by changing position. • Perform action against gravity. 	<p>To improve coordination of transferred muscle:</p> <ul style="list-style-type: none"> • Teach it to work together with fingers for pinch function. • Expect increased ROM. • Discard POP as good control is gained. • Continue anterior slab at night. 	<p>beans with fingers and thumb in lumbrical position Assess at end of 4th week.</p> <p>To train functional use of transferred muscle, activities may include</p> <ul style="list-style-type: none"> • Picking up large objects, progressing to smaller ones. • Games such as ludo, Writing • Activities of daily living, especially those related to patient's needs

TABLE 4A (cont'd)

Surgical Procedure	Pre-Operative Rehabilitation	Post-Operative Rehabilitation			
		1st week	2nd week	3rd week	4th week
Triple Nerve Palsy Correction – Restoration of wrist and finger extension	Perform isolated contraction of Pronator Teres (i.e., Pronation of forearm with all other muscles relaxed).	<ul style="list-style-type: none"> Check that rein deformity does not develop in ring finger Apply thumb spica POP or cylindrical POP to thumb along with anterior slab to hold it in abduction / opposition between treatments.			
<ul style="list-style-type: none"> Restoration of wrist extension – Transfer of Pronator Teres to ECRB Restoration of finger and thumb extension – FCR 	Perform isolated contraction of FCR (i.e., Flexion of wrist joint into radial deviation, with other muscles relaxed).	Patient does gentle exercises as taught pre-operatively. Watch for wrist extension by graft when doing pronation and extension of fingers and thumb and when doing wrist flexion. Apply post-operative anterior slab when not	Perform same exercises, but more strongly, change positions, hold for longer time.	If good control of graft, start gentle flexion of wrist, fingers, and thumb and supination and extension of elbow.	Continue exercises Start functional activities as possible to prepare for lumbrical and opponens operation.

TABLE 4A (cont'd)

Surgical Procedure	Pre-Operative Rehabilitation	Post-Operative Rehabilitation			
		1st week	2nd week	3rd week	4th week
<ul style="list-style-type: none"> • Transfer to EDC and EPL 		exercising.			
Temporalis Muscle Transfer (TMT)	Assess: <ul style="list-style-type: none"> • Face muscles, especially orbicularis oculi • Corneal sensation • Inter lid width of Lagophthalmos – light and tight closure • Strength of Temporalis muscle • Other assessments as for other surgery • Any eye complications, i.e., inflammation, ulcer. Perform isolated contraction of temporalis muscles, i.e., biting. Perform biting exercises on a hard substance, e.g., a piece of rubber or chewing gum, to strengthen temporalis muscle.	Liquid diet	Semi-solid diet	Normal diet Start biting exercises and measure inter lid width when exercising.	Longer exercise sessions Hold contraction for longer time Bite on a hard substance
Tibialis Posterior Transfer (TPT)	Gain isolation of Tibialis Posterior.	To isolate transferred muscle:	To strengthen transferred	To improve coordination of	Gain full weight bearing by

TABLE 4A (cont'd)

Surgical Procedure	Pre-Operative Rehabilitation	Post-Operative Rehabilitation			
		1st week	2nd week	3rd week	4th week
	Strengthen Tibialis Posterior by sitting with affected foot supported on opposite knee and practicing inversion. Resistance may be given to medial side of foot.	<ul style="list-style-type: none"> Remind patient of pre-operative exercises. As patient tries to do "old" action of inversion, watch for "new" action of dorsiflexion (exercise in same position as pre-operative). Movement may be a flicker at first. Perform exercise with gravity eliminated. <p>To prevent damage or misuse of transferred tendon, provide back slab.</p>	<p>muscle:</p> <ul style="list-style-type: none"> Increase amount of exercise. Sit with leg hanging down so that muscle is working against gravity. 	<p>transferred muscle with associated leg muscles:</p> <ul style="list-style-type: none"> Perform partial weight-bearing exercises on parallel bars facing a mirror. Transfer of weight that would be practiced on parallel bar would be side-to-side transference of weight and heel-to-toe transference of weight 	<p>decreasing, then removing, support of parallel bars, crutches, etc. Encourage walking in all situations, progressing to:</p> <ul style="list-style-type: none"> Rough ground, slopes, steps Longer distances Hand ball games which distract patient's attention from feet

* ECRL = Extensor Carpi Radialis Longus; MCP = Metacarpophalangeal; PIP = Proximal Interphalangeal; DIP = Distal Interphalangeal; ROM = Range of motion; POP = Plaster of Paris; FDS = Flexor Digitorum Sublimus; IP = Interphalangeal; FCR = Flexor Carpi Radialis; EDC = Extensor Digitorum Communis; EPL = Extensor Pollicis Longus

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