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Clinical Management of the Neuropathic Limb

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Introduction

As medical research provides methods of extending the life of patients with previously fatal diseases, we in the medical community are seeing a rise in chronic complications. Complications are increasing at an alarming rate and are involving orthotists and prosthetists in the team management and assessment process.

An appropriate approach to this complex subject would be to clarify the condition we will be managing. Repeated articles refer to these patients as dysvascular rather than as neuropathic requiring orthotic intervention. Emphasis should be placed on *neuropathy* (insensitivity) because patients must be accommodated and pressure areas relieved of potential and/or present breakdown. Dysvascular patients (see *Figures 1a* and *1b)* may be neuropathic (see *Figures 2a* and *2b)* as well, but they do not depend on orthotic/prosthetic intervention to improve their condition or long-term medical outcome. Dysvascular patients require immediate attention from vascular specialists (to improve condition) or surgery to remove or debride tissue.

Historically, the neuropathic foot was treated after foot ulceration appeared. We now address neuropathy in an attempt to *prevent* ulceration and ensuing complications, including amputations.

Neuropathy

Many conditions can leave patients with neuropathy in their limbs. Some diseases that can result in neuropathy are:

- diabetes
- cancer
- Hansen's
- guillian barre
- influenza
- hepatitis
- lupus
- periarteritis
- nerve damage and entrapment
- spina bifida
- syringomelia
- tabes dorsalis (pseudo-Charcot)
- syphilis and
- multiple sclerosis

Toxins and syndromes also can cause insensitivity in the limbs. Toxins include alcohol, arsenic, lead, gold, steroids, sulfonamides,

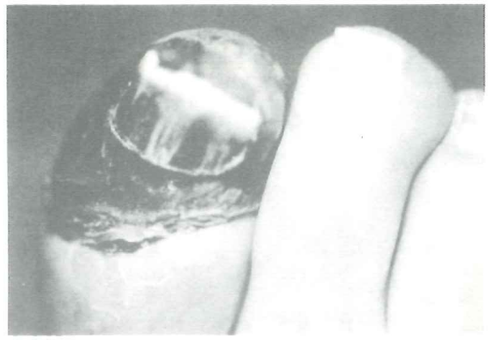

Figure 1a. **Dysvascular patient with normal sensation in foot. Distal end of great toe is gangrene.**

Figure 1b. **Patient is neuropathic and dysvascular with gangrene in fifth toe and infection in foot.**

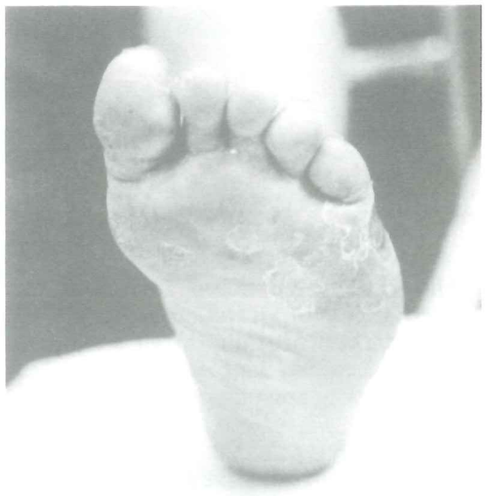

Figure 2a. **Neuropathic foot with Charcot deformity.**

Figure 2b. **Neuropathic foot with amputation, claw toe and dermatological condition.**

penicillin, prolonged INH use and uremia. Syndromes include Charcot Marie Tooth, Refsum's, Dejerine Sotta's and Riley Day. In addition, HIV/ARC/AIDS medications may also result in neuropathy.

Some of these conditions are complicated further by dysvascularity. When arteries are calcified, they provide poor healing potential. Antibiotics (oral or IV) cannot perform optimally in an extremity they cannot reach. Dysvascularity makes an injury or infection in the neuropathic limb a serious medical condition often leading to amputation or debridement.

The insensitive (neuropathic) foot is not much weaker than the normal foot—it is just poorly protected since it lacks pain reflex. Patients lose all sense of identity with the insensitive part. Subconsciously these patients don't have feet. While definitions of neuropathy differ with the diagnosing profession, patients are tested to determine the level of sensation loss and to "map out" the area involved. A common and widely recognized tool is the Semmes Wienstein monofilament (von Frey) set. This is a set of three brush-quality nylon monofilaments (38mm long) that are calibrated to measure the

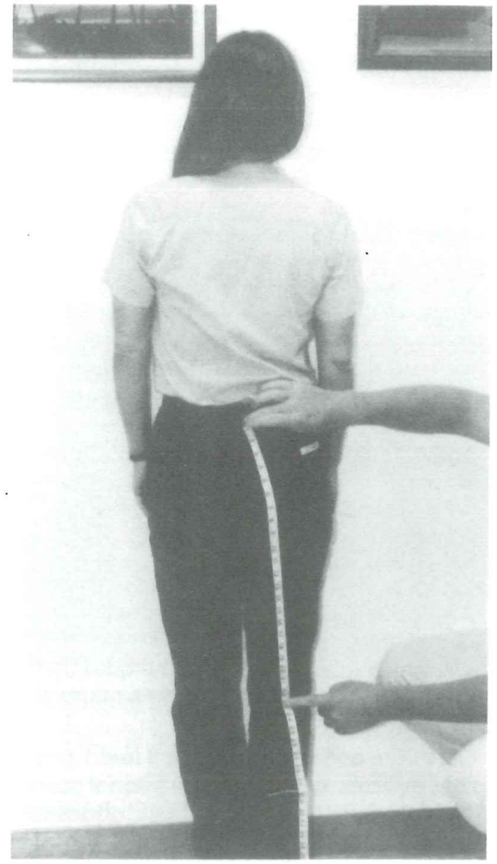

Figure 3. **Measurement from L5/S1 to insensitive area of lower extremity.**

amount of bending force for each monofilament diameter.

The three sizes are 4.17, which applies one gram of force for a normal sensation; 5.07, which applies 10 grams of force to indicate a level of protective sensation; and 6.10, which applies 75 grams of force and determines if a limb is completely insensate. When patients cannot respond to the 5.07 or 6.10 size, they are considered neuropathic because they cannot feel pain and high pressures before damage occurs. No person who is comfortably ambulating with plantar ulcerations can feel 10 grams of force.

Types of Neuropathy

Peripheral neuropathy is a lack of sensation that is symmetrical and equal from the spine

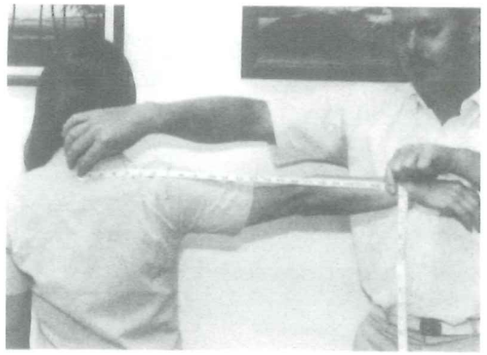

Figure 4. **Measurement from C7 to insensitive area of upper extremity.**

down the extremities. Patients with peripheral neuropathy will show equal mapping in their feet with the insensitivity beginning in the toes and continuing proximally. If the pattern extends up the calf, the patient's fingertips and hands should be tested. True peripheral neuropathy will eventually involve all four extremities and can be checked by measurement from L5/S1 down the leg compared to the measurement of C7 down the arm. The points where the patient is insensitive should be approximately the same (see *Figures 3* and *4*).

Other neuropathic conditions. When the pattern of sensation does not follow the criteria for peripheral neuropathy, other underlying conditions exist. The neuropathy could be caused by single nerve damage or entrapment (following a dermatome pattern). Vascular disease can cause neuropathy, but the patient would have an uneven pattern or have only one extremity involved.

Why are we concerned about neuropathy? Because patients will not compensate for high plantar pressures by changing their gait pattern, will not suffer pain or discomfort, or even limp when damage occurs. When we can provide an optimum environment for the foot, equalize pressures and educate patients, they can continue ambulation without damaging their extremities.

Diabetes and Peripheral Neuropathy

For most practitioners, diabetics display the highest incidence of neuropathic limb complications. This group has a high incidence of

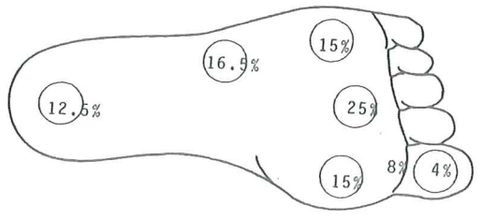

Figure 5. **Seventy-one percent of all ulcers occur on the forefoot.**

peripheral neuropathy as well as dysvascularity to complicate the healing process.

Diabetes is the third leading cause of death in the United States. An estimated 14 million people have the disease (half undiagnosed), and each year about 700,000 new cases develop—many diagnosed when treated for complications. The medical community estimates that $21.5 million is spent annually on diabetic complications.

The diabetic neuropathy process can begin regardless of the patient's history of control although patients with a history of compliancy and good control in their disease may have fewer or less severe complications. Neuropathy begins with nerve damage and motor loss in the feet (claw toes). Patients will suffer sensory loss in their hands, leaving them unable to feel physical changes in their feet. Several complications can occur. Retinopathy causes patients to be unable to see changes in foot conditions. Autonomic neuropathy can impede senses, including smell, as a warning of infection. A third, very destructive complication in the neuropathic limb is Charcot joint, which destroys joint structure and can lead to deformity.

Ulceration

Four types of stress can cause destruction of tissue in the neuropathic limb.

Ischemic necrosis is usually seen on the lateral side of the fifth metatarsal head due to a tight shoe. A very low level of pressure (2 to 3 psi) over a long period of time causes death of tissue.

Mechanical destruction occurs when direct injury caused by a high pressure inflicts immediate damage to tissue. This may also be caused by heat or chemicals that damage the skin.

Inflammatory destruction occurs with repetitive moderate pressures (40+ psi). Inflammation gradually develops and weakens the tissue, leading to callous and ulcers.

Osteomyelitis (and other sepsis) destruction is the result of moderate force in the presence of infection. Infection is spread as forces are applied.

The highest incidence of ulceration occurs at sites of previous ulceration. A newly healed ulcer is covered by thin skin that is likely to tear. In completely healed ulcer areas, some scar tissue may adhere to underlying structures (see *Figure 5*).

The Wagner Scale is used to grade ulcerations.

- Grade 0 ulcers have skin intact.
- Grade 1 is a superficial ulcer.
- Grade 2 is a deeper ulcer to tendon or bone.
- Grade 3 ulcers contain an abscess or osteomyelitis.
- Grade 4 has gangrene on the forefoot.
- Grade 5 has gangrene over a major portion of the foot.

O&Ps are consulted in grade 0 and 1 conditions but may be called in for special cases of higher grades when the patient refuses or is not a candidate for other medical intervention.

Figure 6 shows a typical Grade 1 ulceration that will usually become a Grade 0 after excessive stress to the area is redistributed. *Figure 7* is commonly seen after bony destruction has recalcified, leaving a bony deformity that is subject to high levels of stress. This deformity must be accommodated with footwear to reduce high pressures. *Figure 8* reveals a Grade 2 ulceration with overlying callous buildup due to a hallux valgus condition that was not accommodated with footwear and an insert. *Figure 9* shows a Grade 3 ulcer that is infected and draining due to repetitive stress. This is a common occurrence when one toe is removed, and excessive forces are transferred to adjacent areas. This patient is neuropathic and ambulates without a limp or any sign of discomfort. Grade 4 feet can be found in limbs suffering previous dysvascular lesions as in *Figures 1a* and *1b*.

With regular follow-up and intervention,

Figure 6. **Grade 1 ulceration.**

grade 1 and 2 ulcerations have a high probability of becoming Grade 0. Grade 3, 4 and 5 ulcers require extensive medical attention before orthotists and prosthetists can be involved in treatment.

Clinical Evaluation

Clinical evaluation involves a visual and physical examination, monofilament testing and temperature recording. These processes provide subjective and objective criteria to be used for O&P design as well as in follow-up evaluation.

The visual and physical examination begins before the patient is taken to the exam area. As you greet the patient, note injuries to the hands (burns, etc.) indicating a high level of peripheral neuropathy, especially atrophy of the thenar eminence. Note the patient's gait. Neuropathic patients will not limp if they have ulcers because they are unaware of a problem. Diabetes creates a trineuropathy with loss of sensory, motor and autonomic nerves. Other losses include knee and foot reflexes and hot/cold sensation. If the patient has motor neuropathy, he or she may have a drop foot or other weakness.

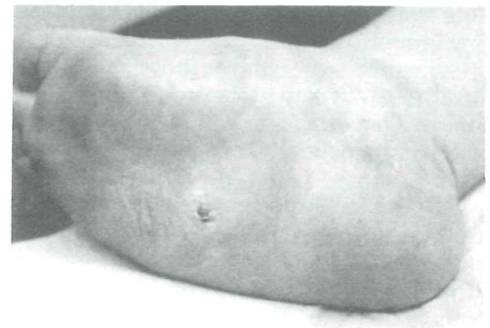

Figure 7. **Grade 1 ulcer over bony prominence.**

Figure 8. **Hallux valgus deformity with Grade 2 ulcer.**

Figure 9. **Grade 3 ulceration.**

Note assistive devices, and visual and other impairments.

The patient will remove shoes and socks. Never take the patient's word for the condition of his or her feet. You must personally examine the patient's feet at every appointment.

With the feet exposed, note skin discoloration, texture, keratin buildup and other abnormalities. Claw toes result from loss of intrinsic control, allowing the PIP and DIP joints to pull into abnormal alignment. Toes may be normal, moderately clawed or severely clawed. Feel the foot and calf for severe temperature differences and loss of hair growth (indication of vascular impairment).

This exam process will usually indicate the level of neuropathic advancement. *Figure 10* shows the physical exam where range of motion is evaluated, especially that of the great toe, which must have extension range to obtain low pressures during gait and toe clearance. Hallux rigidus deformities are usually due to the fibrosis of a healed first metatarsal head ulceration. The rigid great toe will require a full shank in the shoe and a rocker bottom.

Note areas of callous (high stress) and skeletal alignment. Previous injuries and deformities lead to high pressure areas. Fat pads tend to migrate distally, leaving metatarsal heads without padding. Unusual areas of callous and ulceration may be due to wedged shoes or inserts. These patients cannot be corrected, only accommodated.

To determine the amount of sensation the patient retains, use the Semmes Wienstein monofilaments. The monofilament should first be shown to the patient and tested on his or her upper arm so the patient will know what to expect. Begin the test with the 4.17 monofilament indicating normal sensation. If the patient cannot detect sensation, continue to 5.07 and 6.10.

To use the monofilament, hold the handle so the monofilament is perpendicular to the skin surface. Touch the end to the skin, deflect (bend) the monofilament and remove. Note when the patient responds and the size of monofilament he can feel. Map the area that has no sensation. Never apply the monofilament to callous, ulcer site, scar or necrotic tissue—only to good skin closest to desired site (see *Figure 11)*. Readings will not be accurate from areas of damaged tissue.

Figure 10. **Physical and visual examination.**

Figure 11. **Semmes Wienstein monofilament test.**

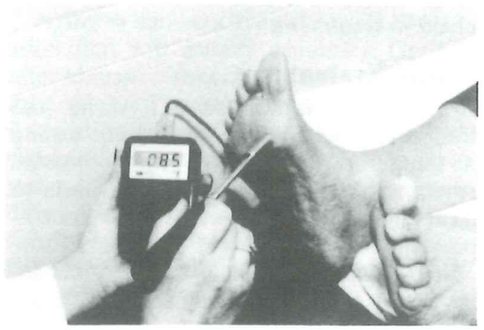

Figure 12. **Temperature recording.**

Temperature readings will be taken at 10 locations on the foot (see *Figure 12)*. Temperature rise is an inflammatory response to trauma. These locations are selected because of incidence of ulcerations (see *Figure 5)*, including the arch, dorsal surface and alternating toes. Temperatures can be taken with a thermocouple unit, which is expensive and must contact the skin or with an infrared unit, which costs more but is a valuable scanning tool.

Recording temperature provides an objective means of determining areas of high stress before ulceration occurs. The foot must be exposed to room temperature for five to 10 minutes to allow normal tissue to cool and differentiate elevated tissues. A difference in 3°F between adjacent areas indicates a highly stressed area. A decrease in temperature in previously highly stressed areas indicates that the insert relief has been successful in redistributing pressure.

Evaluation

With the evaluation and measurements compiled, the information form can be completed. Temperatures should be recorded in corresponding circles, noting areas of high stress. Remember that temperatures normally increase as measurements are taken proximally (closer to the heart). Note ulcer grade using Wagner Scale. *Figure 13a* is a standard evaluation form; *Figure 13b* shows a completed form, noting problem areas and deformities. The categories on the form are used to define insert requirements, ulcer and deformity history, and resulting follow-up.

When following the categories A, B, C, D, E across the form, note important differences in the patient evaluation that will require varied treatment and follow-up schedules. Category A patients may or may not feel the 4.17 (1 g) monofilament, but they do have protective sensation because they detect the 5.07 (10 g). These patients will change gait or remove footwear in response to pain and discomfort. They can be scheduled for annual follow-up and require a well-fitted shoe with cushion for comfort and shock absorption.

Category B, C and D patients are similar only because these patients do not feel the 5.07 (10 g) monofilament and do not have protective sensation. These patients have neuropathy and do not retain enough nerve signals to protect their feet from damage due to mechanical stresses.

The Category B patient is seen every six months and requires accommodative molded inserts. These patients have no history of ulcer or deformity.

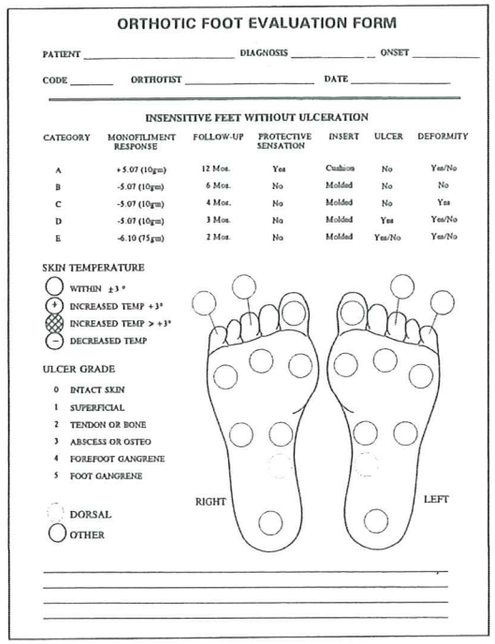

Figure 13a. **Evaluation form.**

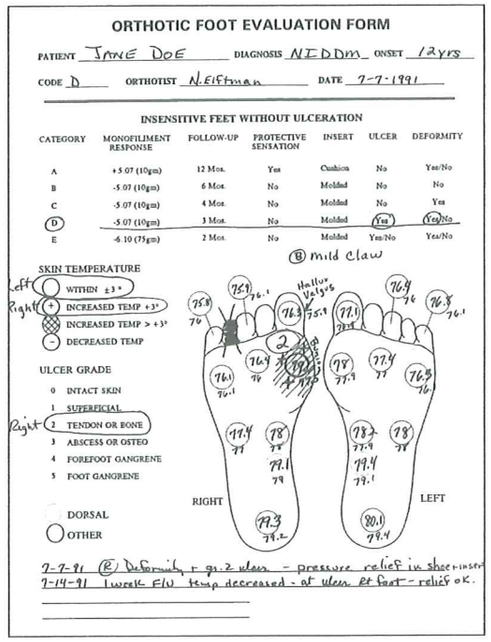

Figure 13b. **Completed evaluation form.**

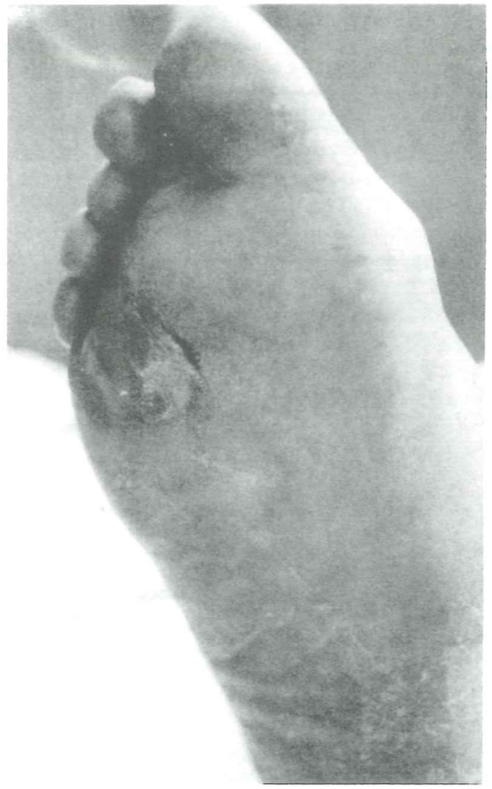

Figure 14. **Callous before debridement.**

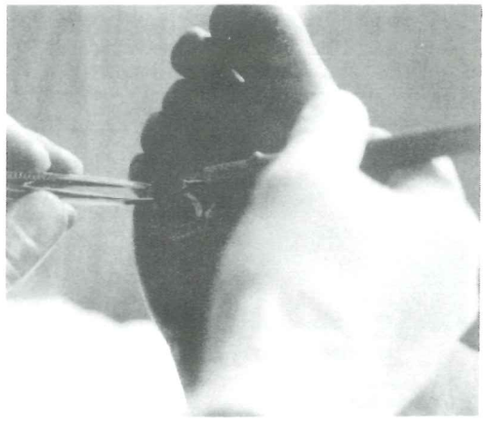

Figure 15. **Debridement of callous.**

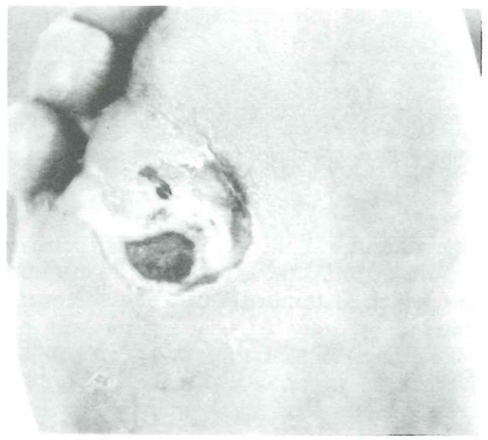

Figure 16. **Exposed sinus tract formation.**

Category C patients require the same protocol as B except follow-up is increased to every four months. These patients have a deformity that may require periodic inspection and insert modification.

Category D patients will increase follow-up appointments to every three months because of a history of ulceration. Previous ulcers will require special care or re-ulceration is likely.

The insensate foot—Category E—is common in diabetics. These patients cannot feel the 6.10 (75 g) monofilament—a force so high that many patients come in with foreign objects embedded in their feet. When patients cannot feel forces of this magnitude, they must be seen every two months regardless of ulcer or deformity history.

Complications of Neuropathic Feet

The goal of orthotic design is to provide accommodative (molded) cushion inserts for the foot that will distribute pressures, reduce high stress areas and provide shock absorption. A common problem occurs when a caloused area is not debrided on a regular basis to reduce pressure. *Figure 14* shows a common area of callous (high stress).

When debrided and exposed (see *Figure 15)*, there is a sinus tract (see *Figure 16)* that, if not treated, continues to migrate under the skin with the mechanical stress of weight-bearing. This can lead to infection of bone and serious complications.

Another problem is the neuropathic foot cannot detect proper shoe size or shape to thereby prevent high pressures. Patients will select a shoe that is one to two sizes too small

Figure 17. **Shoe was not fitted ½- to ¾-inch beyond longest toe.**

Figure 18. **Shoe was too short.**

because they feel it is a good fit. They do not have the sensory feedback to properly select shoes so they must be told what size shoes to buy. The length must be ½- to ¾-inch beyond the longest toe. When it is not, the toe suffers ulceration (see *Figures 17* and *18)*. The shoe must be a soft leather, void of stitching or contours at toes and deep enough to accommodate an insert under the full foot.

When the nail and dorsal area of the great toe show stress, there is usually a problem with great toe extension (thrusting upward) during gait, and a higher toe box is required (see *Figure 19)*. Lesions as in *Figure 20* are commonly from a shoe with a narrow or pointed toe.

The neuropathic foot must be accommodated to reduce risk of ulceration. Common deformities include hypertrophic nails, claw toes and deformities (see *Figures 21, 22* and *23)*. *Figure 24* shows a common ulcer site due to great toe pronation and requires that the insert be high on the medial side of the great toe.

Autonomic Neuropathy

An added complication with diabetes is autonomic neuropathy. Sweat and oil are no longer produced and secreted into skin layers. The elasticity is lost, and keratin builds up, hardens, cracks and allows entry of bac-

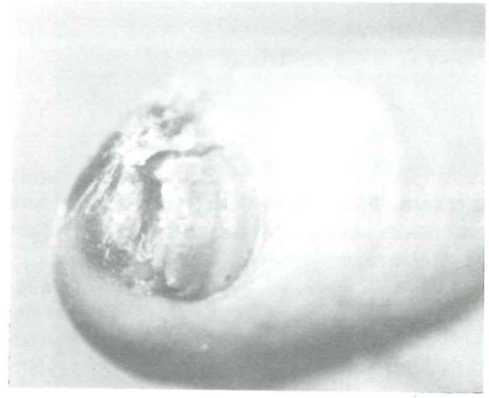

Figure 19. **Great toe extension.**

Figure 20. **Pointed toe shoes provide high pressure to toes.**

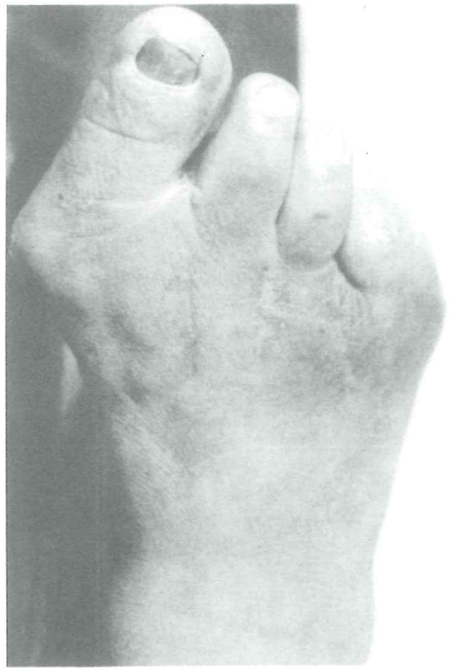

Figure 21. **Hallux valgus deformity.**

Figure 22. **Amputation-lateral resection.**

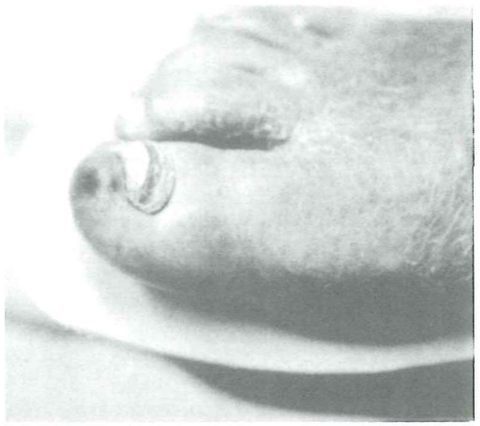

Figure 23. **Great toe extension. Damage to nail and dorsal toe.**

Figure 24. **Ulcer due to great toe pronation.**

teria (see *Figure 25).* Feet that sweat rarely ulcerate. Skin tears with joint flexion and extension because sweat and oils no longer keep the skin elastic and pliable.

The skin tends to suffer many dermatological conditions (see *Figure 26)* and reactions. The patient must be taught to moisturize skin after bathing to retain moisture. Also, patients must not use tape on dry, fragile skin. When a Band-Aid or tape is removed, an open lesion can be created, providing an entry for infection (see *Figure 27).*

Vascular Conditions

The neuropathic limb often exhibits vascular conditions that require control of excess edema. Discuss with the prescribing physician the stocking to be applied to the limb.

Venous stasis is a complication—due to high pressures in the capillary system—that produces open lesions. Venous stasis ulcers (see *Figure 28)* are difficult to treat and manage with pressure-gradiated stockings. Patients with a neuropathic limb cannot continually walk on a stocking seam or opening

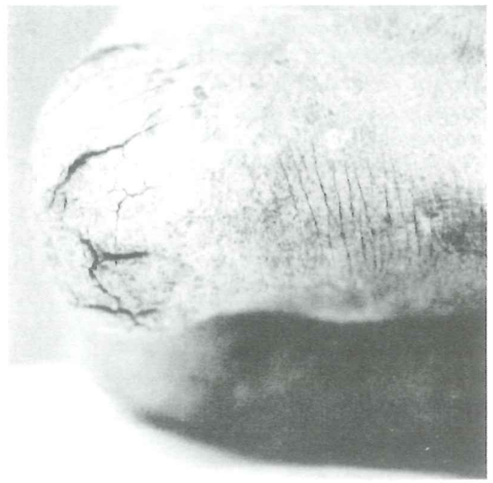

Figure 25. **Keratin layer on heel that is dry and cracked.**

Figure 26. **Common dermatological problems due to autonomic neuropathy.**

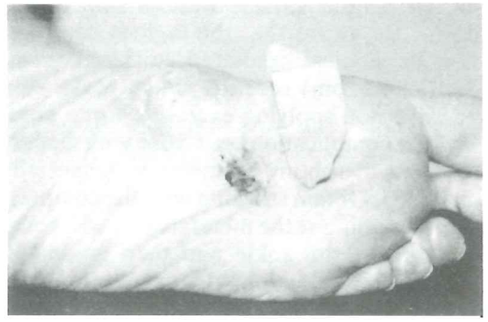

Figure 27. **Removal of bandage can damage underlying tissue.**

Figure 28. **Venous stasis ulceration.**

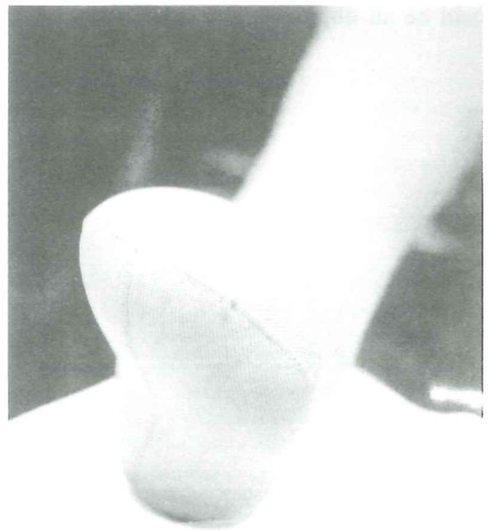

Figure 29. **Compression hose on transmetatarsal amputation.**

on the plantar surface without skin breakdown. Be aware that the highest compression in medical gradiated stockings (standard or custom) is at the ankle. Make sure you are not applying excessive force here. Further complications can arise with zippers or seams over bony prominences (especially malleoli). Obtain stocking with the compression beginning at the metatarsal heads, equal pressure to the ankle and then graduated proximally with minimal seams (see *Figure 29).*

Patient Education

Patient compliancy depends on education. Patients must be taught to inspect their feet daily for fungal (nails) problems, callous, redness, swelling, heat and maceration between toes. Socks must not be mended, have thick seams or holes. Shoes must be inspected for wear and foreign objects.

Neuropathy can cause a "cold" sensation that is disturbing to patients. Burns can be prevented by warming feet with socks instead of hot water bottles or heating pads.

An excellent way to improve compliancy is to trace the perimeters of ulcerations onto transparent film (exposed X-ray) and let patients evaluate their own healing rate between follow-up appointments. Patients may be discouraged that callous areas decrease slowly. The repeated temperature readings will be an objective method of successfully reducing stress to the area. Callouses retain a three- to four-month memory and continue to replenish for a short time even though weight reduction is sufficient for long-term management. Patients can control callous production by following their daily bath with five strokes over the callous area with a pumice stone.

Conclusion

While neuropathy exists in many disease processes, we are concerned with the growing number of diabetics requiring management of chronic disease-related complications. These patients must be evaluated and followed before ulceration occurs. When breakdown begins in one diabetic foot, the contralateral side is commonly involved within 18 to 36 months so prophylactic measures are especially important.

There are many considerations in the neuropathic limb, and it is hoped this method of clinical evaluation with treatment and follow-up will assist the orthotist's and prosthetist's involvement in a complicated disease process. □

Author

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