Altered Biomechanics in Diabetic Foot: Basics and Advances

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Abstract

The diabetic foot is one of the most feared complications of diabetes. The diabetic foot also requires offloading of the foot after medical or surgical management. To understand the offloading of the foot, one has to understand the biomechanics of the foot. Especially the altered biomechanics which occurs in the diabetic foot. If the biomechanics is understood properly, it helps in the wound healing of diabetic foot ulcer. Also, it helps in the prevention of recurrence of the ulcer. An attempt is made in this article to focus on the assessment and various approaches to taking care of altered biomechanics for comprehensive management of diabetic foot.

Keywords: Diabetic foot, off-loading, altered biomechanics, assessment of ABM, surgical correction, splinting, footwear

Introduction

Diabetic foot is one of the most significant and devastating complications of diabetes and is defined as a foot affected by ulceration that is associated with neuropathy and/or peripheral arterial disease of the lower limb in a patient with diabetes.[1] Management involves a multimodal approach involving improvement in neuropathy, vasculopathy, immune system, infection control and appropriate off-loading. Sound knowledge of normal biomechanics and its alterations enables a podiatrist in effective off-loading and enhanced wound healing in diabetic foot ulcers.

The burden of Diabetic Foot in India

According to a recent review to study the burden of diabetic foot ulcers (DFUs) in Indian patients based on findings reported in published literature, out of 62 million diabetics in India, 25% develop DFUs, of which 50% become infected, requiring hospitalization while 20% need an amputation.[2]

We are familiar with the famous pathophysiology triad (Figure 1). We mostly discuss neuropathy, vasculopathy, immune mechanisms & infection control only. But this is only incomplete management of diabetic foot. The diabetic foot also requires offloading of the foot after medical or surgical management. To understand the offloading of the foot, one has to understand the biomechanics of the foot, especially the altered biomechanics (ABM) which happens in the diabetic foot. If the biomechanics is understood properly, it helps in the wound healing of diabetic foot ulcer. Also, it helps in the prevention of recurrence of the ulcer. So, this discussion is only on the Biomechanical aspects of diabetic foot, its understanding and implementation in the management of diabetic foot.

Diabetic Foot and Amputation

Plenty of evidence support that diabetic foot ulcers precede approximately 85% of all amputations performed in diabetic patients and 40–70% of all nontraumatic amputations of the lower limbs occur in patients with diabetes.[3] Diabetic foot neuroischemic ulcers take a longer time to heal and will more often lead to limb amputation.[4]

The prevention of diabetic foot is crucial, considering the negative impact on a patient's quality of life and the associated economic burden on the healthcare system.[5] Thus it demands that every attempt should first be made to preserve the limb.

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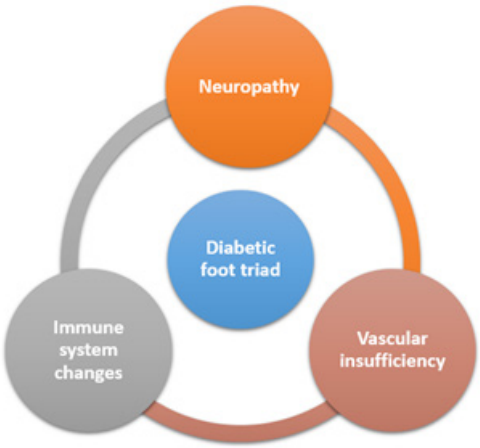

Figure 1. Diabetic foot triad

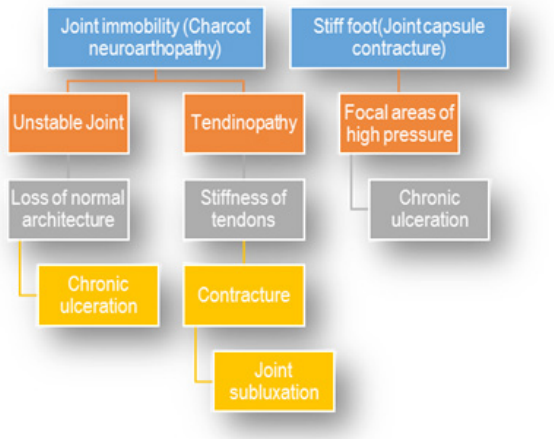

Figure 2: Altered biomechanics of the diabetic foot and its outcomes

Limb Salvage and Biomechanics in Diabetic Foot

The understanding of the biomechanics of the diabetic foot is very important in the context of limb salvage. As rightly pointed out by Paul J Kim, the principal goal of limb-salvage surgery is to preserve as much of the bone and surrounding soft tissue structures as possible to maintain function.[6]

An appropriate biomechanical examination is essential before and after limb salvage. The goal is to prevent ulcer recurrence or new ulcer development at another location by addressing biomechanical imbalances through a custom foot and ankle devices and elective surgical procedures. It is not only important to salvage the foot, but it is as important to provide a functional foot.

Biomechanics of Diabetic Foot

The biomechanics of the diabetic foot is different from that of the non-diabetic foot. Fundamental changes occur in the overall gait with specific maladaptive processes occurring in the diabetic foot.[7]

The biomechanics of the foot is a complicated and broad subject. Joint immobility plays a pivotal role in the faulty biomechanics of the foot and ankle in diabetic patient. Structural changes occur within the tendon and capsule of the diabetic patient. A disorganized pattern emerges in the diabetic tendon, capsule, and ligament. Over the period in the untreated cases, these changes lead to decreased elasticity and tensile strength, which itself may not be problematic but these changes lead to either joint instability or overall stiffness of the foot, which in either case results in poor foot biomechanics. The outcomes of altered biomechanics are illustrated in Figure 2.

The abnormal mechanical loading of the foot, such as repetitive moderate pressure applied to the plantar aspect of the foot while walking. Diabetic peripheral neuropathy causes changes in foot structure, affecting foot function. These changes can compromise the tissue's ability to uniformly distribute forces and increase the likelihood of overloading and injury, subsequently leading to increased plantar foot pressure resulting in the development of diabetic foot ulcer.[8]

In a study involving Ten healthy young (HY), healthy old (HO) and old diabetic patients (DB), upon performing indentation tests at two sites in the heel and measuring the respective thicknesses of the skin and fat at the indentation sites with computed tomography (CT). The Diabetic set of patients had stiffer fat tissue than the normal subjects in the same age group but had the same soft skin.Thus, under the same mechanical loading, these aspects can cause different mechanical stress conditions in a diabetic foot than in a normal foot, making the diabetic foot vulnerable to the initiation of mechanical breakdowns such as ulcers.[9]

Factors affecting normal biomechanical loading in the diabetic foot:

- Deformities
- Abnormal walking pattern
- Limited joint mobility
- Repeated plantar pressure
- Shear stress

Assessment of the Biomechanics of Diabetic Foot

A study concluded that measurements of plantar soft tissue stiffness can improve the prediction of diabetic foot ulcers in moderate- or high-risk patients. Thus, it is at most important that a thorough assessment of biomechanics of the diabetic feet should be performed along with the normal in-depth examination. Biomechanical assessment of the foot and ankle is im-

portant to identify potential risk factors for the diabetic foot. A thorough assessment involves biomechanical assessment for Muscle Strength, muscle length, foot arch, foot deformity, footwear examination, first ray & fifth ray, Q angles and postural examination, as shown in-Figure 3.[10] Various types of foot deformity include flat feet i.e., overpronation of feet, pes calcaneus, pes equinus, club foot, insufficient push-off, achilles tendinitis, plantar fasciitis, hallux abducto valgus, hallux rigidus, metatarsalgia, hammer toes, calluses etc.

Figure 3A: Biomechanical assessment of diabetic foot

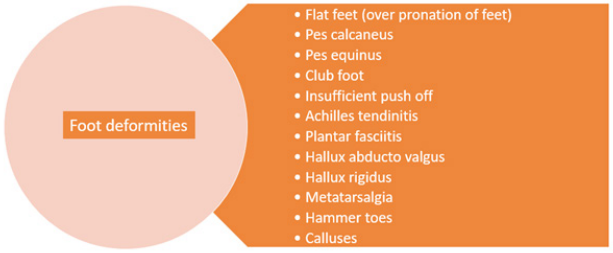

Figure 3B: various foot deformities

The battery of tests are employed to understand the biomechanics of diabetic foot which include

- Touch and pressure -Semmes Weinstein Nylon Monofilament 10gm,
- Vibration Perception Threshold (VPT)- by tuning fork
- Thermal thresholds i.e. sensation of heat and cold
- Foot pressure measurements by pedobarograph
- Reflex assessment by using tendon hammer

Management

The 360-degree care of the diabetic foot is not only limited to salvaging the foot, but it also extends to provide a functional foot. The primary goal here is to prevent ulcer recurrence, prevent the development of new ulcer at another location. This involves addressing biomechanical imbalances through the custom foot and other devices.

Below is the list of few therapeutic interventions which can be considered for the management of diabetic foot and address the problem of altered biomechanics of the diabetic foot.

- Therapeutic Exercises
- Health Education & Homecare activities
- Splinting
- Footwear

Therapeutic exercise

Therapeutic exercises may involve Physiotherapy which can help people to maintain good blood glucose control and achieve optimal weight. Isotonic exercise like walking (with a break interval, in the neuropathic foot) & exercise of small muscle of foot will benefit a person with diabetes. Limited joint mobility is corrected by teaching active exercise to toes and foot. Burger-Allen exercises will facilitate and activate the blood circulation in the lower extremities. Teach the patients offloading techniques that reduce the mean strain like crutch walking, wheelchair training. During offloading it's necessary to prevent muscle wasting by active physiotherapy for leg & foot muscles.

Health care education

Health care education may involve proper education about an insensitive foot. Focusing on the importance of regular examination of the sole. Immediate reporting if there is any change in sensory perception or motor abnormality. Checking the nails for blood flow or any discolouration. Checking the feet regularly for blood circulation, and blisters, callus, corns, wound. Education about proper dressing the wound, adequate rest to the affected part, avoiding long-distance walking and wearing proper footwear.

Surgical correction

Structural deformity with attendant high plantar pressures is a predisposing risk factor to diabetic foot ulceration (DFU) development and recalcitrance in the neuropathic foot. Furthermore, feet with deformities that cannot be adequately offloaded by footwear therapies are at high risk for DFU recurrence. Common deformities contributing to the development of DFU in-

Table 1. Classification of diabetic foot surgery

Class I	**Elective**	Reconstructive procedures on patients without neuropathy. Examples: Hammertoe, bunion, osteotomy, Achilles lengthening (TAL), etc.
Class II	Prophylactic	Reconstructive procedures performed to reduce the risk of ulceration or re-ulceration in neuropathic patients who do not have a wound present. Examples: Keller arthroplasty, TAL, Exostectomy, Charcot reconstruction, etc.
Class III	Curative	Procedures performed to assist in the healing of open wounds. Examples: Metatarsal head resection, Keller arthroplasty, toe amputation, etc.
Class IV	**Emergent**	Procedures performed to arrest or limit the progression of infection. Examples: Incision & drainage, Guillotine/open amputation, fasciotomy, etc.

clude hammertoes, prominent metatarsal heads, hallux limitus, gastrocnemius-soleus equinus, Charcot foot, and partial foot amputations. Each leads to high plantar or in-shoe pressures that contribute to tissue inflammation and subsequent break-down. Ameliorating these high pressures by structurally realigning or removing underlying bony prominences is the underlying rationale for foot surgery. In the presence of infection and/or osteomyelitis, surgery frequently becomes a critical component of care. Although the current Guideline on interventions to enhance the healing of diabetic foot ulcers concentrates primarily on non-surgical modalities, our premise remains that surgery generally plays a key role in the overall management of DFU.[11] The classification of diabetic surgeries is briefed in Table 1.

Splinting

Total contact cast is the appropriate way of resting the foot with a diabetic plantar ulcer. It helps to distribute the weight along the entire plantar aspect of the foot, helps to reduce shear forces and produces shortened stride length and a decreased walking velocity.

Footwear

The education and selection of footwear should take into consideration the necessity to relieve excessive plantar pressure, reduction of shock, reduction of shear (frictional forces), accommodation of minimal deformity and stabilization of deformity. Footwear with rocker soles can be considered for altered biomechanics in the diabetic foot. Different rocker soles are available to serve a different purpose. Mid rocker soles help to relieve pressure metatarsal. Heel to toe rocker soles is useful in fixed claw toes, hammertoes, calcaneal ulcers. Toe only rocker soles are good for ulcer metatarsal heads. Severe angle rocker sole is useful in hallux rigidus, ulcer on the distal part of the toe, hammertoe, ulcer metatarsal heads, whereas negative heel rocker sole is good for the fixed ankle in dorsiflexion.

Conclusion

Normal biomechanics of the foot and ankle are extremely important for the normal functioning of the lower limbs. Faulty or altered biomechanics of the foot and ankle in the diabetic patient can be considered pivotal in the pathogenesis of diabetic foot. Various approaches are available for the effective management of altered biomechanics. After a thorough assessment, every attempt should be made to salvage the limb and prevent amputation. The management should be individually tailored to every patient, after understanding the biomechanics of the affected foot.

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