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Rehabilitation of a Diabetic Amputee: Sequelae, Impact and Effect on the Precious Limb

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Abstract

Background: In a patient who has undergone a major amputation of one lower limb, the role and function of the precious limb is of paramount importance. We assume that once the patient has been rehabilitated with a prosthesis, the static plantar pressure distribution is equal over both the amputated limb and the precious limb. There is not much published literature that actually compares the distribution of the static plantar pressure over the precious limb available in India. This study aimed at studying the characteristics of static plantar pressure distribution after a major amputation in the precious foot of diabetic patients with and without prosthesis once they have been rehabilitated.

Objectives:

1) To compare the relationship between static plantar pressure distribution in the precious limb with and without the prosthesis in diabetic patients who have undergone a below knee amputation and have been rehabilitated.

2) To identify areas of high pressure over the precious limb and suggest appropriate modifications in the prosthetic footwear so as to reduce the static plantar pressure in those high-pressure regions.

Results: The static plantar pressure distribution was found to be significantly higher without the advocated prosthetic device on the amputated limb over the 1st, 2nd, 3rd, 4th, and 5th metatarsal- . The ratio of the forefoot versus the hind foot pressures with and without a prosthesis was also noted to be significant ($p = 0.002$).

Conclusions: This variation in the pressure distribution over the precious foot disproved our hypothesis that there is an equal spatial redistribution in static plantar peak pressures in the precious limb following rehabilitation with a prosthetic device in a diabetic patient who has undergone a below knee amputation and that a prosthesis alone is not adequate to protect the precious limb.

Keywords: *Diabetes mellitus, precious foot, static plantar pressures.*

Introduction

The life of a diabetic amputee depends much on the status of the precious limb. The precious limb is exposed to the same factors as the amputated limb and is under great risk. The rate of a major amputation involving the precious limb has been documented to vary between 6-30% and that too mostly within 1-3 years. This limb is therefore rightly referred to as the precious limb.

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This study aims to look at the redistribution of plantar pressures that can trigger the initiation of pathological changes and compound progression leading to an amputation. At the start of the study we assumed that the use of a prosthetic device addresses plantar pressure adequately to prevent further pathological changes in the precious limb. This study aims to look at the redistribution of plantar pressure, in such rehabilitated patients.

Diabetes mellitus is an epidemic with a projected estimate of 69 million affected by 2025 in India[1]. The CURES study estimates that 50% of the population affected with diabetes mellitus will develop some sort of neuropathy, causing impairment resulting in foot ulcerations and subsequent amputations over the next twenty years [2]. Sinnock et al showed that diabetic patients had a 15-fold higher rate of lower limb amputations and Reiber et al–added that nearly 6%-30% of amputees had the possibility of undergoing a contralateral amputation within 1-3 years of the initial amputation[3,4]. A similar trend was noted in our institution, hence it was decided to look closely at this group of patients with an aim to identify preventable causes. The prevention and management of diabetic foot pathology is very varied in the country with no common management protocols. The most dreaded of the various diabetic foot pathologies include a diabetic foot ulcer leading on to a major amputation. A combination of diabetic foot pathologies could result in increased financial burden on patients including a life long physical disability[4,5].

The aim of this study was to identify areas of high plantar pressures on the contralateral precious limb and to see if the given prosthetic device had any deleterious effect on plantar pressures along with recommendations to alter the footwear.

Material and Method

This was designed as an observational study and approved by the Institutional Review Board (9682). A total of 48 consecutive diabetic patients who had undergone a trans-tibial amputation and were rehabilitated with a Jaipur foot prosthesis were recruited for the study. The precious limb was the main focus of the study and static plantar distribution was measured over the precious limb with and without the prosthetic limb. The Harris Mat was used as the tool to assess the static plantar pressure distribution. The following parameters were also assessed: Sensory testing assessment, Vibration testing assessment, Temperature assessment, Fasting, post-prandial and glycosylated hemoglobin levels.

All subjects were subjected to the following as part of the assessment. A full medical history including age of onset of diabetes mellitus, type of antihyperglycemic therapy and history of foot ulceration was documented. Complete examination , anthropometric measurement, including height, weight and Body Mass Index (BMI) were assessed. Sensory assessment of the precious foot was achieved using the Semmes-Weinstein monofilament. Failure to sense the 10g monofilament was used as the determining factor for use of protective footwear and accommodative orthotics. The monofilament tests the single point perception test with a specificity being as high as 92%[6].

Neurological assessment was carried out according to the modified neuropathy disability score (MNDS) designed by Young et al. The total maximum score was 5 and a score of >1 was defined as diabetic peripheral neuropathy [7]. All the 48 patients recruited in the study had an MNDS score of > 1.

Findings

The static plantar distribution over the first metatarsal was 15.5N/cm2 compared to 72 N/cm2 without the prosthesis,(Figure 1) similarly the pressure over the second metatarsal was 16.6N/cm2 and 65N/cm2(Figure 1). The pressure distribution over the third metatarsal was 14.5N/cm2 and 71N/cm2(Figure 1) and over the fourth metatarsal was 14.5N/cm2 and 73.5N/cm2 (Figure 1). The pressure distribution over the fifth metatarsal with and without the prosthesis was 9.5N/cm2 and 84N/cm2(Figure 1). All the static plantar pressures over the precious foot with and without the prosthesis over the contralateral side were statistically significant. We also calculated the ratio of the forefoot pressures versus the hind foot pressures and that too was found to be statistically significant.(Figure 1). This implies that the prosthetic limb off- loads but transfers the pressure to the forefoot.

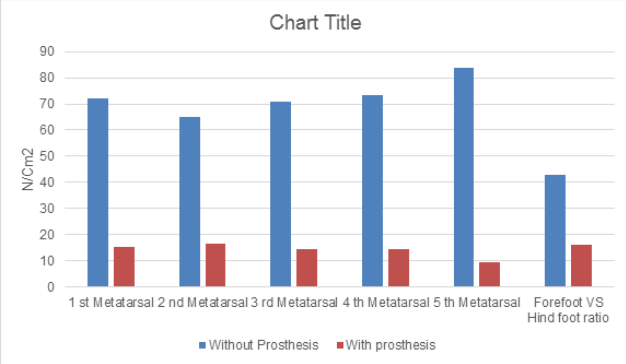

Figure 1

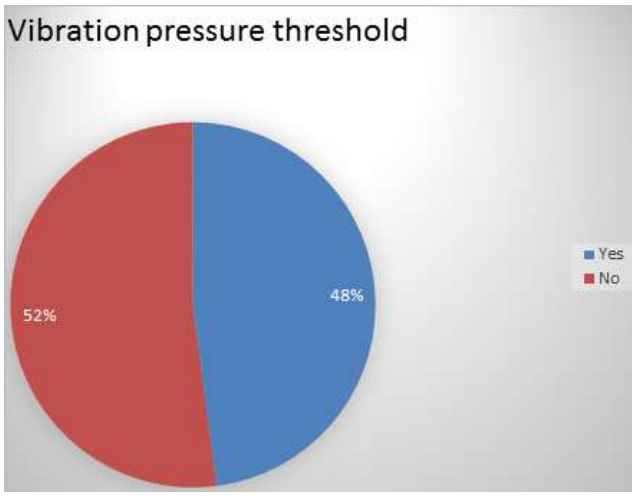

Figure 2

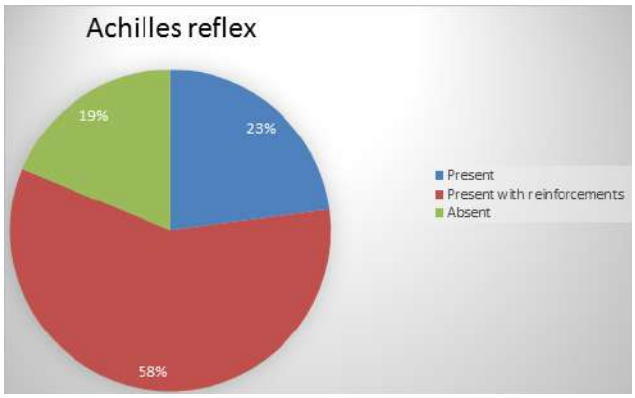

Figure 3

Discussion

Plantar ulceration , leading to amputation of a limb or part of a limb is a dreaded complication of diabetes mellitus.. The etiology of diabetic ulceration is known to be multi-factorial, and while plantar pressure is thought to play an important role in triggering it , the direct association between elevated baseline plantar pressure and subsequent ulceration at that specific location has not been shown. Nearly 30-50% of diabetic patients suffer from Diabetic peripheral neuropathy of which chronic sensorimotor distal symmetric polyneuropathy is the most common and the development of diabetic foot ulcers and subsequently limb amputation remains a major complication[7,8,9,10].

Diabetics have a 15% chance of undergoing a lower extremity amputation during the course of their lives. Patients above the age of 65 years account for nearly 55% of people who have undergone a non traumatic cause of lower limb amputation[11]. Nearly 65% of the lower extremity amputations were observed to be in those patient who had a chronic non healing diabetic foot ulcer and were diabetic for a duration of more than 30 months[12,13].

The role of elevated plantar pressures in diabetic foot ulcers has been evaluated previously by a number of authors (Boulton et al, 1983, Frykberg et al , 1998, Pham et al, 2000). The role of plantar pressures over the precious limb has not been evaluated at any center to the best of our knowledge. The novel finding in our study therefore is that the static plantar pressures were found to be statistically significantly higher($p<0.001$) without the prosthesis over the fifth metatarsal head, in contrast to the work of DV Rai et al, where they found the highest pressures to be located over the second and third metatarsal head. The ratio of the forefoot versus the hind foot pressures with and without the prosthetic device was also found to be significant ($p<0.002$). A similar study in the West by Ledoux et al proved elevated plantar pressures over the metatarsal heads [14]. There are three most common sites over the precious foot which are prone for ulceration and these include, the metatarsal heads, the heel and the hallux. There are a number of theories that have been put forth as to why the metatarsal head is the most common of these sites. Bosjen-Moller, 1979 and Gooding et al 1986 have explained this phenomenon. They feel that the weight borne by the forefoot was significantly higher than that of the body weight. The anatomical factors such as a tight Achilles tendon and thin plantar fascia over the forefoot, as compared to the hind foot are also cited to be contributory factors(Orendurff, Rohr, Weaver 2006).

Peak plantar pressure can be defined as the highest value pressure experienced and this can be measured at both the forefoot and the hind foot. Caselli et al showed that the peak plantar pressure is a good measure of trauma to the plantar foot, and an important factor prior to skin breakdown and ulceration [15]. Attempts to determine a peak plantar pressure threshold for ulceration have

failed and the absolute magnitude of pressure values among different studies is not consistent [16] . In our study, the average pressure over the metatarsal heads were found to be 36.3N/cm2, previous studies have shown the average non ulcer pressure in diabetic feet to be 19.428N/cm2[17]. These differences seen in these plantar pressure measurements was possibly due to the differences in sensitivities of the instruments; Harris mat used in this study for economical reasons versus the F-scan Mat Tekscan used in other studies quoted.

We also found that ratio of the forefoot versus the hind foot pressures with and without the prosthesis was 16N/cm2 and 42N/cm2, was noted to be statistically significant ($p<0.002$). We postulate the theory behind this phenomenon to the glycosylation of the body proteins resulting in a functional shortening of the Achilles tendon, leading to equines deformity and subsequently limited joint mobility, tip toeing and accumulative pressure on the forefoot[18].

Sensory assessment was carried out using the 2g, 4g and 10g monofilament. There were only 9 patients who were able to sense the 2g monofilament and 19 patients who were not able to sense the 10g monofilament. Two studies conducted earlier prove that the prevalence of monofilament insensitivity among patients who went on to develop plantar ulcers was 69% and 91% respectively[19].

The vibratory sensation of the precious foot was analyzed using a biothesiometer. There were 25 patients who were unable to appreciate the vibratory stimulus(52.1%).(Figure 2)

Temperature assessment revealed that 22 subjects had an areas of higher pressure distribution compared to the corresponding area.

The Achilles tendon reflex was evaluated as part of the complete examination of the precious foot. There were 11 patients in whom the reflex was absent, 28 patients who had the reflex present on re-enforcement and 9 patients in whom the reflex was present. (Figure 3)

This clearly strengthens the fact that there are many other reasons why a contralateral amputation is a serious threat.

Short comings of the study

In our study we concentrated only on static vertical plantar pressure. The importance of shear stress has been suggested by a number of authors[20]. We have initiated further studies using of an in-house designed device that will enable us to monitor dynamic plantar pressures over the precious foot this may add to the findings of the completed study.

Conclusions

This variation in the pressure distribution over the precious foot disproved our hypothesis that there is an equal spatial redistribution in static plantar peak pressures in the precious limb following rehabilitation with a prosthetic device in a diabetic patient who has undergone a below knee amputation and stresses that a prosthesis device alone is not adequate to protect the precious limb. Specific foot wear is to be designed to reduce plantar pressure induced anomalies. In addition regular inspection of the foot is of paramount importance.

Interest of Conflict: We declare no conflict of interests.

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Ethical Clearance: Taken from the Institutional Review Board at the Christian Medical College and Hospital, Vellore.

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