Egyptian Journal of Surgery Vol 26, No 3, July, 2007

FUNCTIONAL OUTCOME AND COMPLICATIONS OF PARTIAL FOOT AMPUTATIONS IN DIABETICS

By

Usama Imam,[1] Ahmed Elsawy,[2] Alaadin Balbaa [3]

[1] Departments of General Surgery, Faculty of Medicine, Beni-Suef University, [2] Critical Care Medicine, Faculty of Medicine, Cairo University, [3] Rehabilitation, Faculty of Physical Therapy, Cairo University

Correspondence to: Usama Imam, Email: usama1000eg@yahoo.com

Aim: ***This study was conducted to test a protocol for the management of diabetics scheduled for partial foot amputation in a trial to improve the outcome.***

Methods: ***60 patients underwent partial foot amputation with planned osseous resection and soft tissue coverage followed by postoperative pressure offloading between January 2002 and January 2006.***

Results: ***Amputations performed were ray in (51.6%), trans-metatarsal in (43.3%), Lisfranc's in (3.3%), and Chopart's in (1.7%). Coverage was done by planter flaps in (70%), combined flaps in (13.3%), skin grafts in (5%), and second intention in (11.7%). Complications were failure in (8.3%), adjacent limited arthritis or osteomyelitis in (11.7%), deformities in (15%), and instability in (11.7%). Further interventions were delayed primary closure in (6.7%), skin grafts in (5%), further partial foot amputation in (11.7%), and below knee amputation in (8.3%). The outcome was 53 partial foot amputees (88.3%) able to use their feet for one year without recurrent ulceration.***

Conclusion: ***The marked reduction in failure rate from (52%) in literature to (8.3%) with such protocol is encouraging to pay more interest in partial foot amputations as an alternative to higher ones.***

Keywords: ***Durable, functioning, foot residuum.***

INTRODUCTION

The prevalence of diabetes is increasing allover the world. In the United States, the prevalence is estimated to be %7.3 of adult population.(1) In 1993, the prevalence of diabetes in the Egyptian population over 20 years of age was 9.3%.(2) Furthermore, in the same study, it was estimated to reach 13.3% by the year 2025. Unfortunately, 2.5% of these individuals are added every year to the population suffering from diabetic foot problems. Thus diabetic foot disorders constitute a growing and costly problem of public health concern.(1)

Because of peripheral neuropathy and angiopathy; chronic wounds and /or fungal infections can result in ulcerations, osteomyelitis, severe infections and destruction of the different structures of the feet.(3) Unfortunately, amputation surgery is still a very important line of treatment for stage 3 diabetic foot infections and ulcers.(4) In this field, the option of partial foot amputation, instead of higher ones, has gained a wide acceptance by patients and treating physicians. With a pathology localized to the foot, the removal of necrotic soft tissues and involved osseous portions (partial foot amputations) can provide a good healing environment and save a higher amputation.(5)

In most of partial foot amputations, the midfoot and rearfoot covered by the plantar load-bearing tissues can maintain weight bearing and walking abilities.(6) Consequently, it save the increased energy expenditure by

25% in below knee amputees and 65% in above knee amputees.[7] In addition, the preserved sense of earth after partial foot amputations, usually improves the psychological outcome of surgery.[8]

Unfortunately, the long-term results of partial foot amputations are known to have a high failure rate that end in a more proximal re-amputations in 52% of cases.[9] This was referred to the postoperative altered biomechanics, foot instability, deformities and/or disturbed plantar pressure distribution. These factors induce soft tissue disruption with ulceration, bone exposure, and osteomyelitis that end in recurrence of the diabetic foot state and a future higher amputation.[10]

This study was conducted on diabetic patients scheduled for partial foot amputations. A protocol of certain surgical principles followed by complementary postoperative care was tried. The reflections on the outcome, complications and failure rate were observed and documented.

PATIENTS AND METHODS

Study design: This study involved 60 patients with different patterns of diabetic foot disease treated by partial foot amputations. It was conducted in Kasr el-Aini and Mabarat Misr Kadema hospitals (after approval of the ethical and scientific committees of both hospitals) during the period from January 2002 to January 2006.

Inclusion Criteria: All included patients were 21 years old or more (with no expected further bone growth). Deeply infected wounds, extensive ulceration in a diabetic foot (with Type 3 ulcer depth as classified by Wagner[19] and modified by Brodsky),[3] foot osteomyelitis, resistant or recurrent ulcer after a previous foot amputation were all included. Failed conservative treatment including debridement, wet wound care with hydrocolloid absorbent materials and offloading as stated by Pinzur[4] was accepted as another inclusion criterion.

Exclusion Criteria: All patients with active Charcot arthropathy of the ankle join, associated ischemia, associated venous insufficiency, or collagen vascular disease were excluded from the study. In addition, those with uncontrolled hyperglycaemia or under treatment with corticosteroids, immunosuppressive drugs or chemotherapy were excluded also.

Methodology:

- ***Preoperative assessment:*** Optimization of the general condition and diabetic state was initially done by the internist in accordance with the guidelines of the Diabetes Committee of the American Orthopaedic Foot and Ankle Society.[4] Then local clinical examination to assess the affected parts of the foot, any loculi of infection, state of planter and dorsal skin, the pedal pulsations, sensory and motor functions, joints of the foot and ankle, and the presence of any deformities. Vascular examination was done to check intact pedal pulsations, good capillary circulation with a pressure index more than one (by arterial duplex examination). Patients with inter-pedal white wet skin, bad odor, blistering, peeling, or cracking were referred to dermatological examination. Plain X-ray was done in different views to search for signs of bone or joint infection. Then the patients signed an informed morbidity and mortality consents.

- ***The operative technique:*** According to the rules stated by Wagner,[19] Brodsky[3] and Armstrong,[17] planning for the type of amputation was done considering the site affected, the viable healthy planter skin, and the extent of bone and joint affection. Anesthesia by ankle block was given the priority. Other types as epidural, hemi spinal, spinal, and general anesthesia were used also.

  Depending on the vast arterial supply from the plantar artery, a planter flap adequate to cover the stump was prepared (Fig 1a). If the plantar flap was inadequate, due to nonviable skin, other options were explored as a combination of flaps (Fig 2b), or skin grafts (Figs 3a,b) according to the available cutaneous tissue and osseous contouring.[20]

  Bone cutting, being the cornerstone in these operations, was done as described by Salonga and Blume[8] considering that; A) Intact longitudinal rays were preserved. B) If 3 or more rays were affected, trans-metatarsal amputation was done. C) Planter beveling of the cut osseous edge in case of transverse sectioning (Fig 1a). D) Medial beveling of the first metatarsal and lateral beveling of the fifth one if they were cut (Fig 1-a). E) Osseous prominences were removed to prevent high-risk pressure areas. F) Further remodeling of the bony stump was done to remove necrotic tissues and to have adequate skin cover.

  To avoid deformities, the tibialis anterior and peroneus brevis tendons were preserved as much as possible.[15] To achieve rapid good healing, sharp meticulous dissection ,gentle tissue handling ,minimization of using the diathermy with careful cutting and ligation of nerves and vessels were done. In addition, sesamoid bones, plantar fascial plates, and tendons were removed as stated by Salonga and Blume.[8]

  When feasible, primary closure with drainage was done by approximating the planter flap to the dorsal skin (Fig 1b). Otherwise, delayed primary closure and secondary healing were options for infected cases or those with inadequate soft tissue cover.[8]

- ***Postoperative care and evaluation:*** In addition management of the diabetic state by the internist, the proper antibiotics were given according to culture and sensitivity. Daily care of the wound using saline and skin antiseptics was done for cases with primary closure, but septic cases left for delayed closure or secondary intention were dressed with wet hydrocolloid absorbent materials as described by Pinzur.[4]

  As the recent algorithm suggested by Dahmen[29] for pressure offloading is not yet established, the offloading strategy used was implemented to match the age, activity level, strength, social situation, neurological status and the amputation type of each individual. Early before healing, complete offloading was ordered (for all amputees regardless of body weight) by bed rest, suitable crutches or wheelchairs.

  Later on, after healing, the physical therapist selected the suitable off-shelf offloading device on individual basis (OrthoPrim, Orthomedics, Egypt). The used devices were posterior walking splints, orthotic dynamic system splint and the high supportive shoes (cam walker type) (Figs 6a,b). In addition, diabetic foot shoes and silicone insoles were prescribed for the normal other foot of the patient.

  All the patients were followed over one year for stump healing, soft tissue disruption, the development of ulcers, osteomyelitis, deformities, functional disabilities, and psychological satisfaction.

RESULTS

The age of the enrolled 60 diabetic patients ranged from 38 to 72 years with a mean of 56.5 years. This population was 70% males (42 patients) and 30% females (18 patients).

Presentation: Out of the 60 included patients, 37 (61.7%) were new cases having infections and deep ulcers. As shown in Table 1. The remaining 23 patients (38.3%) presented with complications after previous partial foot amputations in the form of failure of healing due to missed osteomyelitis (Fig 5a) in 6 (10%), planter ulcers opposite inadequately resected bone (Fig 4a) in 13 (21.7%) and stump ulcer after inadequate soft tissue coverage (Fig 2a) in 4 (6.7%).

The extent of bone affection: Clinical and radiological assessment revealed bone and joint affection in the patterns shown in Table 2.

Types of amputation performed: According to the affected bone and available viable soft tissues, the initial amputations were performed as shown in Table 3.

Patterns of coverage: The Planter flap alone (Fig. 1b) was adequately used in 42 patients (70%), 3 of them were closed by delayed primary sutures. In the remaining 18 patients, combination of flaps (Fig 2b) was used in 8 (13.3%) one of them was closed by delayed primary sutures', partial thickness graft (Fig 3a,b) was used in 3 (5%) and 7 (11.7%) were left for Healing by secondary intention Table 4.

Postoperative complications: The most serious complication encountered was failure of the procedure in 5 cases (8.3%) who were managed with a later below knee amputation. These failures were due to uncontrolled ascending infection in 2 patients (3.3%), septic arthropathy of the ankle in one (1.7%), extensive heel sloughing in one (1.7%), and a deep heel ulcer in one (1.7%) Table 5.

The other encountered complications were adjacent limited arthritis or osteomyelitis in 7 cases (11.7%) managed by a further partial foot amputation, deformities of the residuum in 9 (15%) (4 with medial deviation of toes and 5 with equinovarus deformity) corrected with external prosthetic support, and unstable foot residuum 7 (11.7%) (4 with trans-metatarsal amputation and 3 with Lisfranc's or Chopart's amputations) Table 5. The unstable residuum became more stable within few months after being supported by an orthotic device.

Further surgical interventions: As shown in Table 6. 19 patients (31.7%), were subjected to further procedures which were delayed primary sutures in 4 (6.7%), partial thickness skin graft in 3 (5%), below knee amputation in 5 (8.3%) and another partial foot amputation in 7 (11.7%). The 7 further foot amputations were 3 (5%) adjacent ray amputations, 3 (5%) conversions to trans-metatarsal amputation and one (1.7%) higher tarso-metatarsal amputation.

Pressure offloading: Crutches or wheelchairs were used to completely avoid weight bearing before healing of the stump. In addition, prosthetic/orthotic support devices were used to support, protect, and/or correct deformities of the foot residuum. The used devices were posterior walking splints (Fig. 6a) in 9 cases (15%), dynamic system splints in 2 (3.3%), high supportive shoes (cam walker type) (Fig 6b) in 6(10%) and diabetic foot shoes with silicone insoles for all the patients.

Follow up, walking ability and patient satisfaction: During the one year follow up period, 2 patients died because of associated cardiac disorders and 5 underwent below knee amputation. The remaining 53 patients (88.3%) were capable to use the foot residuum successfully in weight bearing and walking. Although they were dependant on the orthotic devices, they expressed a definite satisfaction by such an outcome.

Table 1. Complications of previous partial amputations.

Presentation	Aetiology	No.	%
Failure of healing	Missed osteomyelitis	6	10%
Planter ulcers	Inadequately resected bone	13	21.7%
Stump ulcer	Inadequate soft tissue coverage	4	6.7%

Table 2. The patterns of bone affection in the cases.

Site of infection	No.	%
One toe and its metatarsal	20	33.3%
Two toes and related metatarsals	11	18.3%
More than 2 toes and related metatarsals	26	43.3%
Affection proximal to the metatarsals	3	5%

Table 3. The initial amputation procedures performed.

Type of amputation	No.	%
Ray amputation of one toe and metatarsal	20	33.3%
Ray amputation of 2 toes and metatarsals	11	18.3%
Transmetatarsal amputation	26	43.3%
Tarsal metatarsal disarticulation (Lisfranc's amputation)	2	3.3%
Talonavicular and calcaneocuboid disarticulation (Chopart's amputation)	1	1.7%

Table 4. The different patterns of coverage used.

Patterns of coverage	No.	%
Planter flap alone	42	70%
Combination of flaps	8	13.3%
Partial thickness graft	3	5%
Secondary intention	7	11.7%

Table 5. Complications encountered after surgery.

Complication		No.	%	Total
Failure of the procedure	uncontrolled ascending infection	2	3.3%	5 (8.3%)
	septic arthropathy of the ankle	1	1.7%	
	extensive sloughing of the heel	1	1.7%	
	deep planter ulcer in the heel	1	1.7%	
Adjacent limited arthritis or osteomyelitis		7	11.7%	7 (11.7%)
Deformities	medial deviation of lesser toes	4	6.7%	9 (15%)
	equinovarus deformity	5	8.3%	
Unstable foot residuum	transmetatarsal amputation	4	6.7%	7 (11.7%)
	Lisfranc's and Chopart's amputations	3	5%	

Table 6. The further surgical interventions performed.

Further procedures		No.	%
Delayed primary closure		4	6.7%
Partial thickness skin graft		3	5%
A below knee amputation(failure)		5	8.3%
Further partial foot amputation	Removal of adjacent ray	3	5%
	Conversion to transmetatarsal amputation	3	5%
	Higher tarso-metatarsal amputation	1	1.7%

Fig 1a. Transmetatarsal amputation with bone beveling and adequate planter flap.

Fig 1b. Closure of the stump with a drain.

Fig 2a. Transmetatarsal amputation complicated with ulcer.

Fig 2b. A higher Lisfranc's amputation covered with combination of flaps.

Fig 3a. Chopart's amputation covered with skin graft.

Fig 3b. Lateral ray amputation covered with skin graft.

Fig 4a. Planter ulcer due to inadequate 1st & 2nd metatarsal bone resection.

Fig 4b. X-ray showing the inadequate bone resection.

Fig 5a. Persistent infection due to missed 2nd & 3rd metatarsals osteomyelitis.

Fig 5b. Ray amputation of the 2nd & 3rd toes and metatarsals.

Fig 6a. Plastic foot and leg posterior walking splint.

Fig 6b. Right posterior walking splint and left high supportive shoes (cam walker).

DISCUSSION

Partial foot amputation is becoming a more reliable and common surgical alternative to below knee amputation for the treatment of many foot disorders.[11] The ability to ambulate short distances without a prosthesis is easier and safer for the partial foot amputee as compared to the below knee amputee. Moreover, bilateral partial foot amputees may aid transfer and offer enhanced mobility as compared to bilateral leg amputees.[12]

The preferential decision by the patients indicated for amputation to have partial foot amputation (and not the more proximal types) is motivated by the reduced psychological impact, minimized trauma and better cosmetic outcome.[13] This was the case with all the patients in the current study. They were impressed with the idea and preferred it even after informing them with the known high failure rate.

The significant high failure and complication rates stated by previous investigators,[9,14] were noticeable in this work as 38.3% of included patients presented with complications of previous foot amputations. The growing recent awareness with such failure rate has attracted attention to the inadequate understanding of the mechanisms of weight bearing and walking in partial foot amputees. Proper understanding has changed the target to be preservation of function not the mere preservation of tissues.[15]

The decision-making process for these amputations must be done thoughtfully, remembering that blood flow and antimicrobial drugs are not the only issue.[16] In this study, the plane was based on the patient's general condition, ambulation ability, local tissue destruction, the expected suitable bone resection and available soft tissues. Armstrong et al stated that adherence to such planes can make the difference between a successfully durable amputation and continuous complications and frustrations.[17]

Amputations up to disarticulation of the metatarsophalangeal joint had little impact on the ankle power generation, but proximal ones reduce such power (regardless of residual foot length). Thus, to get the ideal functional outcome, surgery should strive to preserve the metatarsal heads.[18] On the other hand, once amputation is proximal to the metatarsophalangeal joint, the target of surgery should be the simple achievement of a good, healthy and healed stump regardless of the residuum length.[19]

This concept was adopted in all types of amputation performed in this study. As all the patients presented with lesions proximal to the metatarsophalangeal joint, adequate bone resection was the target both to remove diseased osseous tissues, have adequate soft tissue coverage, and to avoid future bone projection from the stump.

To avoid soft tissue disruption by the sharp bony edges, beveling of the transversely cut bones was carefully considered in this study. Salonga and Blume, in their study about transmetatarsal amputation, emphasized the importance of beveling to optimize a weightbearing surface. Furthermore, they claimed that such a modification (the functional metatarsal parabola) allow propulsion and preserve the gait pattern.[8]

The importance of the plantar tissues as a shield to minimize complications and recurrence have been emphasized in many studies.[8,12,14,16,19] Knowing its unique capability in pressure toleration, in this work, careful trials succeeded to prepare a viable plantar soft tissue flap in 42 patients (70%). In the remaining 18 patients (30%), the solutions used were combination of flaps (13.3%), skin grafts (5%), and healing by secondary intention (11.7%). In previous studies, other podiatric surgeons applied these solutions in similar situations and paid stress on the use of skin grafting only to the non weight bearing border or dorsum of the foot.[19,20]

After healing of the stump, the increased dynamic plantar foot pressure comes as another major risk factor of failure, ulceration and recurrence of diabetic foot state in partial foot amputees.[21] Based on the definition of pressure as force by area, it was speculated that reduction in foot print (foot/ground contact area), after partial amputation, may induce a direct increase in planter foot pressures.[14] The following biomechanical compensation concentrates this pressure at new focal pressure points inducing excessive pre-ulcerative keratosis, tissue breakdown and ulceration.[22] In the current study, the influential effect of increased planter pressure was evident in the 13 patients (21.7%) who presented with planter ulcers after a previous partial foot amputation.

In literature, many publications emphasized the successful control of this problem by postoperative offloading of weight bearing pressure.[23] Theoretically, the optimal device to dissipate weight bearing load is a total below knee contact cast.[24] The same targets can be achieved with prefabricated walking braces that have a plantar weight bearing surface lined with pressure-dissipating materials.[25] Modifications of the idea into different orthotic devices were done to accommodate the needs of patients with variable foot amputations.[26,27] In this work, as the total contact casting (the gold standard for offloading) was not practical and the custom made (moulded) devices were very expensive, the physiotherapist used prefabricated prosthetic/orthotic devices which could help 53 partial foot amputees (88.3%) to use their feet for one year without recurrent ulceration.

Correction of residuum deformities in 9 patients (15%) and support for unstable residuum in 7 (11.7%), were the other privileges of the applied prosthetic/orthotic devices. As both deformities and instability are known short cuts to higher amputations, it is better to be avoided by preserving the tibialis anterior, peroneus brevis and Achilles tendons.[19] If inevitable, lengthening of tendo-Achilles, splitted tibialis anterior tendon transfer, or peroneus brevis reinsertion were described techniques to avoid deformities.[28] The externally applied prosthetic/orthotic devices (as a non-operative alternative) is a less effective but more practical solution. Later on, contractures and fibrosis of muscles, tendons and ligaments in the correct position assist in stabilization of the residuum in a good position.[27] In the current study, this phenomenon was observed in many of involved patients during the follow up period.

In conclusion, foot salvage by partial foot amputation deserves particular attention. Proper planning, adequate proper bone resection, and viable planter flap are the prerequisites of durable functioning residuum. Postoperative pressure offloading devices are of great help to reduce complications of increased planter foot pressure, correct deformities, and support instability. Following this protocol enabled 53 partial foot amputees (88.3%) to use their feet for one year without recurrent ulceration.

Finally, a failure rate of (8.3%) in this work as compared to the (52%) documented in literature is encouraging to continue research in this field.

REFERENCES

1. Ramsey SD, Newton K, Blough D. Incidence ,outcomes ,and cost of foot ulcers in patients with diabetes .Diabetes Care.1999;22:382-7.

2. Herman WH, Aubert RE, Ali MA, Sous ES, Badran A. Diabetes mellitus in Egypt :risk factors, prevalence and future burden. Eastern Mediterranean Health Journal. 1997;3:144-148.

3. Brodsky JW. The diabetic foot .In :Coughlin MJ ,Mann RA , eds .Surgery of the Foot and Ankle .St .Louis: Mosby Inc. 1999,895-96.

4. Pinzur MS, Slovenkai MP, Trepman E. Guidelines for diabetic foot care. The Diabetes Committee of the American Orthopaedic Foot and Ankle Society. Foot Ankle Int. 1999;20:695-702.

5. Sanders LJ, Dunlap G. Transmetatarsal amputation: a successful approach to limb salvage . J Am Podiatr Med Assoc. 1992;82:129-35.

6. Hosch J, Quiroga C, Bosma J, Peters EJG, Armstrong DG, Lavery LA. Outcomes of transmetatarsal amputations in patients with diabetes mellitus. J Foot Ankle Surg. 1997;36:430-4.

7. Satterfield VK. Amputation considerations and energy expenditures in the diabetic patient. Clin Podiatr Med Surg. 2003;20:793-801.

8. Salonga C , Blume P. A Guide To Transmetatarsal Amputations In Patients With Diabetes . Podiatry Today. 2006;19:82-90.

9. Drerup B, Wetz H.H, Koller A, Hafkemeyer U. Long-term results of partial foot amputations and resections in diabetic patients .Journal of Bone and Joint Surgery – British. 2000;88 B, SUP-123.

10. Lavery LA, Lavery DC, Quebedeax-Farnham TL. Increased foot pressures after great toe amputation in diabetes. Diabetes Care. 1995;18:1460-2.

11. Santi MD, Thoma BJ, Chambers RB. Survivorship of healed partial foot amputations in dysvascular patients. Clin Orthop Rel Res. 1993;292:245-9.

12. Ohsawa S, Inamori Y, Fukuda K, Hirotuji M. Lower Limb Amputation for Diabetic Foot . Arch Orthop Trauma Surg. 2001;121.

13. Pollard J, Hamilton G, Rush S, Ford L. Mortality and Morbidity After Transmetatarsal Amputation :Retrospective Review of 101 Cases .JFAS. 2006;45:91-97.

14. Armstrong DG, Lavery LA. Plantar pressures are higher in diabetic patients following partial foot amputation. Ostomy Wound Manage. 1998;44:30-2,34,36.

15. Funk C, Young G. Subtotal Pedal Amputations; Biomechanical and Intraoperative Considerations. J Am Podiatr Med Assoc. 2001;91:6-12.

16. Smith DG. Principles of partial foot amputations in the diabetic. Instr Course Lect. 1999;48:321-9.

17. Armstrong DG, Lavery LA, Nixon BP, Boulton AJM. It is not what you put on ,but what you take off: techniques for debriding and offloading the diabetic foot wound. Clin Infect Dis. 2004;39:92-99.

18. Dillon MP, Barker TM. Preservation of residual foot length in partial foot amputation :a biomechanical analysis. Foot Ankle Int. 2006;27:110-6.

19. Wagner WF. Amputations of the foot and ankle, p.93. In Moore WS(ed). Lower Extremity Amputation. 1st Ed. 1989 WB Saunders, Philadelphia.

20. Moore JC, Jolly GP. Soft tissue considerations in partial foot amputations. Clin Podiatr Med Surg. 2000;17:631-48.

21. Lavery LA, Vela SA, Lavery DC, Quebedeaux TL. Reducing dynamic foot pressures in high-risk diabetic subjects with foot ulcerations .A comparison of treatments .Diabetes Care. 1996;19:818-21.

22. Mvan Schie C. H. A Review of the Biomechanics of the Diabetic Foot. International Journal of Lower Extremity Wounds, September1. 2005;4:160-170.

23. Armstrong DG, Nguyen HC, Lavery LA, van Schie CH, Boulton AJM, Harkless LB. Offloading the diabetic foot wound :a randomized clinical trial. Diabetes Care. 2001;24:1019-22.

24. Pua B. B., Muhs B. E., Maldonado T., Ben-Arie E., Sheehan P., and Gagne P. J. Total-Contact Casting as an Adjunct to Promote Healing of Pressure Ulcers in Amputees Vascular and Endovascular Surgery, March1,2006;40(2):135-140.

25. Armstrong DG, Lavery LA, Wu SC, Boulton AJM. Evaluation of removable and irremovable cast walkers in the healing of diabetic foot wounds :a randomized controlled trial .Diabetes Care. 2005;28:551-54.

26. Armstrong DG, Boulton AJ. Pressure offloading and "advanced" wound healing: isn't it finally time for an arranged marriage ?Int J Low Extrem Wounds. 2004;3:184-7.

27. Moore JW. Prostheses, orthoses ,and shoes for partial foot amputees .Clin Podiatr Med Surg. 1997;14:775-83.

28. Catanzariti AR, Blitch EL, Karlock LG. Elective foot and ankle surgery in the diabetic patient . J Foot Ankle Surg. 1995;34:23-41.

29. Dahmen R, Haspels R, Koomen B, Hoeksma AF. Therapeutic Footwear for the Neuropathic Foot: An algorithm. Diabetes Care. 2001;24:705-9.