Increased Foot Pressures After Great Toe Amputation in Diabetes

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OBJECTIVE — To compare peak pressures on the sole of the foot in non-insulin-dependent diabetic patients with isolated, unilateral amputations of the great toe and first metatarsal with the patients' contralateral, intact foot.

RESEARCH DESIGN AND METHODS — Eleven patients with a unilateral great toe and partial first metatarsal amputation of at least 6 months duration were evaluated with the F-Scan in-shoe pressure measurement system. Patients were studied in the same brand and style of footwear—a thin, rubber-soled, canvas boat shoe. We compared mean peak plantar foot pressures under the first metatarsal, lesser metatarsals, lesser toes, and heel in feet with and without a great toe amputation using the Wilcoxon's matched pairs signed-rank test.

RESULTS — Peak foot pressures were significantly higher under the first metatarsal head ($P = 0.046$), lesser metatarsal heads ($P < 0.001$), and toes ($P < 0.001$) in feet with a great toe amputation compared with the contralateral foot without an amputation. Pressure under the heel was higher on the contralateral foot ($P < 0.01$).

CONCLUSIONS — After a great toe amputation, pressure distribution of the foot is significantly altered. Because preamputation risk factors such as peripheral neuropathy, foot deformity, and limited joint mobility for many of these patients remain unchanged, an increase in foot pressures contributes to an increased risk of reulceration and reamputation in these patients.

Diabetes is the most common contributing factor to lower-extremity amputation in the U.S. (1–3). After an amputation, the chance of another amputation of the same extremity (4–6) or contralateral extremity within 4 years is as high as 50% (7–9). There are multiple risk factors for foot amputation in people with diabetes (10–12). Peripheral neuropathy, high-pressure areas on the sole of the foot, prolonged activity (13,14), limited joint mobility (15), and foot deformity (16) have been linked to the development of foot ulcerations, the most common component in the causal pathway to limb amputation in people with diabetes (11).

In many amputees, the elements that contributed to the first amputation have not been altered, and in the case of partial foot amputations, disruption of normal foot biomechanics probably increases existing areas of high pressure and the risk of ulceration. Our aim was to measure pressure under the foot of patients with isolated, unilateral great toe and first metatarsal amputations and compare them with the patients' own contralateral extremity.

RESEARCH DESIGN AND METHODS

We evaluated seven men and four women with non-insulin-dependent diabetes and a unilateral amputation of the great toe and first metatarsal of at least 6 months duration. Eleven consecutive patients from Podiatry and Orthopaedic Clinics at the University of Texas Health Science Center at San Antonio that fit the study criteria were invited and agreed to participate in the project. The average age of participants was 65.1 years (range, 39–79). The participants' average duration of diabetes was 9.9 years (range, 3–37), and their average body mass index was 28.1 kg/m^2 (range, 23.6–38.5). Patients were excluded if they had a history of contralateral lower-extremity amputation, Charcot arthropathy, trauma, or rheumatoid arthritis. All patients were evaluated with Semmes Weinstein monofilaments and had peripheral neuropathy after the testing method and criteria described by Birke and Sims (17) and Holewski et al. (18).

Plantar pressures were evaluated with the F-Scan in-shoe pressure measurement system (Tek-Scan, Boston, MA). The application of this equipment and software has been described elsewhere (19–21). We compared foot pressures under the first metatarsal head,

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Table 1—*Foot pressure measurements*

Peak pressure (g/cm^2)	Great toe amputation	No foot amputation
First metatarsal	6,329 ± 4,658*	4,611 ± 2,511
Lesser metatarsals	8,267 ± 3,909†	4,935 ± 2,557
Lesser toes	3,666 ± 2,704†	1,701 ± 1,229
Heel	3,604 ± 1,424	4,323 ± 1,782‡

Data are means ± SD. *$P < 0.05$; †$P < 0.001$; ‡$P < 0.01$.

lesser metatarsal heads, lesser toes, and heel in patients with a great toe and partial first metatarsal amputation with their contralateral, intact foot. The amputations in this study group comprised subjects with resection of the distal portion of the first metatarsal head. Generally, compared with the contralateral foot, the peak pressures were several centimeters proximal. In these cases, interpretation of in-shoe sensors was adjusted to measure the highest pressure at the distal portion of the first metatarsal. Foot pressures were measured in a pair of canvas boat shoes with a thin rubber sole. Three gait trials were repeated for each participant. Data collection began after the second step and continued for at least six consecutive steps in each trial. We averaged the highest pressures under the four sites described above for the purposes of analysis.

We used the Wilcoxon's matched pairs signed-rank test to compare the peak plantar pressures between amputated and intact feet. We used SPSS statistical software to perform the analysis (SPSS, Chicago, IL).

RESULTS— Mean peak plantar foot pressures for feet with great toe amputations and the contralateral extremity are presented in Table 1. Peak pressures were significantly higher under the first metatarsal head ($P < 0.05$), lesser metatarsal heads ($P < 0.001$), and toes ($P < 0.001$) in feet with great toe amputations compared with the patient's contralateral foot. Pressure was higher under the heel of the contralateral foot ($P < 0.01$).

CONCLUSIONS— In this study, we have demonstrated that diabetic subjects with a great toe and partial first metatarsal amputation have higher foot pressures under the first metatarsal head, lesser metatarsal heads, and lesser toes compared with the contralateral foot. For the purposes of this study, we assumed that feet in the same individual were matched and therefore should have similar structure, function, and pressure distribution on the sole of the foot. Symmetry of gait during normal ambulation is a well accepted concept (24,25). Kinematic laboratory studies of gait in normal subjects have demonstrated that asymmetry of integral, temporal, and loading parameters account for less than 5% of variance in 98% of the gait cycles studied (25).

For most of these patients, the same risk factors for ulceration and amputation that existed before their amputation have remained unchanged, and compared with the contralateral foot, pressures on the forefoot increase. This suggests that amputation of the great toe and first metatarsal significantly alters the function, structure, and pressure distribution of the foot and potentially puts these patients at greater risk of developing another ulceration or requiring a subsequent amputation. Our results help explain previous observations by Greteman and Dale (26) who reported that 65% of diabetic subjects with a great toe amputation develop an ulceration and 53% require a subsequent amputation of the same foot. The most common site of ulcer formation was under the lesser metatarsal heads.

Increased pressure under the heel of the contralateral foot may be part of a mechanism to compensate for abrupt changes in normal foot mechanics caused by destruction of the first metatarsophalangeal joint. Root et al. (27) have described a transfer of pressure through the first metatarsal region and great toe in normal gait. Mann et al. (28) described a change in the progression of the center of pressure under the third metatarsal head in feet with great toe amputations rather than the usual medial progression under the great toe. During the propulsion phase of gait in normal subjects, toe-off occurs at the same time that the contralateral foot begins heel strike (27). The inability of the amputated foot to smoothly transfer pressure medially and propulse off the great toe may cause more pressure to be applied to the contralateral heel as it is loaded.

Diabetic patients with a great toe amputation should be targeted for frequent and intensive preventive care. The effectiveness of multispecialty high-risk foot clinics to prevent lower-extremity amputations has been described in both the U.S. and Europe (29–31). Primary care physicians, podiatrists, endocrinologists, vascular and orthopedic surgeons, physiatrists, diabetes nurse educators, and pedorthists have vital roles to play in the care of high-risk patients. Specific education about the warning signs of foot complications and prevention strategies should be emphasized and repeated at regular intervals to both patients and physicians (32,33). Because the vast majority of medical visits for patients with diabetes are provided by primary care physicians, examination of the foot, identification of complications, and appropriate referral by these physicians could dramatically affect diabetic foot outcomes. Foot inspection by primary care physicians should be a mandatory part of every diabetic patient encounter. This is especially important in the high-risk patient with a previous amputation.

Many of these patients are best managed in specialty foot clinics that can bring consultants together in a timely, aggressive fashion. Special insoles and footwear to protect the foot and reduce high-pressure areas are relatively inexpensive measures and should be routinely used in patients with partial foot amputations. The Medicare-supported Therapeutic Shoe Bill makes special footwear and insoles available to more patients than ever before. The Medicare shoe benefit provides one pair of custom molded shoes (including the insoles provided with the shoes) plus two additional pairs of insoles or one pair of over-the-counter extra-depth shoes and three pairs of insoles per year. The physician that manages the patient's diabetes must document that the patient has had a previous amputation of all or part of the foot, a history of ulceration, a preulcerative callous, foot deformity, or poor peripheral circulation. The use of therapeutic footwear has been demonstrated to be an effective adjunct to prevent limb loss in high-risk patients (34). Early identification of high-risk patients, appropriate education, and preventative care could reduce reulceration and reamputation.

References

1. Most RS, Sinnock P: The epidemiology of lower extremity amputations in diabetic individuals. *Diabetes Care* 6:87–91, 1983
2. Rutkow IM: Orthopaedic operations in the United States, 1979 through 1983. *J Bone Joint Surg* 68:716–719, 1986
3. Miller AD, Van Buskirk A, Verhoek-Oftedahl W, Miller ER, Trenton MA: Diabetes-related lower extremity amputations in New Jersey, 1979 to 1981. *J Med Soc NJ* 82:723–726, 1985
5. McCollough NC, Jennings JJ, Sarmieto A: Bilateral below-the-knee amputation in patients over fifty years of age. *J Bone Joint Surg* 54:1217–1223, 1972
6. Ecker ML, Jacobs BS: Lower extremity amputations in diabetic patients. *Diabetes* 19:189–195, 1970
7. Whitehouse FW, Jurgensen C, Block MA: The later life of the diabetic amputee: another look at fate of the second leg. *Diabetes* 17:520–521, 1968
8. Kucan JO, Robson MC: Diabetic foot infections: fate of the contralateral foot. *Plast Reconstr Surg* 77:439–441, 1986
9. Bodily KC, Burgess EM: Contralateral limb and patient survival after leg amputation. *Am J Surg* 146:280–282, 1983
10. Holewski JJ, Moss KM, Stess RM, Graf PM, Grunfeld C: Prevalence of foot pathology and lower extremity complications in a diabetic outpatient clinic. *J Rehabil Res Dev* 26:35–44, 1989
11. Pecoraro RE, Reiber GE, Burgess EM: Pathways to diabetic limb amputations: basis for prevention. *Diabetes Care* 13: 513–521, 1990
12. Rieber GE, Pecorato PE, Koepsell TD: Risk factors for amputation in patients with diabetes mellitus. *Ann Intern Med* 117:97–104, 1992
13. Kosiak M: Etiology and pathology of ischemic ulceration. *Arch Phys Med Rehab* 40: 62–69, 1959
14. Brand PW: Repetitive stress in the development of diabetic foot ulcers. In *The Diabetic Foot*. 4th ed. Levin WM, O'Neal LW, Eds. St Louis, MO, Mosby, 1988, p. 83–90
15. Fernando DJS, Masson EA, Vevas A, Boulton AJM: Relationship of limited joint mobility to abnormal foot pressures and foot ulceration. *Diabetes Care* 14:8–11, 1991
16. Muller MJ, Miner SD, Diamond JE, Blair VP: Relationship of foot deformity to ulcer location in patients with diabetes mellitus. *Phys Ther* 70:356–361, 1990
17. Birke JA, Sims DS: Plantar sensory threshold in the ulcerative foot. *Lepr Rev* 57: 261–267, 1986
18. Holewski JJ, Stess RM, Graf PM, Grunfeld C: Esthesiometry: quantification of cutaneous pressure sensation in diabetic peripheral neuropathy. *J Rehabil Res Dev* 25: 1–10, 1988
19. Young CR: The F-Scan system of foot pressure analysis. *Clin Podiatr Med Sur* 10: 455–461, 1993
20. Sarnow MR, Veves A, Giurini JM, Rosenblum BI, Chrzan JS, Habershaw GM: In-shoe foot pressure measurements in diabetic patients with at-risk feet and in healthy subjects. *Diabetes Care* 17:1002–1006, 1994
21. Albert SF, Christensen LC: Diabetic foot pressure studies: comparison study of patient-selected shoes versus clinician-selected shoes. *Lower Extremity* 1:21–27, 1994
22. Boulton AJ, Betts RP, Franks CI, Ward JD, Duckworth T: The natural history of foot pressure abnormalities in neuropathic diabetic subjects. *Diabetes Res* 5:73–77, 1987
23. Brand PW: Management of the insensitive limb. *Phys Ther* 59:8–18, 1979
24. Attinger D: Subjektive gangbeobachtung in vergleich zu gemessener asymmetrie. *Swiss Med* 9:58–61, 1987
25. Debrunner HU: Biomechanik des fues. In *Beihefte zur Zeitschrift Orthopädie*. Vol. 49. Otte P, Schlegel KF, Eds. Stuttgart, Ferdinand Enke, 1985
26. Greteman B, Dale S: Digital amputations in neuropathic feet. *J Am Podiatr Med Assoc* 80:120–126, 1990
27. Root ML, Orien WP, Weed JH: *Normal and Abnormal Function of the Foot: Clinical Biomechanics*. Vol. II. Los Angeles, CA, Clinical Biomechanics Corporation, 1977
28. Mann RA, Poppen NK, Konski M: Amputation of the great toe: a clinical and biomechanical study. *Clin Orthop* 226:192–205, 1988
29. Edmonds ME, Blundell MP, Morris ME, Thomas EM, Cotton LT, Watkins PJ: Improved survival of the diabetic foot: the role of a specialized foot clinic. *Q J Med* 232:763–771, 1986
30. Lippmann HI: Must loss of limb be a consequence of diabetes mellitus? *Diabetes Care* 2:432–436, 1979
31. Runyan JW: The Memphis Chronic Disease Program: comparison in outcome and the nurse's extended role. *JAMA* 231: 264–267, 1975
32. Del Aguila MA, Reiber GE, Koepsell TD: How does provider and patient awareness of high-risk status for lower-extremity amputation influence foot-care practice? *Diabetes Care* 17:1050–1054, 1994
33. Litzelman DK, Slemenda CW, Langefeld CD, Hays LM, Welch MA, Bild DE, Ford ES, Vinicor F: Reduction of lower extremity clinical abnormalities in patients with non-insulin-dependent diabetes mellitus. *Ann Intern Med* 119:36–41, 1993
34. Chantelau E, Haage P: An audit of cushioned diabetic footwear: relation to patient compliance. *Diabetic Med* 11:114–116, 1993