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Foot Pressures During Gait: A Comparison of Techniques for Reducing Pressure Points

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ABSTRACT

Purpose: **Various methods have been used to redistribute plantar surface foot pressure in patients with foot ulcers. This study was conducted to determine the effectiveness of four modalities (fracture walker, fracture walker with insert, and open and closed toe total contact casts) in reducing plantar foot pressure.**
Methods: **Ten healthy, normal volunteer subjects had an F-scan sensor (ultra thin shoe insert pressure monitor) placed under the right foot. They then ambulated on a flat surface, maintaining their normal gait. Dynamic plantar pressures were averaged over 10 steps at four different sites (plantar surface of great toe, first metatarsal head, base of fifth metatarsal, and plantar heel). All subjects repeated this sequence under five different testing conditions (barefoot, with a fracture walker, fracture walker with arch support insert, open and closed toe total contact cast). Each subject's barefoot pressures were then compared with the pressures during the different modalities.**
Results: **All four treatment modalities significantly reduced ($p < 0.05$) plantar pressure at the first metatarsal head (no method was superior). The fracture walker, fracture walker with insert, and open toe total contact cast significantly reduced pressure at the heel. Pressures at the base of the fifth metatarsal and great toe were not significantly reduced with any treatment form.**
Conclusion: **The fracture walker, with and without arch support, and total contact cast can effectively reduce plantar pressure at the heel and first metatarsal head.**

INTRODUCTION

Diabetes affects as much as 15% of the population in many developed countries.[2,3] In patients with diabetes, ulceration with ensuing infection is one of the most common causes of lower extremity amputation.[4,5,15] The initial ulceration is frequently associated with peripheral neuropathy and associated impairment of protective plantar surface sensation.[3,5,18] Arterial occlusive disease also plays a role, but three times as many patients are hospitalized for neuropathically induced lesions as for primary ischemic lesions.[6,7] Peripheral neuropathy is reported in 50% to 90% of patients with diabetes.[8]

The initiating event in a diabetic foot ulcer is often a mechanical, chemical, or thermal trauma.[7,18] The resultant ulcers often occur at areas of highest pressure, with the metatarsal heads, especially the sesamoid or first metatarsal head, being the most common site of ulceration.[8,16,19] Studies have demonstrated that present and former sites of neurotrophic lesions correspond to the sites of greatest loading.[9,10]

Ulcer healing can often be achieved by decreasing the pressure at the ulcer site.[11,20,21,22] This can be done by a number of methods. Simple bed rest for four to 12 weeks may be attempted, but this is associated with a large number of severe side effects.[5] Crutch assisted gait will offload the affected foot, but is often impractical because of concurrent obesity, limited cardiovascular reserves, poor upper body strength, unsteadiness, and visual impairment. Total contact casts (TCC) have also been used to help ulcer healing.[5] Many physicians, however, are reluctant to use TCC's because of possible cast irritation, wound deterioration, and availability of a technician to properly apply a TCC.[5,12] Removable orthoses have been used as an alternative to the TCC. These braces were initially thought to be inadequate due to inability to exert circumferential pressure to decrease plantar pressure and swelling, contour to the foot and dissipate plantar pressure, and accommodate for foot deformities.[3,13]

The purpose of this study was to compare measured plantar pressures on the feet of 10 normal non-diabetic subjects. Comparison was made between the following conditions: open-toe total contact; closed-toe total contact cast; fracture walker; fracture walker with felt metatarsal pad (Hapad, Bethel Park, PA). The areas

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measured were: great toe plantar surface; first metatarsal head/sesamoids; fifth metatarsal base and plantar heel.

METHODS

Informed consent was obtained from 10 non-diabetic volunteer subjects (five male and five female). The average age of the subjects was 30 (range 26 to 35). Each volunteer had a F-scan (Tekscan, Inc., Boston, MA), an ultra thin shoe insert pressure monitor, placed under their right foot.[1] It was held in place by double-sided tape. The F-scan is a disposable monitor, which was trimmed to fit each foot. They then ambulated 10 meters on a flat vinyl floor surface at an even pace. Plantar maximum pressures were measured and averaged over 10 steps by the F-scan program. The four sites examined were the plantar surface of the great toe; plantar first metatarsal head; base of the fifth metatarsal and the plantar surface of the heel. The F-scan sensors recorded the maximum pressure at these sites for each of the 10 steps and then averaged the figures. The five test conditions were: barefoot, fracture walker (Bledsoe fracture walker with rocker sole; Grand Prairie, TX), fracture walker with felt prefabricated metatarsal arch support, open toe total contact cast (OTTCC) and closed toe total contact cast (CTTCC). The fracture walker used has a flat non-conformable inner surface contacting the plantar surface of the foot. In each of the conditions, the F-scan sensor was fixed to the plantar surface of the foot with double-sided tape. The subjects then walked the 10 steps for the test condition. The sensor was checked to insure that no migration had occurred. All subjects started with the barefoot condition. The other four test conditions were then randomly performed to insure that there would be no bias introduced by testing conditions in the same order for all subjects. Each subject had their own sensor that was used in each of the five testing conditions and a new sensor was used for each subject. The same orthopaedic technologist trained in total contact cast application applied all total contact casts.

Measurements made for each subject were averaged over the 10 steps at each of the plantar sites yielding an average maximum pressure in pounds/square inch. Each of these figures was then averaged among subjects to yield the average maximum pressure recorded at the four measured sites. Student t-test analysis was then performed to compare each of the test conditions to the barefoot (control) condition. Individual comparisons were also made between each test condition. Each subject served as their own control.

Table 1: Mean Maximum Pressure Measurements

	Heel	MTB 5	MTH 1	Great Toe
Barefoot	55.1	8.1	81	6.4
OTTCC	43.0	4.6	34.9*	6.1
CTTCC	52.1	5.3	38.0*	2.8
FW	32.4*	3.0	37.2*	4.7

All measurements in pounds/square inch
***denotes statistically significant ($p<0.05$) from the barefoot condition**

Legend:
- OTTCC: open toe total contact cast
- CTTCC: closed toe total contact cast
- FW: fracture walker
- FWI: fracture walker with felt insert
- MTB: base of 5th metatarsal
- MTH 1: first metatarsal head

RESULTS

The mean maximum pressure measurements for each site are listed in table 1. The plantar pressure at the first metatarsal head was significantly ($p < 0.05$) reduced in all the test conditions compared to the barefoot condition. Only the fracture walker (FW) and fracture walker with felt insert (FWI) reduced plantar pressure at the heel. When comparing treatment modalities with each other, no statistical difference could be shown between the treatment modalities.

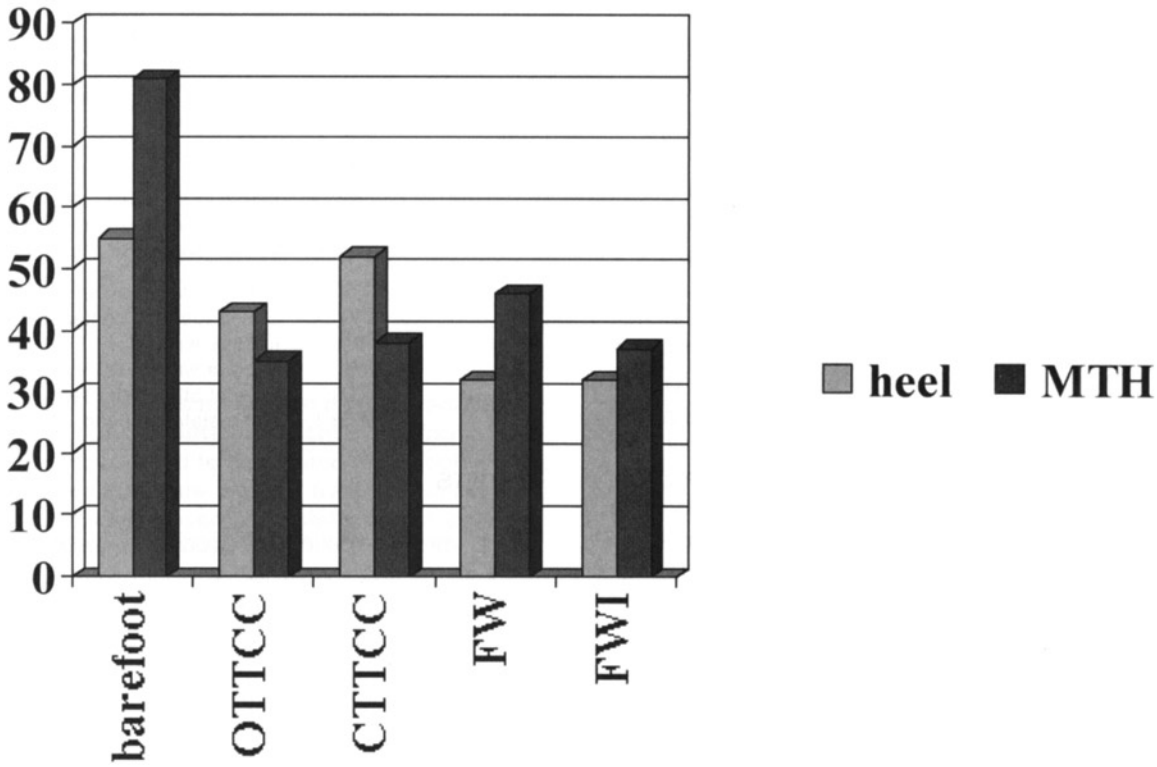
None of the treatment modalities statistically lowered the pressure at the base of the fifth metatarsal; however, the two fracture walker conditions seemed to lower the pressure the most, but this was not statistically significant. Pressures at the plantar surface of the great toe were lowered from 6.4 lbs/in^2 to 2.8 lbs/in^2 with a closed toe total contact cast; but, this was not statistically significant.

Pressure measurements on the heel were lowered from 55.1 lbs/in^2 in the barefoot condition to 32 lbs/in^2 in both the fracture walker conditions. This was statistically significant. The total contact casts did not have a significant effect on pressure at the heel (Fig. 1). There was no significant difference between the plantar pressures for males and females. The average plantar pressures at the four sites are listed in table 1.

DISCUSSION

In comparing maximum averaged pressures at four sites on the plantar surface of the foot, this study sought to describe changes obtained with commonly used methods for pressure reduction. The results indicated that pressure in the regions of the first metatarsal head can effectively be reduced with both fracture walkers and total contact casts. However, the pressure at the

Figure 1: Comparison of hindfoot and forefoot pressures.



OTTCC = open toe total contact cast
CTTCC = closed toe total contact cast
FW = fracture walker
FWI = fracture walker with insert
MTH = metatarsal heads
UNITS = lbs / square inch

heel is not as easily reduced. The fracture walkers provided statistically significant reduction compared to the total contact casts. This is most likely explained by the rocker sole on the fracture walker. It provides a wide stable base and transfers weight to the arch, away from the heel. The total contact cast used in this study emphasized dorsiflexion at the ankle to reduce forefoot pressures. This positioning is not offset by the addition of a standard cast shoe with a rocker sole.

None of the treatment modalities used produced a statistically significant decrease in plantar pressure at the great toe or base of the fifth metatarsal. The plantar pressure values at these sites are so low initially that the resultant decrease in pressure would not likely be statistically significant. There was a trend toward lower pressures at the plantar great toe with a closed toe total contact cast which may be attributable to the immobilization obtained with this modality compared to the others.

Total contact casts have long been the standard treatment for plantar neuropathic ulcers.[14,17] They provide immobilization, compression for edema control and distribute pressure away from the ulcer. In addition, when they are changed frequently, they effectively become like a periodically adjusted custom orthosis. The disadvantages of total contact casting are the cost and labor involved in their use.[2]

This is the main advantage in using fracture walkers for treatment of these ulcers. An effective, commercially available fracture walker would involve a one time charge and allow for frequent dressing changes which is advantageous if some of the newer wound care modalities are concurrently being used. (i.e., growth factors, skin graft substitutes). They could also be used in conjunction with compressive devices to control edema. Finally, a fracture walker could be reused in the case of recurrent ulceration, which is a common finding in the diabetic population.[17]

The purpose of this study was not to recommend one modality of treatment over another. Patient selection is an important point that must be emphasized.[12,14] Both total contact casting and fracture walkers require a compliant patient and close follow-up. The fracture walker may require adjustment or modification to accommodate changes in the foot that are inherently accounted for with total contact casting.[14] Based on this study, fracture walkers can provide adequate pressure relief on the plantar surface of the foot and may be a useful alternative to total contact casting.

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