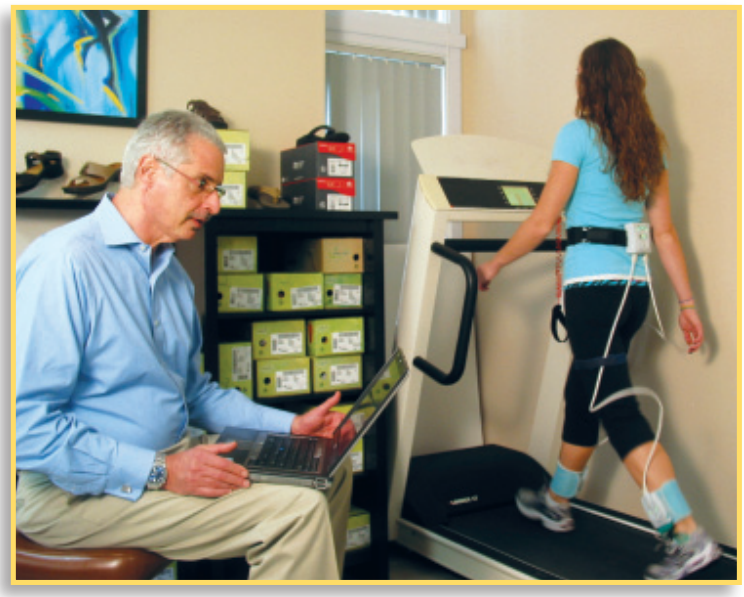
FOOT PRESSURE MEASUREMENT
IN A CLINICAL SETTING



- gait analysis & biomechanics
- diabetic offloading
- sports medicine
- pre- and post-treatment evaluation
- orthotic prescription confirmation

Tekscan®

INTRODUCTION

Foot pressure measurement systems provide unique insight on foot function and gait, helping clinicians conduct more complete assessments and objectively evaluate treatments. In the clinical setting, these systems are used by podiatrists, orthotists, prothestists, and physical therapists around the world to:

- identify underlying pathomechanical dysfunctions
- validate treatments
- improve athletic performance
- offload high pressure areas at increased risk for ulceration

This eBook contains a selection of case studies that demonstrate how clinicians use in-shoe and floor mat plantar pressure measurement systems to diagnose the root cause of their patients' problems and ensure effectiveness of prescription orthotics, rehabilitation and surgery.

Gait Analysis & Biomechanics

Identifying Asymmetry During Gait Using the Force-Time Graph in F-Scan®
Norman Murphy, Ph.D.
Director of Product & Market Research & Development, Tekscan, Inc.

Enhanced Foot Function and Gait Analysis Using the 3Box Approach with F-Scan®
George C. Trachtenberg, DPM
Owner of George C. Trachtenberg Podiatry, Vestal, New York

Pressure measurement technology captures data on plantar pressure distribution, timing and Center of Force (CoF) trajectory throughout the gait cycle. In the first case, Dr. Murphy uses data analysis tools in the *F-Scan* in-shoe system to identify and correct gait asymmetry, thereby improving functionality and eliminating pain. The case provides an introduction to the Force-Time graph and explains how it is used in treatment of pathomechanical dysfunction. In the second case, Dr. Trachtenberg utilizes the foot segmentation software feature to execute the 3Box approach for more in depth analysis of the gait cycle.

Diabetic Offloading

The Use of F-Scan® in the Treatment of Diabetic Foot Ulcers
Jayne Arlett, B. Sc. Podiatric Medicine, FASMF, FAAPSM
Managing Director of 3 Franchises within The Athletes Foot Group, Owner and Consultant Sports Podiatrist at Townsville Podiatry Centre, Owner of Kinetic Edge, Queensland, Australia

High-resolution pressure sensors provide objective and accurate information on location and severity of high pressure areas on the plantar surface, making them an ideal tool for developing or selecting offloading footwear. In this case, Dr. Arlett uses pressure measurement technology to quantify pressure at the ulcer site of a diabetic patient and confirm that the orthotic treatment is producing the desired effect, helping her patient heal faster and avoid further complications.

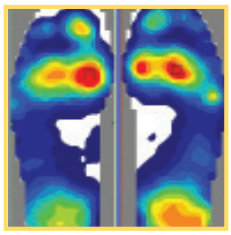
Sports Medicine

Using F-Scan® to Treat Chronic Knee Pain

Bruce E. Williams, DPM

Owner of Breakthrough Podiatry, Merrillville and Valparaiso, Indiana

Athletic trainers and podiatric specialists use pressure measurement to get their patients back on their feet and back in the game faster. In this case, Dr. Williams uses the *F-Scan* on himself to treat his knee pain associated with marathon running.



Pre- and Post- Treatment Evaluation

Using F-Scan® to Treat Chronic Ankle Pain Following Multiple Knee Replacements

Bruce E. Williams, DPM

Owner of Breakthrough Podiatry, Merrillville and Valparaiso, Indiana

Plantar pressure and timing data provides clinicians with an objective way to measure change after or during treatment or rehabilitation. In this case, Dr. Williams uses the *F-Scan* to assess the gait of a patient who suffers from chronic ankle and lower back pain following several knee surgeries. The patient had previously been treated with multiple ankle braces with no improvement.

Orthotic Prescription Confirmation

Using F-Scan® to Investigate Orthotic Failure

Peter Barrow, B.Sc., Podiatric Medicine

Owner of Clifton Chiropody/Podiatry Practice, United Kingdom

Using F-Scan® to Evaluate Orthotic Prescriptions, Orthoses, and Orthotic Labs

George C. Trachtenberg, DPM

Owner of George C. Trachtenberg Podiatry, Vestal, New York

Prescription orthotics do not always produce the desired effect on the first try. In-shoe pressure measurement removes the guesswork from orthotic development by allowing clinicians to validate new footwear immediately, improving patient comfort and reducing the need for follow-up visits. In the first case, Dr. Barrow uses the *F-Scan* to assess a set of orthotics that have exacerbated a patient's pre-existing condition, and then to develop a new pair of orthotics and confirm their effectiveness. In the second case, Dr. Tractenberg uses the *F-Scan* to compare the execution of the same prescription by two different orthotic labs.

A Special Thank You...

Thank you to all the case authors for contributing their experiences with Tekscan's foot pressure measurement systems. Learning about real world applications of this technology is what unlocks the possibilities for other practitioners and we are truly grateful to the authors for sharing those applications with us.

Improving Asymmetry during Gait Using the Force-Time Graph in *F-Scan*
By Norman Murphy, Ph.D.

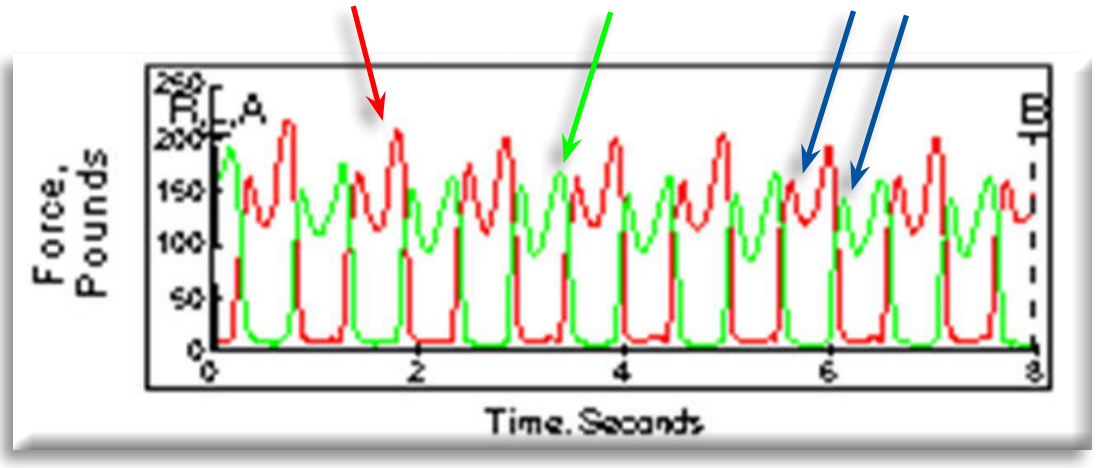
When symmetry in foot function during gait is perturbed, undesired torque can be generated, and stress is transmitted along and within the tendons and muscles, ligaments and bones. Torque and stress are mechanical components that wear and tear body tissues over time, potentially causing discomfort and pain.

Asymmetry in gait can be measured using the *F-Scan*. Symptoms associated with gait asymmetry include:

- Left knee pain when running
- Stiff big toes when walking.
- Calluses on medial side of big toe.

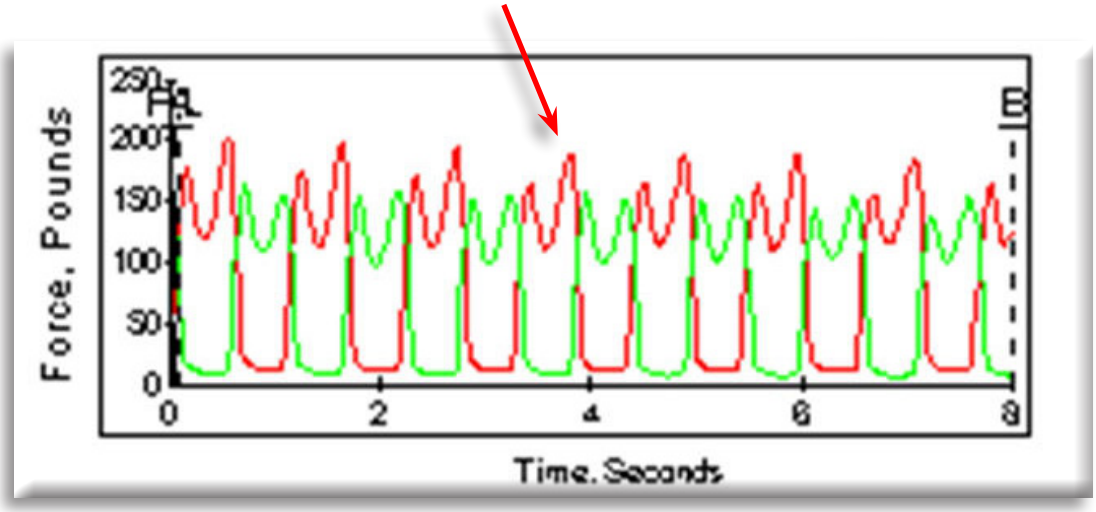
| Before - Force vs. Time Graph (Gait Curve) of vertical ground reaction forces |

Note asymmetry in curve patterns. Right foot shows greater forces at toe-off relative to left foot, and during heel strike for both feet. Desired outcome is to reduce differences in peak forces during toe-off for right foot relative to right heel strike, and relative to heel strike and toe-off of left foot.



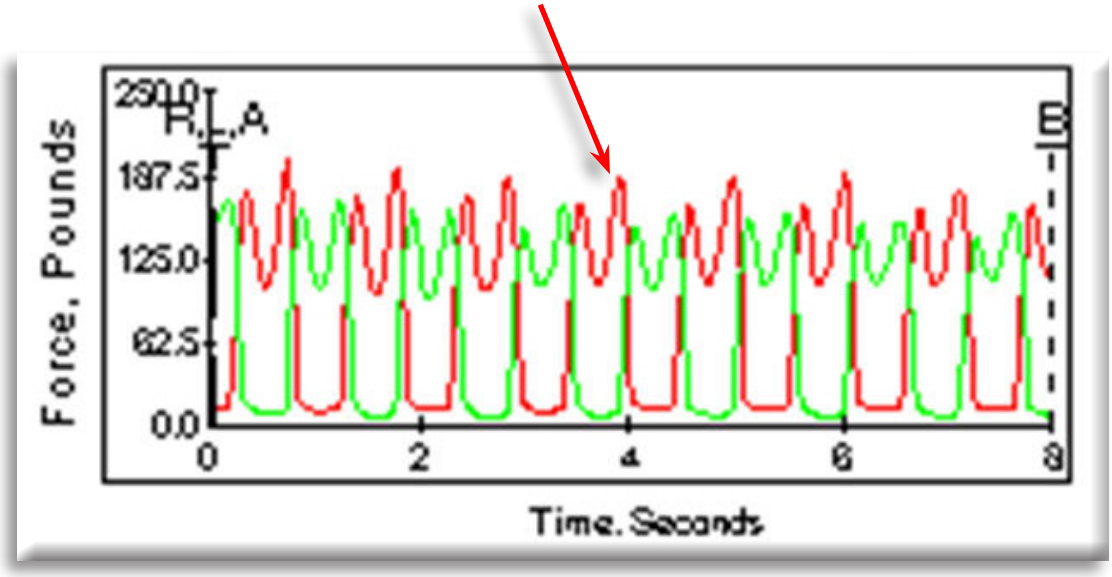
| Treatment 1 - 3/4 length test/temp orthotics with 1/4 in. heel lift added under right heel |

Note reduction of peak forces at toe-off for right foot with respect to right heel strike, and relative to heel strike and toe-off of left foot. Some reduction in asymmetry has been achieved.



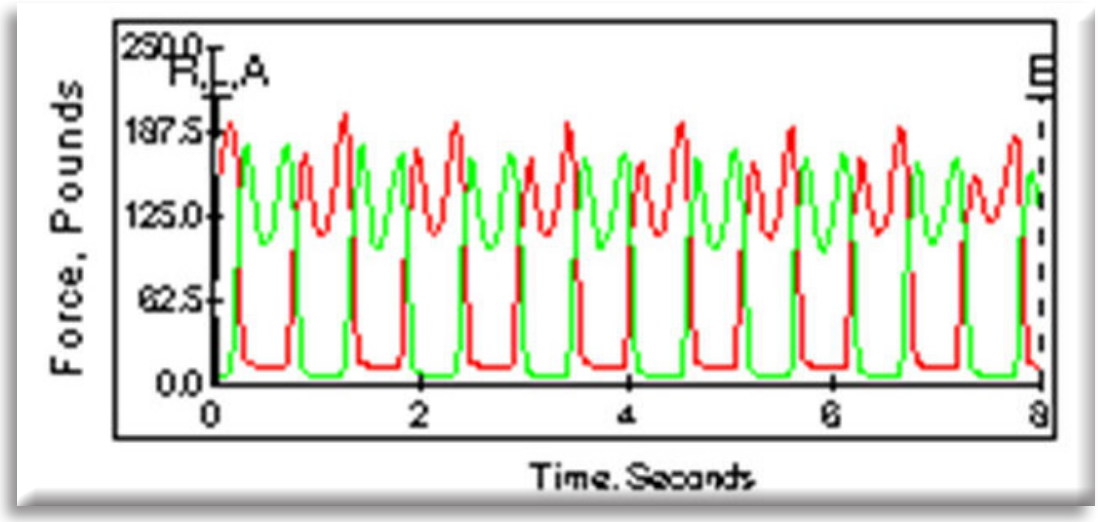
| Treatment 2 - Cut-outs made in orthotic under 1st metatarsal head |

Note more reduction in peak forces during right toe-off relative to right heel strike, left heel strike and toe-off. There is now much improved symmetry between left and right curve patterns.



| Final - 1/8 in. heel lift added under both heels |

1/8 in. heel lift did not have an effect on peak forces and patterns of curves. Lower limb mechanics can be such that 1/8 in. under both heels has little effect on symmetry of gait for this patient.

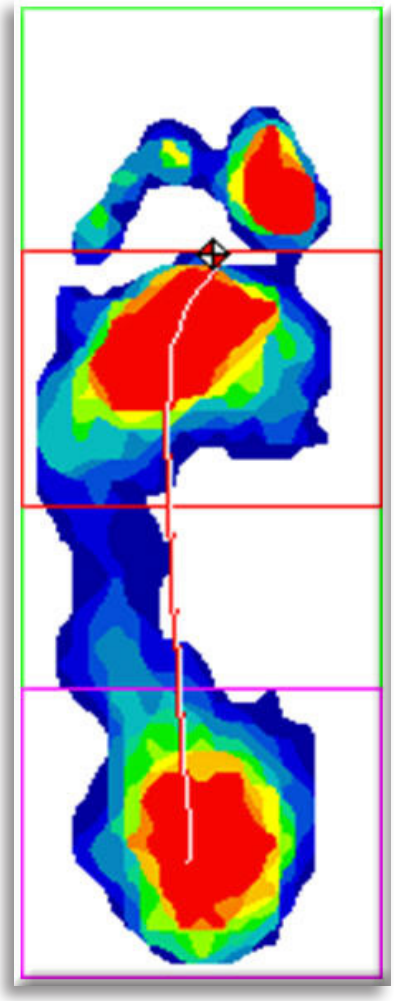


Enhanced Foot Function and Gait Analysis Using the 3Box Approach with *F-Scan*
By George C. Trachtenberg, DPM

When evaluating pressure profiles obtained with the *F-Scan* system, Force versus Time (FvsT) curves plotted on graphs can be created that will correlate the force (loading) pattern with each of the pressure profiles (right and left feet). The trajectory (rises and falls) of a FvsT curve is also referred to as loading pattern. Since foot function and gait related disorders alter the pattern of FvsT curves, these loading curve patterns can be viewed for each foot, and then used to assess and evaluate for disorders and/or pathologies as well as be compared to each other for symmetry.

The 3Box Approach subdivides the Gait Curve (total vertical ground reaction force from heel strike to toe-off) into two components: heel and forefoot. This approach provides specific loading patterns during heel contact and forefoot contact, independent of and in conjunction with the Gait Curve. The addition of the specific force loading curve patterns for the heel and forefoot to the gait curve allows for and provides a more detailed understanding of what is happening (events) in foot function during the stance phase of gait. This additional information does lead to a better understanding of the disorder and/or pathology that is/are present, since foot function and gait related disorders alter the pattern, and thus help in the decision process for treatment.

Illustrated below is the set-up for using the 3Box Approach to enhance analysis, interpretation, and treatment of foot function and gait related disorders.



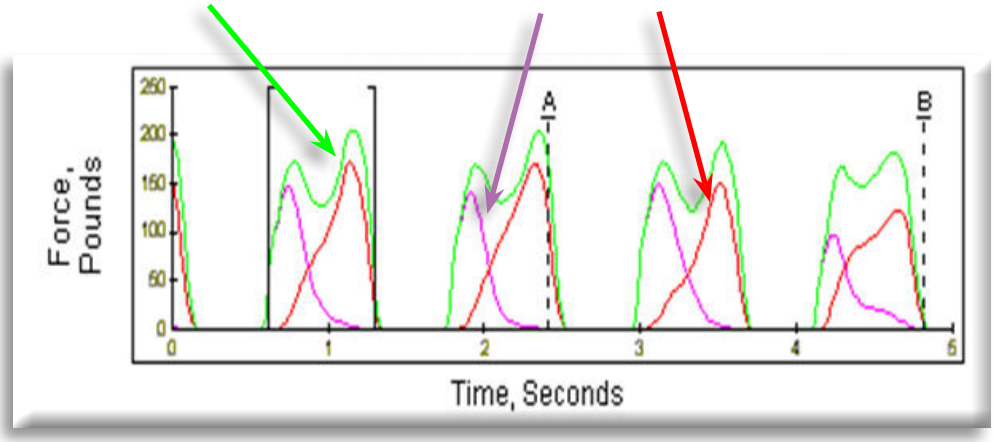
| Left foot pressure profile |

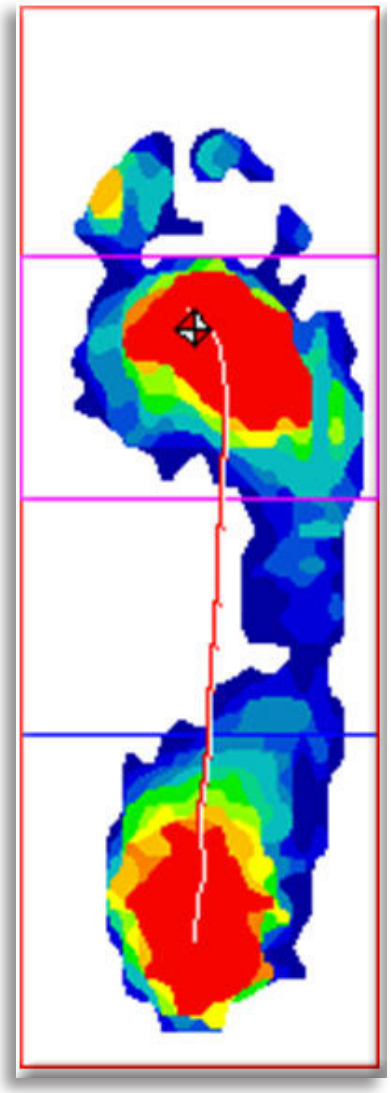
At left is a left foot pressure profile from an *F-Scan* recording. The green box encompassing the entire foot is used to create the gait (FvsT) curve. The red box encompassing the forefoot segment and the lavender box encompassing the heel segment are used to create the specific FvsT curves during heel and forefoot contacts.

| Left foot force vs. time (gait) curve |

The graph below represents the FvsT graph created as per the boxes in the pressure profile. The green curves represent the gait curves, the lavender curves represent the specific loading pattern of the heel, and the red curves represent the specific loading pattern for the forefoot during gait for several steps.

Note the rises and falls in the curves, which represent the loading pattern on the plantar surface of the foot, and specific to the isolated heel and forefoot .





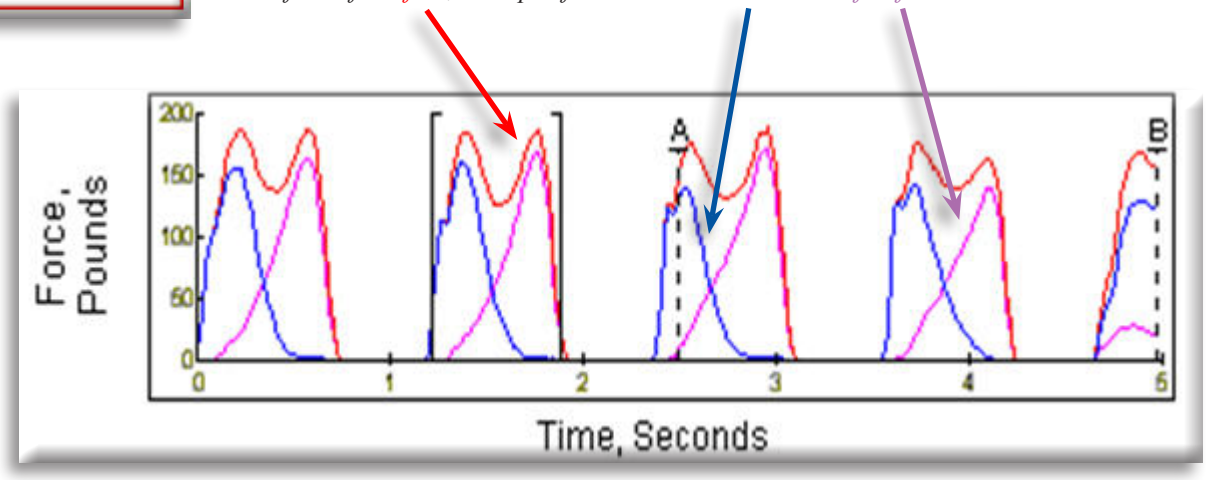
| Right foot pressure profile |

At left is a right foot pressure profile from the same *F-Scan* recording. The red box encompassing the entire foot creates the gait (FvsT) curve, the lavender box encompassing and isolating the forefoot creates the forefoot FvsT curve, while the blue box encompassing and isolating the heel creates the heel FvsT curve.

| Left foot force vs. time (gait) curve |

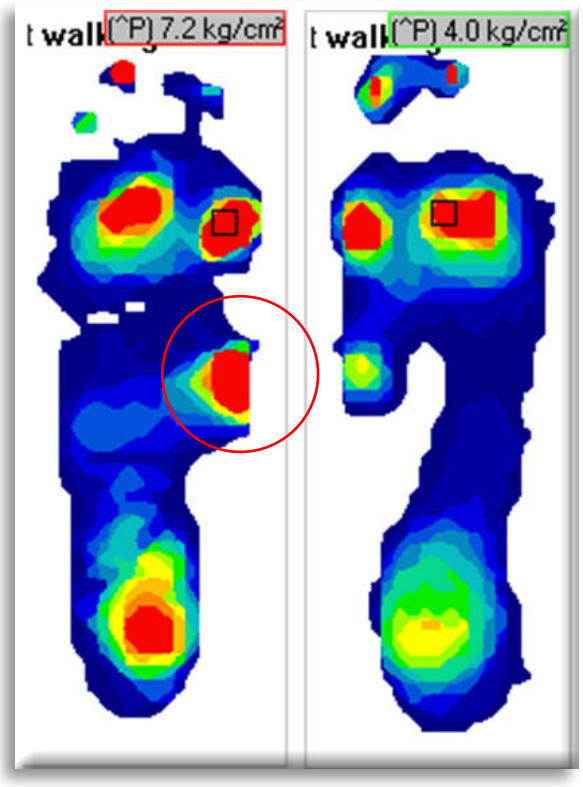
The graph below represents the FvsT graph for the right foot created as per the boxes in the pressure profile. The red curves represent the gait curves, the blue curves represent the specific loading pattern of the heel, and the lavender curves represent the specific loading pattern for the forefoot during gait for several steps.

Note the rises and falls in the curves, which represent the loading pattern on the plantar surface of the foot, and specific to the isolated heel and forefoot.



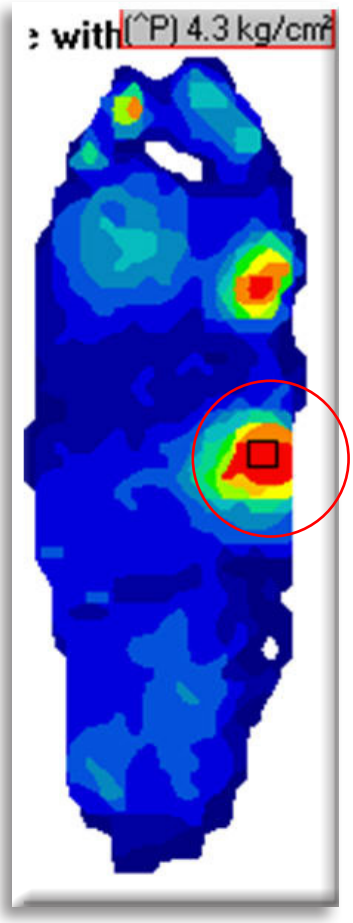
The Use of *F-Scan* in the Treatment of Diabetic Foot Ulcers
By Jayne Arlett, B. Sc. Podiatric Medicine, FASMF, FAAPSM

A diabetic patient with a long term (15 months) non-healing ulcer under the left midfoot (Charcot Joint) was presented to private practice. The *F-Scan* In-Shoe Pressure Analysis System and the *F-Mat*™ floor mat were used to assist the podiatrist and the patient to achieve optimal treatment outcomes. The ulcer site healed within one month of orthotic modification with the assistance of the *F-Scan*. More importantly, the patient was significantly more compliant with recommended treatments once he could visualize the extremely high and abnormal pressures that his ulcer site was generating while walking barefoot on the *F-Mat*. The *F-Scan*'s ability to demonstrate to the patient the importance of footwear and orthotic therapy in this case perhaps outweighs the assistance that it gave to the podiatrist in maximizing treatment outcomes.



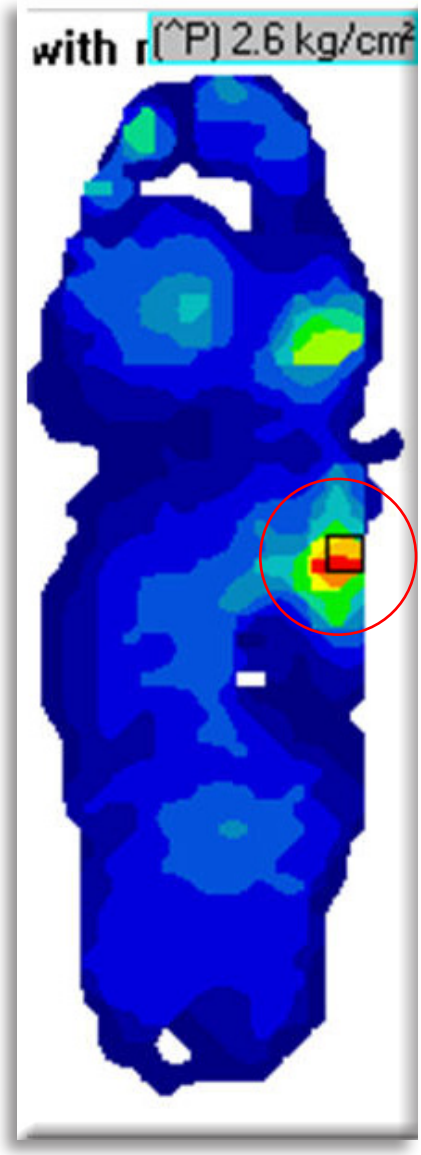
| Barefoot *F-Mat* screening |

The image at left is an *F-Mat* pressure profile showing peak pressures over the ulcer site (red circle) and the 1st MTPJ of the left foot. The peak pressure over the ulcer site is 7.2 kg/cm² (102 psi).



| *F-Scan* pressure profile of left foot with orthotic |

The image at right is the in-shoe pressure profile for the left foot with orthotic before modifications. The pressure over the ulcer site is reduced compared with barefoot; however, the ulcer is still present. The peak pressure has been reduced to 4.3 kg/cm² (61 psi).

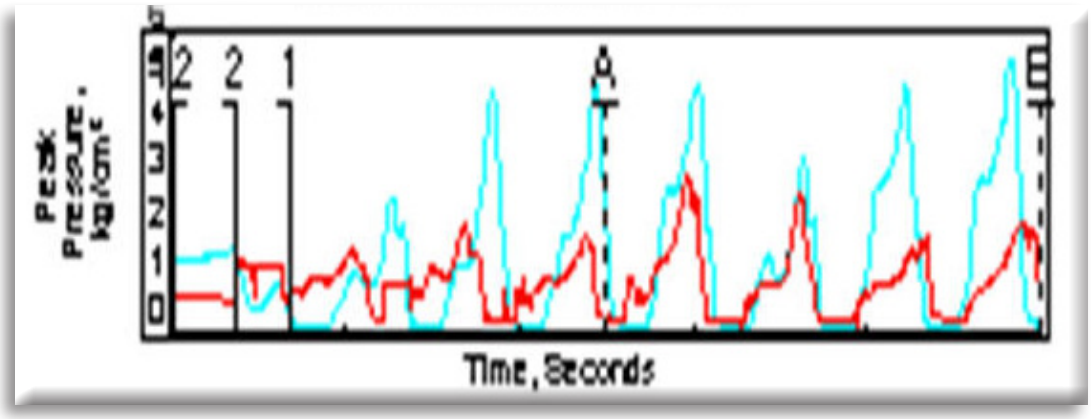


| Left foot pressure profile with modified orthotic |

The image at left is the left pressure profile for in-shoe with modified orthotic. The pressure over the ulcer site is reduced even further to 2.6 kg/cm^2 (37 psi) and after 3 weeks of wear, the ulcer has healed completely. The orthotic was modified "on-the-spot" with the assistance of the *F-Scan* to allow for immediate feedback on the suitability of the modification.

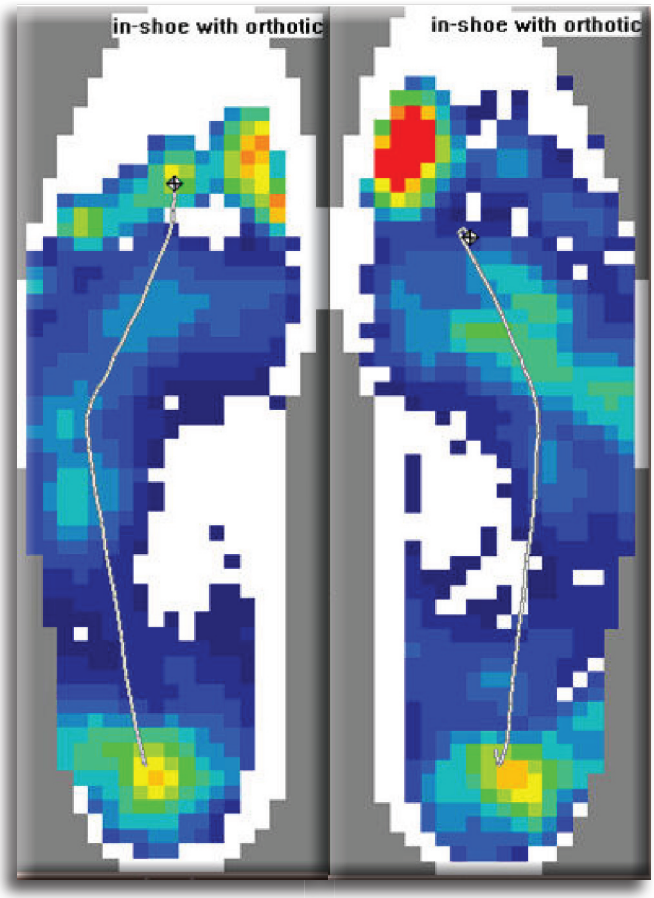
| Peak pressures over time |

In the graph below, the blue curve shows the peak pressure versus time before the orthotic was modified. The red curve shows peak pressure versus time for in-shoe with modified orthotic. Clearly the magnitude of peak pressure with the new modified orthotic is much lower than before the orthotic was modified. This significant reduction in peak pressure has assisted in the healing of the ulcer.



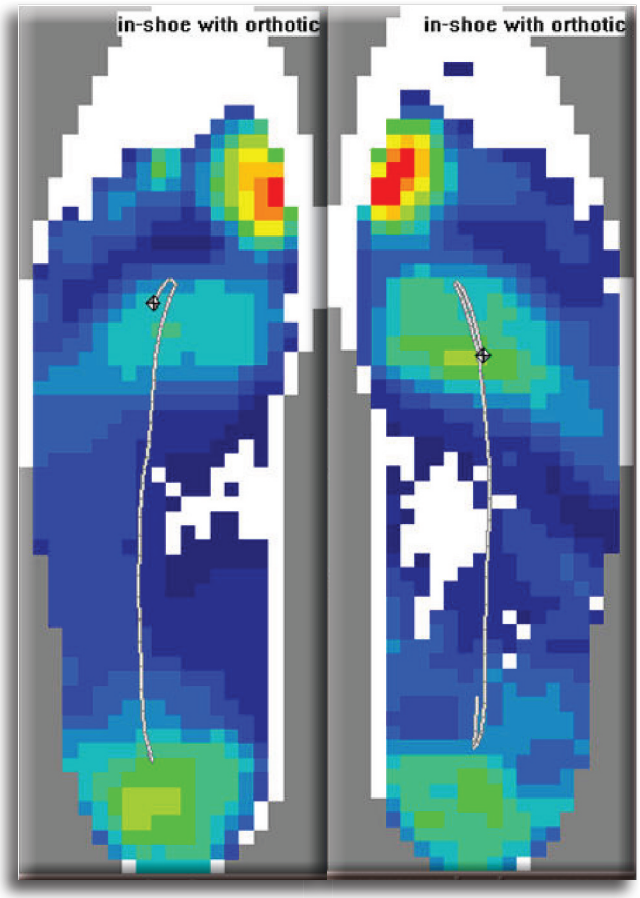
Using *F-Scan* to Treat Chronic Knee Pain
By Bruce E. Williams, DPM

Physician heal thyself! Below is my own personal case in treating my chronic knee pain. I'm a slow marathon runner and recently began experiencing anterior right knee pain after running and lateral left knee pain after sitting and when sleeping. I had performed several different *F-Scan* tests and orthotic modifications without success. I finally figured out by feel, intuition, and with the *F-Scan* that my limb length difference was not on the side that I thought it was. Switching the heel lift made a very obvious improvement in foot function and gait, and also in relief of my chronic pain. I'm still slow, but my feet and knees feel great!



| *F-Scan* pressure profiles before modification |

Above are the *F-Scan* pressure profiles of my orthotics with a moderate 1st ray cutout and a 1/8 in. heel lift on the left side. You can see the extreme lateral deviation from the center of force (CoF). Note the decreased sub 1st metatarsal phalangeal joint (mpj) pressures bilateral, and the high hallux pressure on the right. Note as well the lack of medial arch pressures.

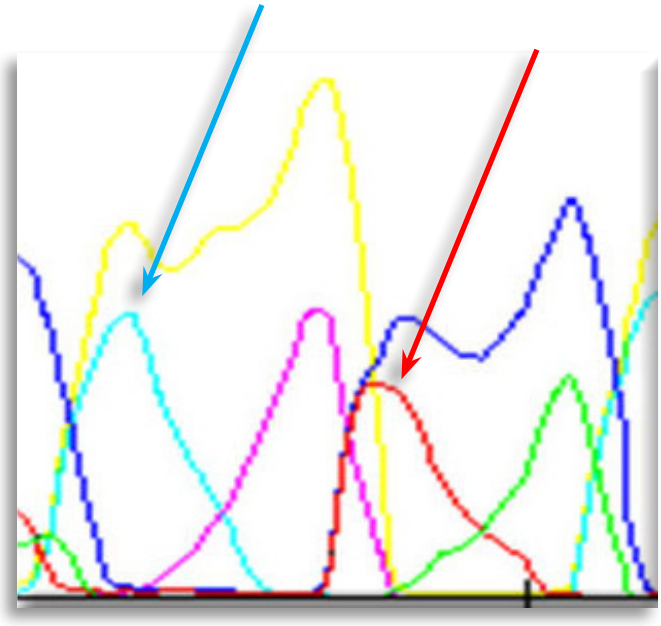


| *F-Scan* pressure profiles after modification |

The pressure profiles above are for a moderate 1st ray cutout and a 1/8 in. heel lift on the right side. Notice the symmetrical hallux pressures and the midline CoF bilateral. Notice as well the increase in medial arch pressures, as compared to the pressure profiles at left for before the modifications were done to the right orthotic.

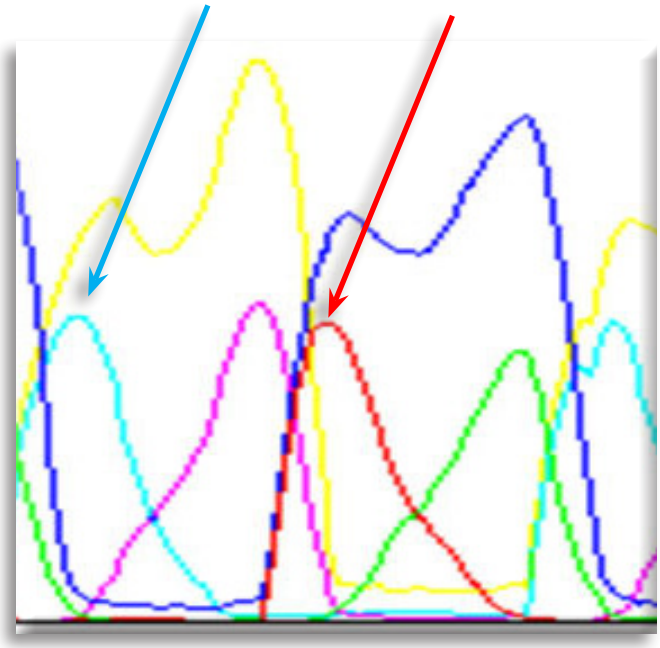
| Force vs. time graph before modification |

Below are the Force vs. Time curves with my orthotics, a moderate 1st ray cutout and a 1/8 in. heel lift on the left side. The total force of the right foot is represented by the highest blue curve, and the force during right heel contact is the red curve. The highest yellow curve is the total force of left foot, and the force during left heel contact is the aqua curve. Notice the longer contact time and higher peak force of left heel (aqua curve) compared to right heel (red curve). Obviously, the 1/8 in. heel lift on the left heel is making the contact period longer with an increase in peak force.



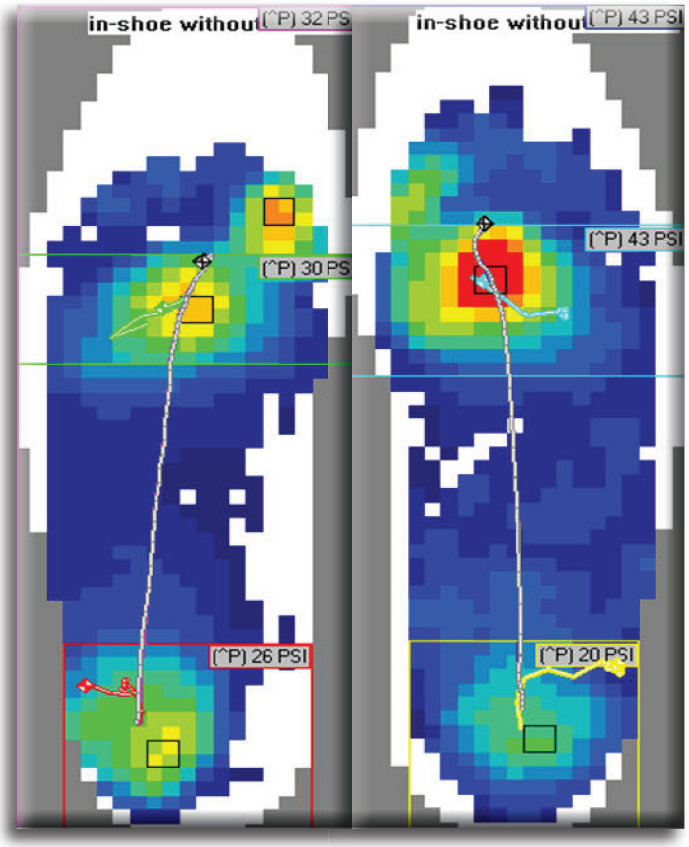
| Force vs. time graph after modification |

Below are the Force vs. Time curves with the addition of the 1/8 in. heel lift on the right side. The right heel force curve and left heel force curve now show much more equal symmetrical patterns. You can also notice how the curves are smoother and more consistent, as opposed to the asymmetry in the previous curves above before the modifications were done to the orthotics. This switch in the heel lift made all the difference in the world!



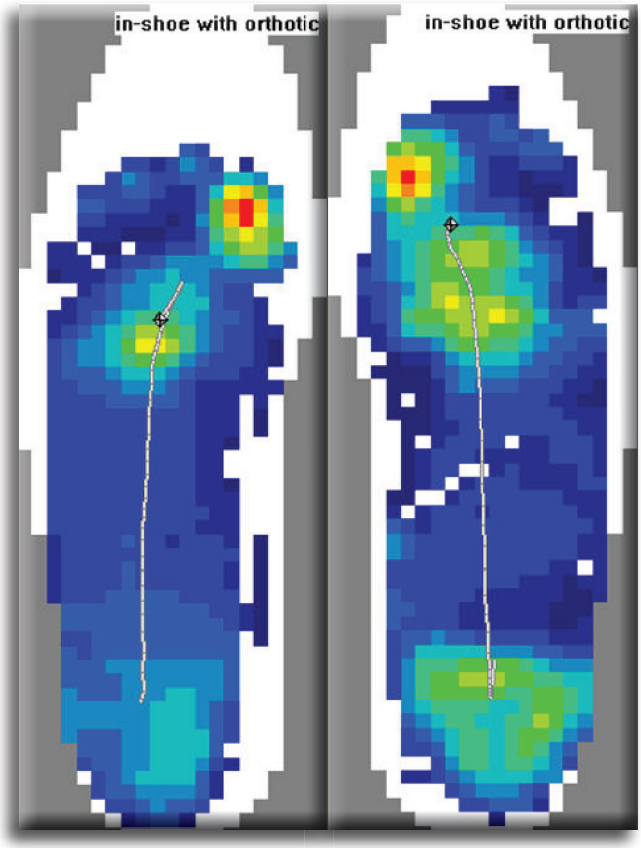
Using *F-Scan* to Treat Chronic Ankle Pain Following Multiple Knee Replacements
By Bruce E. Williams, DPM

The patient presents the primary complaint of chronic ankle and foot pain. The patient has had multiple knee replacements secondary to a blood disorder that causes chronic osteoarthritis. The patient has had treatment failure with multiple braces for his ankles. He also suffers from chronic low back pain and the beginnings of chronic hip pain. The patient also had a 1st metatarsal phalangeal joint (mpj) fusion on the left foot due to chronic structural hallux limitus.



| *F-Scan* pressure profiles without orthotics |

Above are the *F-Scan* pressure profiles of the patient with no orthotics. The patient has no motion in the right 1st mpj, but has available 1st ray motion. He has a functional hallux limitus on the right with a significant structural limb length difference. His Center of Force (CoF) progression (gray line) is mostly midline bilateral, and he has little sub 1st mpj pressure left vs. right.

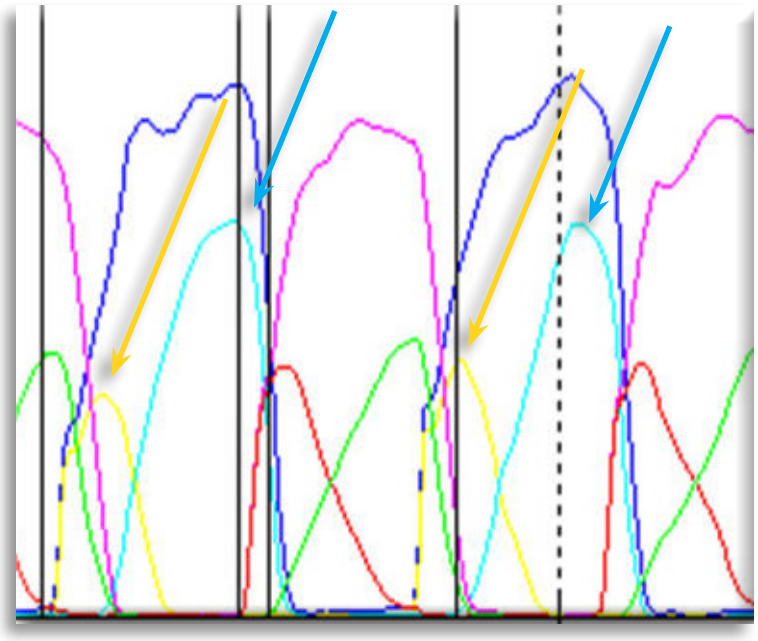


| *F-Scan* pressure profiles with orthotics |

Above is the patient with orthotics. The prescription is a moderate 1st mpj cutout bilateral and a 3/8 in. heel lift on the right. Notice the decrease of the metatarsal pressures bilateral and the more symmetrical hallux pressures bilateral. The CoF progression has not significantly changed.

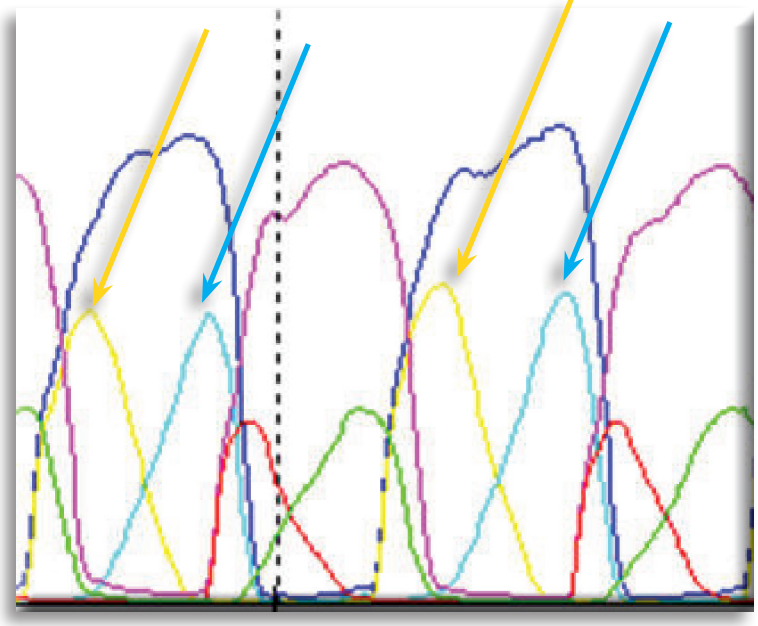
| Force vs. time graph without orthotics |

Below are the Force vs. Time curves with no orthotics. The highest blue curve is for the right foot, the highest pink curve is for the left foot. The low red curve is for left heel strike and the low yellow curve is the right heel strike. Notice the clear asymmetry between the right forefoot (aqua curve) and the lower heel (yellow curve) force.



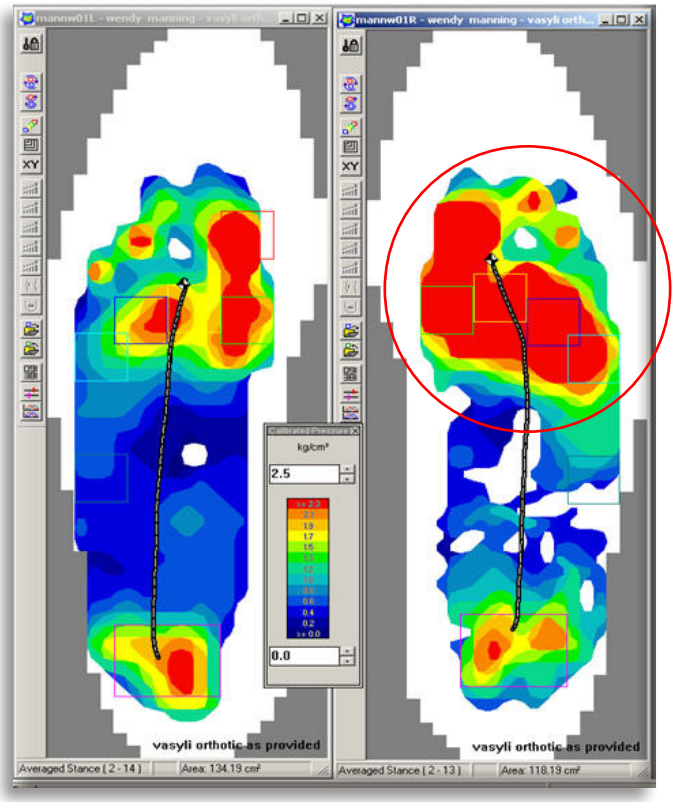
| Force vs. time graph with orthotics |

Below are the Force vs. Time curves with the orthotics. The right has a moderate 1st ray c/o and a 3/8 in. heel lift. Notice now the much more symmetrical curves right vs. left. See how the addition of the 3/8 in. heel lift right has equalized the forefoot and rearfoot forces on the right (yellow-heel and aqua-forefoot). The patient has improved symmetry of function with elimination of his chronic ankle pain.



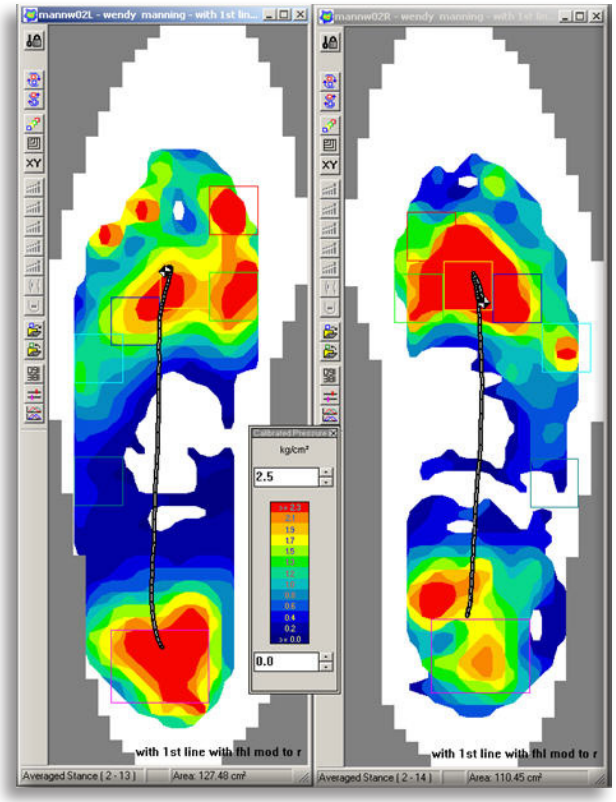
Using *F-Scan* to Investigate Orthotic Failure
By Peter Barrow, B. Sc. Podiatric Medicine

A keen dog-walker in her mid-forties had not been able to exercise her dog for 4 months as a result of severe pain in her right great toe joint. She lived out of town and her local practice had prescribed pre-formed orthoses of a type which are sometimes appropriate. On this occasion the devices made things worse. *F-Scan* in-shoe pressure/force system analysis was used to rapidly identify the reason for orthotic failure, and then indicate an instant solution. For the patient, there was identification of functional hallux limitus (FHL), exacerbated by the pre-formed orthoses and resolved objectively. The new devices were tested for efficacy and were prescribed with full confidence that the pain would be much improved, which it was. The patient was impressed with the speed of analysis and resolution of her problem.



| *F-Scan* pressure profiles with original orthoses |

In the pressure profiles above, the original orthoses had 6 degrees varus posts throughout its length. The shell seemed to be preventing adequate plantar flexion of the 1st rays (big toes), particularly on the right as indicated by the high loading (in red). Maximum pressure under the halluces (big toes) was 9.7 kg/cm^2 for the right and 3.4 kg/cm^2 for the left.



| *F-Scan* pressure profiles with new orthoses |

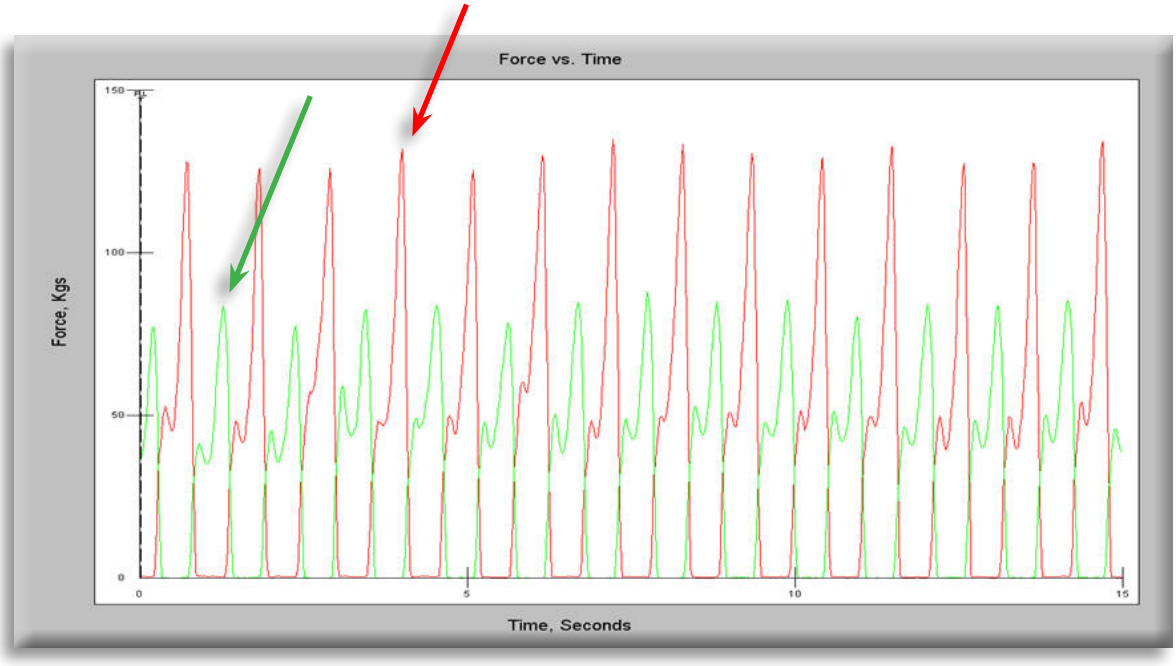
In the pressure profiles above for the new orthoses, FHL was addressed with immediate improvement (as indicated per reduction of loading under the halluces). Objective findings enable the practitioner to predict the outcome.

The original devices were then substituted for new orthoses. These were non-posted, pre-formed, full-length EVA. A cut out was provided for the right 1st ray.

When patients experience the predicted improvement, their confidence in the clinician/practice increases.

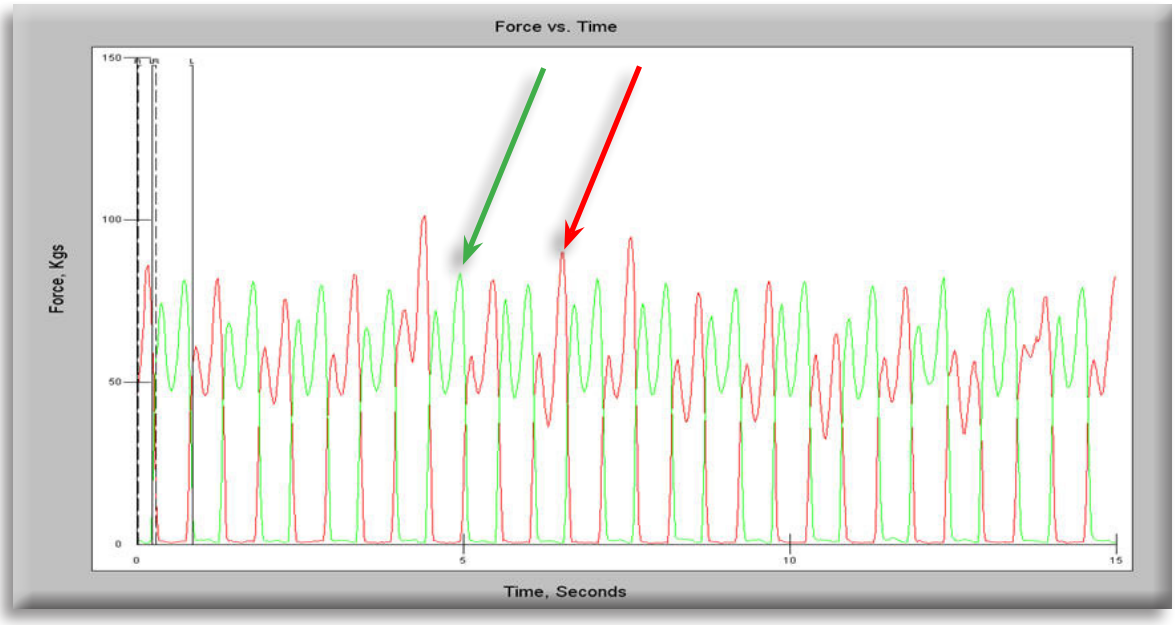
| Force vs. time graph with original orthoses |

In the Force versus Time graph below, the Gait (vertical force vs. time) curves are presented for the left and right feet for several foot steps. The curve for the left foot is in green while the curve for the right foot is in red. The second hump on each gait curve indicates the quality of forward rotation of the forefoot at the great toe joint. Note the lack of symmetry, where the right forefoot spikes (red curves) are 45% higher than the left (green curves).



| Force vs. time graph with new orthoses |

In the Force vs. Time graph below, the gait curves are more symmetrical. The right forefoot spike is reduced with respect to the left spike. Note also that the heel loading represented by the first hump in the curves are also more symmetrical and normal. Further work could include enlarging the cut out and adding a right heel raise. The practitioner can proceed to do this on custom orthotic shells; with the patient now having full confidence, even after experiencing initial disappointment with the clinician and orthoses.

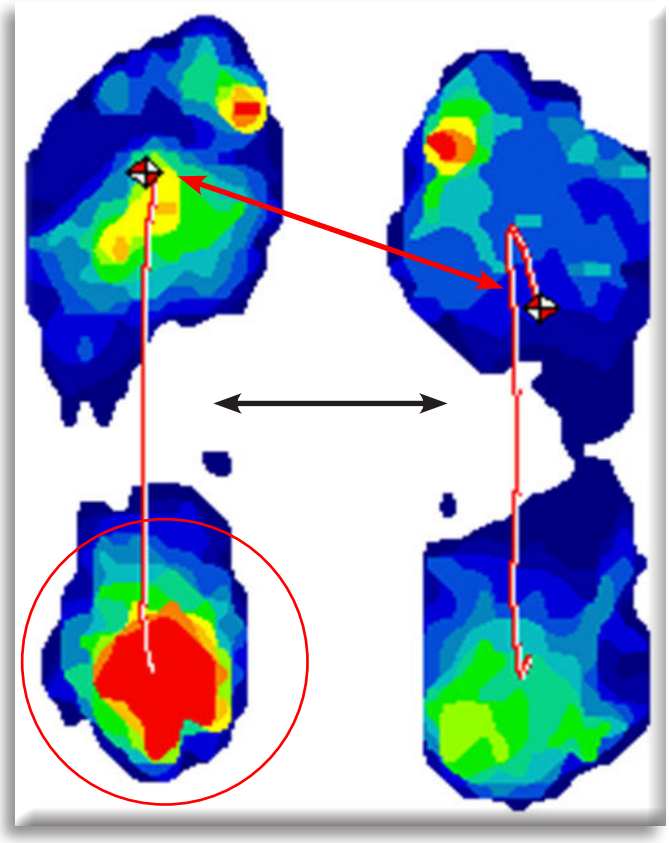


Using *F-Scan* to Evaluate Orthotic Prescriptions, Orthoses, and Orthotic Labs
By George C. Trachtenberg DPM

Did you achieve and/or arrive at the treatment outcome you desired for your patient with your orthotic prescription? If not, then, why not? Was your prescription inappropriate for the problem at hand and/or was your orthotic lab unable to provide appropriate orthoses per your prescription? The *F-Scan* can help you evaluate and obtain these answers, and thus enhance meeting and achieving patient treatment outcome.

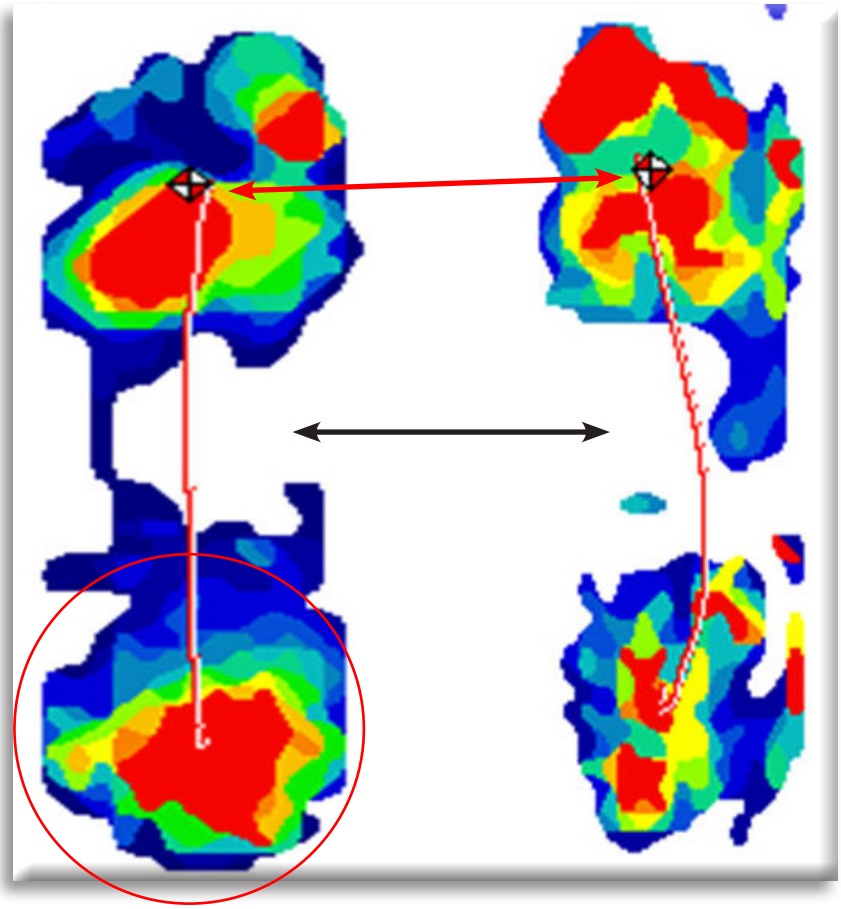
The same prescription was sent to two independent orthotic manufactures (names withheld) after evaluating the plantar pressures recorded with the *F-Scan* without wear of the orthoses (before treatment). The effects (outcomes) with the wear of the orthoses from each laboratory were then recorded and assessed with *F-Scan*.

Illustrated below are the pressure profiles (mappings) during the stance phase while walking, and for each condition (Before Treatment, Laboratory 1 and Laboratory 2). Several steps were recorded, and within each condition, the pressure profile patterns were similar, repeating from step to step. For Laboratory 1 versus Laboratory 2, note the large variability in the pressure profile (color) gradients and distribution, indicating that for the same prescription, effect/influence (outcome) from the orthoses is very different. Without in-shoe pressure mapping technology such as the *F-Scan*, it would be difficult for a practitioner to have this information. "Looking and Seeing" into the patient's shoes while walking is very revealing and is "a must" to know the effect on pressure distribution among other parameters.



| Pressure profiles without orthotics |

Desired Treatment Outcomes:
- Improved symmetry in trajectory (red line) for the Center of Force (CoF) from heel to forefoot
- More support of the lateral column and arch at mid-foot
- Reduction in pressure (less red) under left heel
- Improved symmetry in pressure between left and right heels (more even color gradient)

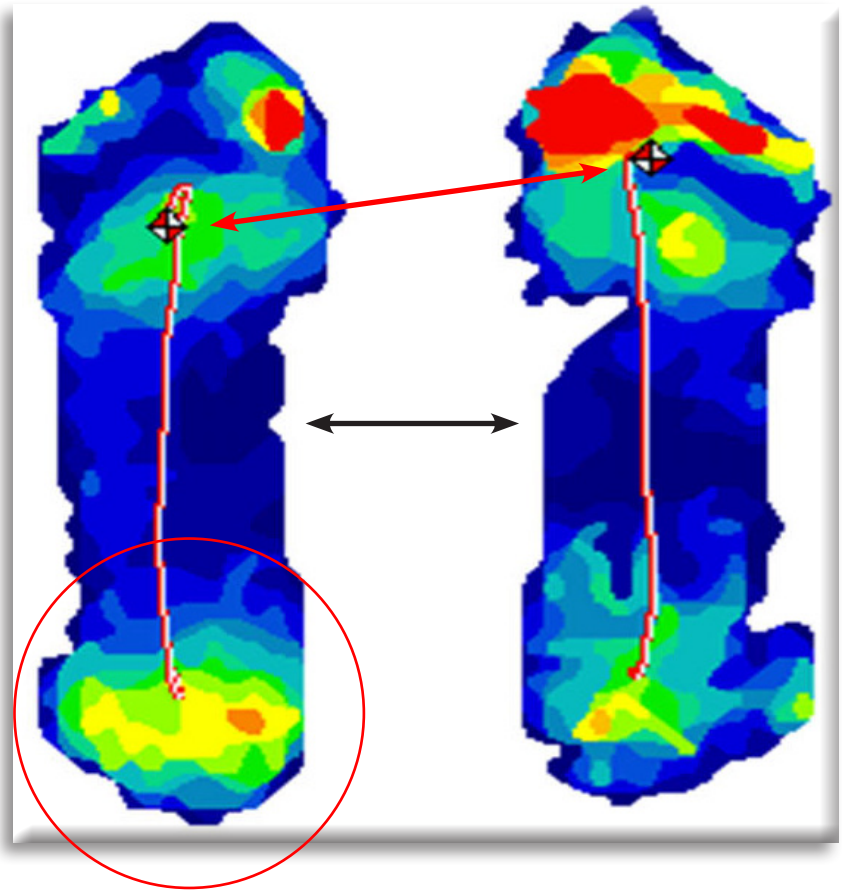


| Pressure profiles Lab 1 |

Have the desired treatment outcomes been met? You be the judge.

Summary:
When looking at the pressure profiles Lab 1 versus Lab 2, it is hard to believe that for the same prescription, very different effects (outcomes) have occurred.

Conclusion:
Lab 2 orthoses do help and are more effective in achieving treatment outcomes. Lab 1 orthoses do not help and are non-effective in achieving treatment outcomes.



| Pressure profiles Lab 2 |