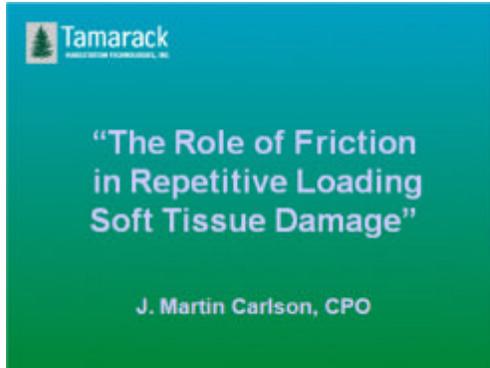


The Role of Friction in Repetitive Loading Soft Tissue Damage (Marty Carlson)



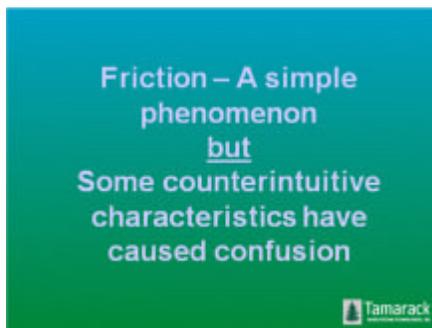
I first became aware of the destructive power of friction while addressing skin breakdown in wheelchair users. That awareness of friction and the damage it can do in static loading, opened my eyes to investigate the role of friction in dynamic repetitive loading situations. This presentation will focus almost entirely on repetitive loading such as occurs within a shoe, orthosis or prosthesis during ambulation.

a microscopic scale and proceeds very slowly until material fractures reach a critical stage and begin to coalesce. Then the damage accelerates. Little was known about material fatigue until passenger planes began falling apart in mid-flight in the 1950's. That continued into the 1960's. This is a photo of a Lockheed L188 Electra. One of these fell out of the sky on March 17, 1960 over Tell City, Indiana. Those tragic events ushered in a flurry of fatigue research, including my own at the University of MN in the 1960's.

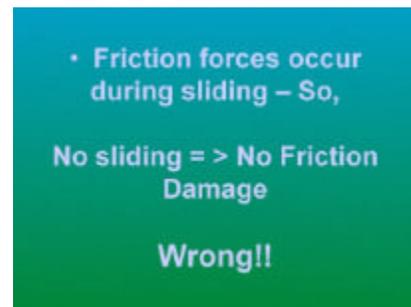


This type of damage proceeds similar to what material engineers call fatigue damage. Fatigue damage starts on

Skin tissue is similar. Trauma is not detectable or noticeable until it has been subjected to quite a large number of loading repetitions. By the time human skin damage reaches an easily detectable (painful) level, the trauma created by each load cycle is escalating very rapidly.



Friction is all around us. We often use it; we often avoid it; we seldom think about it. Baseball players spit on their hands to get a better grip on the bat handle. The moisture increases the friction. But, if our hands are too wet, we dry them for a better grip. That is managing friction



for better function. It is very common to associate friction and shear damage with sliding and not realize that one way to avoid high, damaging friction forces is to allow/facilitate sliding.



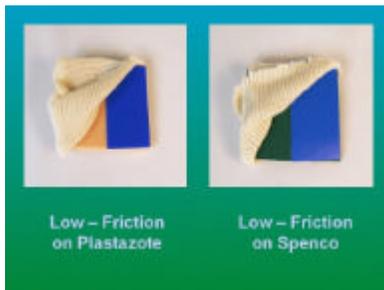
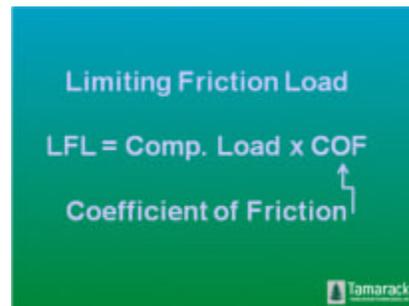
Before we go any farther, it is important to clarify some terms and concepts: In this photo, I am applying pure pressure against my cheek. I am compressing the skin and soft tissue against the cheek bone.

In this photo, I have added some upward force to the compression. Friction between fingers and cheek skin has caused the skin to be displaced relative to the cheek bone. The skin and soft tissue are clearly subjected to a shear distortion, shear strain, shear stress. Since the friction force is causing this, it is often also called a shear force in medical literature.



In this photo, the friction force is quite large, but because of friction, we still have seen no sliding at the skin-skin interface. A few dozen repetitions of such loads would certainly begin producing skin damage. If I push upward any harder, my fingers will begin to slide. We have reached the limiting friction load (LFL).

You may remember this equation from high school physics: The limiting friction force/load $LFL = \text{Compression Load} \times \text{COF}$, where COF stands for the coefficient of friction. So, we could protect the cheek skin from such high friction/shear loads by lowering the pressure or the COF or both.



I have distributed some demonstration samples consisting of either Plastazote or Spenco insole material. Half of one side is covered with a low-friction interface patch. You can quickly feel the effect of a lower COF by pressing down on the stockinette and twisting or pushing on your thumb.



ShearBan Friction Control Technology Video
http://youtu.be/YOQzU_EUNRc

This video clip shows, with an actual cut-away view what is happening when the bony elements of the foot move within a shoe. When the pressure and COF are both great enough, the skin and sock remain essentially “stuck” to the insole. The shear distortion is clearly visible during each loading/movement cycle. If we apply a low-friction interface patch under the first metatarsal head, the skin is freed to move in concert with the metatarsal heads before the friction load reaches the higher, more damaging level.

Dr. P.F.D. Naylor
British Journal of Dermatology (1955)
"There is an inverse relationship between the friction force and the number of rubs required to form a blister"

Military people have always been concerned about repetitive loading tissue damage. Blisters and deeper friction wounds can severely challenge the health and effectiveness of a marching army. Dr. PFD

Naylor's Data:
Soft tissue damage (wound generation) took three times as long if friction load peaks were cut in half (with no reduction of load pressure)

Naylor, a British dermatologist conducted some elegant experimental research more than 50 years ago to learn more about the physical cause of skin wounds. He found that peak friction force was the first order determinant of how many load repetitions were required to produce acute, painful skin wounds.

Naylor's Experiment:
Friction load peaks were measured and changed by allowing moisture to increase the friction coefficient (COF)

His data reveals that when friction loads were doubled, damage proceeded three times as fast (equal damage in one-third of the number of load cycles). This was observed with no changes in the vertical/pressure component of the loadings.

Sulzberger, Cortese, Fishman & Wiley
The Journal of Investigative Dermatology
Vol. 47, No. 5, pp 456-465
1966
Linear rubbing and twist rubbing experiments collaborated and extended Naylor's work.

Sulzberger's team of researchers expanded on Naylor's experimental work ten years later. They confirmed and extended Naylor's findings. In fact, his conclusions have

In a January 1972 issue of Military Medicine Dr. Sulzberger and co-author, William Akers, speculated on how to reduce skin trauma:
"One can also begin to systematically investigate the selection of fabrics and materials in the design of footwear and other gear to reduce friction over the most hazarded points."

been cited and endorsed by many researchers and clinical experts over the years. Sulzberger and Akers, writing in Military Medicine in 1972 actually came very close to describing strategic friction control when they wrote "One can also begin...footwear and other gear to reduce friction over the most hazarded points".

"For years, the biomechanics community has been talking about pressure...while its counterpart, shearing, was generally left out of the discussion..."

In the most recent five years, attention to the role of friction has been accelerating rapidly. This is one of the most recently published comments. It is high time orthotists, prosthetists and

...It turns out that the same force that causes blisters in runners may be the key to unlocking ulcer (foot wound) prevention." Ben Paul, DPM
Podiatry Management,
September 2011

pedorthists fully wake up to friction control as a way improve comfort, extend function and avoid wounds among the people we care for.

But, Friction is not a problem in all areas of support and containment devices

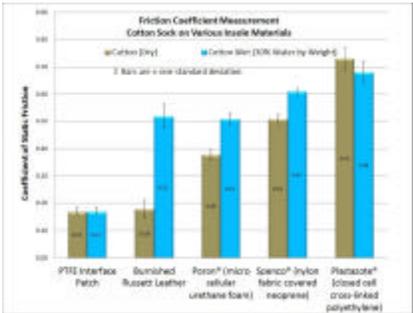
Now that we have thoroughly indicted friction, we must point out that friction is not all bad. In most areas inside our shoes, orthoses and prosthetic sockets, friction is functioning in a beneficial way to help stabilize and suspend. It is just in specific, relatively small areas



where friction peaks are excessive and causing damage. These are the “at risk” areas Sulzberger referred to as “the most hazarded points”.



The principle of Friction Management/control is to identify those “at-risk” areas and strategically reduce friction in those and only those locations. A very powerful low friction patch technology is available to easily do this.



This is a graph which compares the COF of various commonly used custom insole materials. As you can see, those values range from about 0.4 on up to over 0.7. The presence of perspiration further increases the COF of most of those materials. PTFE coated interface patch materials, to the far left of the graph, exhibit a COF less than 0.2 dry or wet. This means that in most cases, limiting

friction loads (LFL's) may be reduced by at least 50%. Remembering Dr. Naylor's findings, we can know that that will extend and expand comfortable function for people with intact sensation. For people with impaired sensation, it will create a much greater margin of safe activity. For existing wounds, friction control greatly improves the healing environment.

Benefits of Friction Control

- Greater patient comfort
- Fewer wounds
- Improved environment for wound healing
- More pleased patients and referers

Strategic friction management probably dates back to the earliest ox cart wheel and axel constructions. Automotive engineers today choose materials for maximum friction in some parts (clutches, brakes, belts, tires, etc.) and they minimize friction in other locations (pistons, gears,

Strategic Friction Management should be as present in our habits and thoughts as pressure management.

cams, bearings, etc.). A PTFE low friction interface patch is like applying a bit of oil to a critical location, but this “oil” doesn’t smear and spread beyond where it is needed. It does not hydrate and weaken the epidermis like oils and emollients. It stays in just one place and keeps acting like a lubricant for a long time.

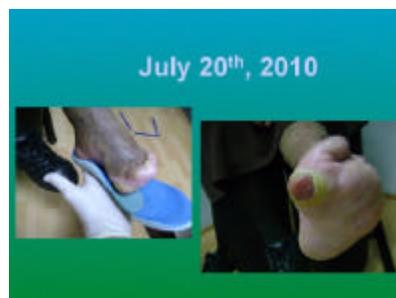
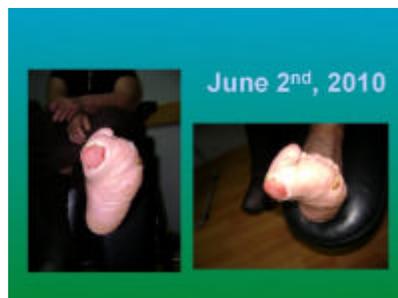
So far, this paper has focused on using strategic friction management to prevent skin trauma. It follows directly that reducing friction rubbing at a wound site will dramatically improve the physical healing environment.

A case from Luis Rodil, BOCPD Guatamala

I receive some wildly enthusiastic testimonials but very few arrive with photo documentation like the one I received from Mr. Luis Rodil, a practitioner in Guatamala.



These first photos track his frustrated efforts to heal a foot wound with widely accepted pressure off-loading procedures.



Then, in the Fall of 2010 he received a low friction interface product sample and applied it to the patient's insole.



These last three photo collages document the wound healing that commenced over the following months.



Of course we know that grafted skin and adhered scar tissue are especially susceptible to rubbing. The very first patient we used low friction interface patch material on was this fellow. He had skin grafting and an area of adhered scarring after closure of a bad wound in the area of his ankle. After playing a period of hockey, the wound re-opened at the scar. We lined the tongue of his skate with a low-friction interface material. He healed up and returned to playing hockey without further wound problems.



I have a limited number of published reprints to give to those of you who may be interested.

Thank you for your attention.

[Electronic format of this presentation is available at
<http://www.tamarackhti.com/resources/education.asp>]