

The Shear Factor in Decubitus Ulcer Development
 (RESNA Workshop, 2013)
 J. Martin Carlson



The Shear Factor in Decubitus Ulcer Development

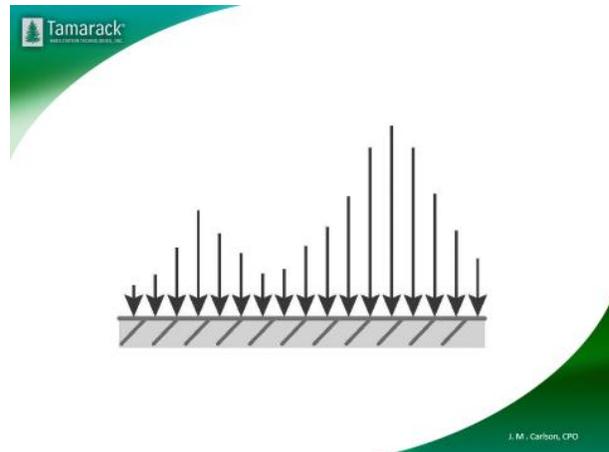
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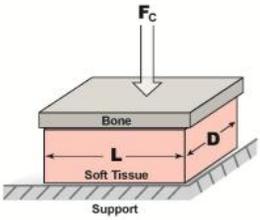
This presentation is designed for clinicians. Engineers and research people will notice some “sins of omission”, necessary because of time. I will begin with a brief definition of some terms and concepts tailored to this workshop subject. If I mention units, it will be in the English system which is most common in everyday use.

We will use an arrow to indicate a force. Arrow size and direction indicate magnitude and direction, respectively.

When the Force is distributed, we might refer to it as a pressure, but we must recognize that body support pressure varies sharply from location to location. The force vectors diagramed here are perpendicular or “normal” to the surface they act upon.



This diagram shows how compressive stress is defined and computed. The total force (lbs.) exerted upon a given area is divided by the size of the area (in²). This gives a lbs. per in² number.

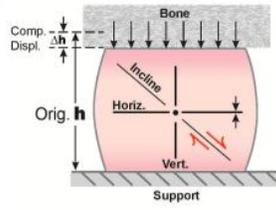



**Compressive Stress (S_c)
 Across Horiz. Planes
 In the Soft Tissue**

$S_c = \text{Force} \div \text{Area}$
 $S_c = F_c \div (L \times D)$
 (lbs. per in.²)

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The amount of compressive deflection (in.) caused by a force, divided by the original height or thickness (in.) of the material gives us the

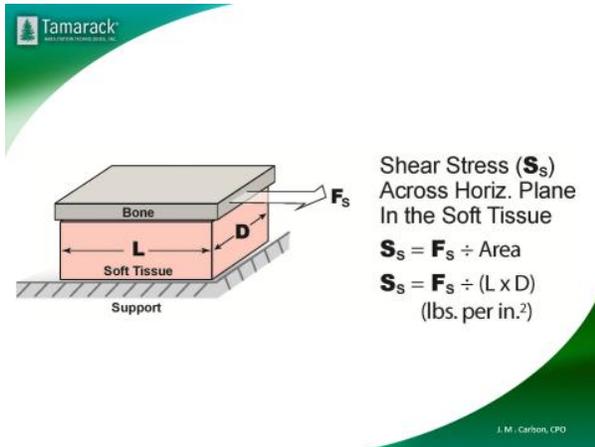
Compressive Strain (E_c)

Horiz. Plane: $E_c = \Delta h \div h$

Shear Strain?
 Horizontal Plane - None
 Vertical Plane - None
 Inclined Plane - Yes

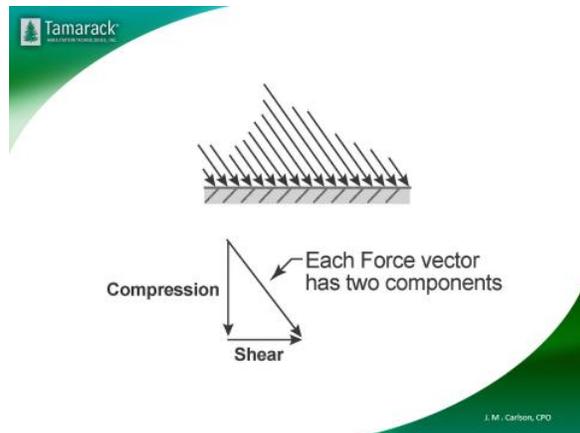
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compressive strain magnitude (in. of compression per inch of thickness, in./in.)



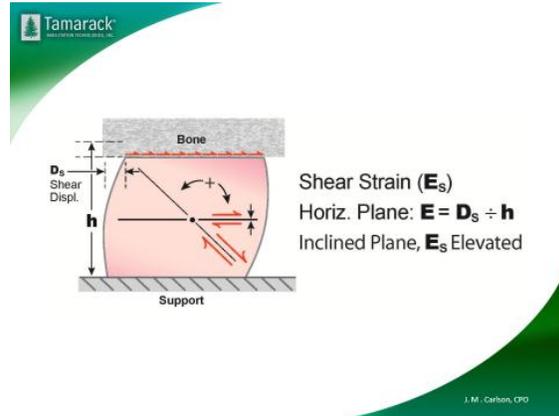
divided by the tissue thickness is how shear strain is calculated. The type of deformation caused by shear is much different than compression but the units are the same; inches per inch.

Both compression and shear change the dimensions of the soft tissue micro structure but investigators concur that shear deformation is very distortional and potentially more damaging in a structural sense. The other important thing to keep in mind is that, for a given body weight and movement of the skeleton, both compressive and shear strain will be greatest where the soft tissue is thinnest.

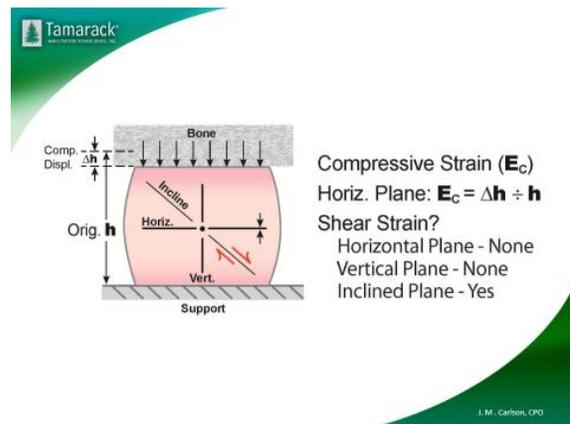


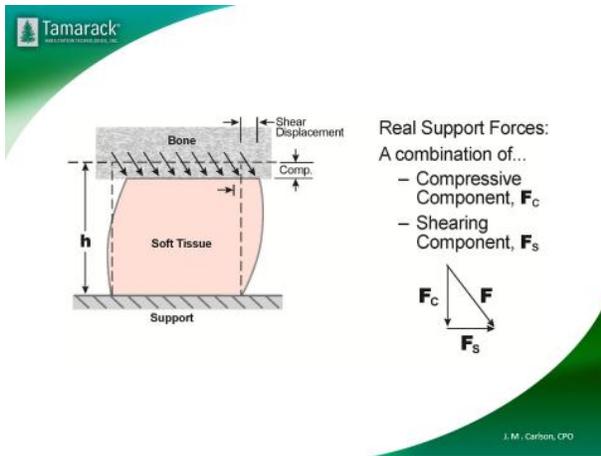
because of the type of tissue deformation it directly causes. Keep in mind that neither support loading nor the body tissue is uniform. Even if they were, stress depends on the specific location on, or in, the tissue and relates to a specific plane within the tissue. To illustrate, let us refer back to this idealized diagram of soft tissue being uniformly compressed between bone and support surface. Consider the state of shear stress at point A with respect to three planes. There is no shear stress across either the vertical or horizontal planes at point A but the purely

These next diagrams indicate how we define shear stress and strain. Shear stress is defined and calculated in a manner very similar to compressive stress. The difference is that the force is tangential to the surface or plane of interest, instead of perpendicular. The magnitude is expressed as force per unit area. The amount of shear displacement



Forces generated between skin and cushion are virtually always oblique to the skin surface, so the contact force has a component perpendicular to the skin surface and a component parallel to the surface. The normal component and how it varies under the pelvis is what a pressure mat indicates (with questionable accuracy). At the skin surface, F_t is due to friction and will be no greater than what is allowed by the most "slippery" interface between skin and support surface, if clothing is reasonably roomy. The friction force is also referred to as a "shear" force





compressive condition does generate a shear stress across an inclined plane. In fact shear stress is maximum along incline angles of 45°.

Now, if the bone had been moving to the right as the soft tissue was compressed and friction prevented the skin surface from sliding/gliding along with the moving bone, the soft tissue would be both compressed and sheared, when coming to rest.

The maximum shear stresses along planes inclined to your right are driven higher by the friction

constraint.

This is the case, early in my custom orthotic seating work, that first taught me about how damaging friction can be. This man suffered an industrial injury which “de-gloved” his right buttock and thigh as it crushed his right hip and knee. He was referred to us because areas of his right buttock and thigh broke down within days after a healing regimen that included months of prone bedrest healing and resuming wheelchair use. This happened repeatedly.



Because this man’s right hip and knee were fused, it was clear that, as he settled down into his pneumatic cushion, only friction prevented him from continuing to settle and slide, right on out of his wheelchair.



My prosthetics experience alerted me to the fact that adhered scar tissue and especially grafted skin were very vulnerable to friction damage. I didn’t at that time, know how to improve the pressure distribution provided by his pneumatic cushion, so I focused on reducing the friction. We adjusted and reinforced his right leg support and footrest so that



his settling and sliding would be halted very early by his foot and shoe instead of by friction on his butt and thigh.



That is all we did. He continued to use his wheelchair with the same cushion and these photos document how he healed over the following months.

The first well-instrumented research into the role of friction in skin damage began with Naylor's work in the 1950's. Naylor's findings were verified and carried forward by Sulzberger and colleagues in the 1960's and 1970's. Those early works investigated repetitive friction loading such as occurs in footwear and cause dermal blisters.

Research into the causes of deeper, more serious decubitus ulcers heated up a bit later and was based on the ischemia model...that cell death is caused by pressure cutting off capillary blood flow. That tissue trauma model obviously has some validity and dominated research, intervention technology and prevention thinking by caregivers almost totally for decades. As early as the 1970's, Leon Bennet

Research

Friction-Induced Tissue Trauma

- Naylor – 1955
- Sulzberger, et. Al. 1960's & 1970's
(Repetitive Loading)

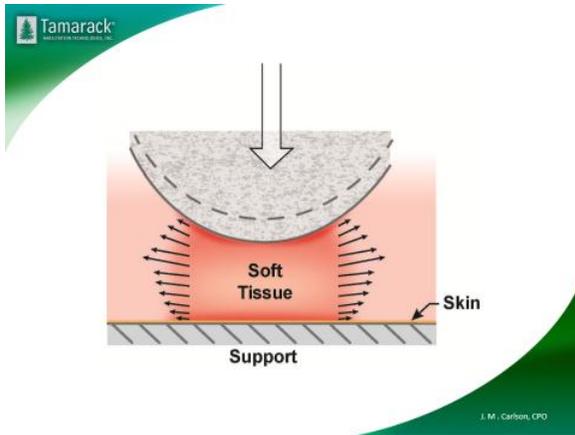
(Static Loading)

- Bennet – Ischemia caused at much Lower Pressure when Friction/Shear was Added

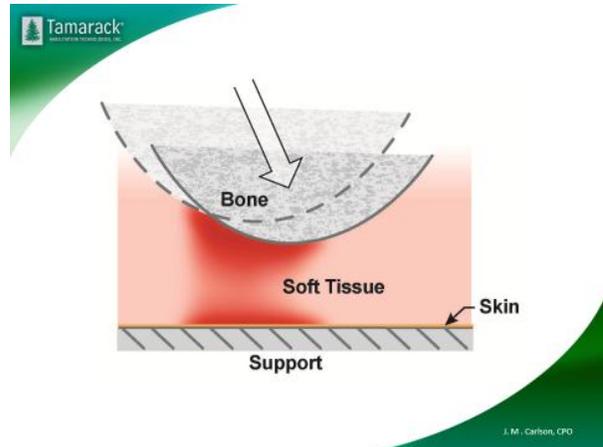
investigated the role of shear stress on capillary flow and found that ischemic conditions occurred at much lower pressures when shearing loads were super-imposed.

Since Bennet's research, there has been a slow acceleration of investigations and reports regarding the role of shear. Some of those indicate that elevated shear conditions compromise capillary diameters, cell wall permeability and, possibly, cell wall continuity. Recognizing this increasing evidence, the National Pressure Ulcer Advisory Panel (NPUAP) and others established the Shear Force Initiative, an international consensus group to explore the current level of knowledge about the role of shear.

- Steklenburg, et. al. '07 –
Tissue trauma from indentation loading occurred in a briefer time than from pure ischemia (2 hour reversibility)
- Linder- Ganz, et. al. –
Effects of pressure and shear on capillary closure in muscle.
- Gefen –
Effects of pressure and shear on nutrient and cell waste diffusion rates, etc.



When skin and other soft tissue is “pinched” between a bony prominence and a support surface, the compression causes the soft tissue to be squeezed out from under the bone. The result is a complex combination of compressive, tensile and shear stresses, on different planes within the tissue. If the bone also moves rightward as the body settles into a resting location, friction forces pulling at the skin surface will further elevate the magnitude of shear stress levels in the soft tissue.



There are many details yet to be learned by the researchers, but two things have been clearly established:

1. Shear stresses are a significant ulcer generation factor; and,
2. Friction forces applying tangential traction upon the skin surface can dramatically increase peak shear stresses in the skin and deeper soft tissue.

Strategic Friction Management

Lower COF Material Located in the At-Risk Locations

This means that friction management to reduce peak shear stress is an emerging tool for decubitus ulcer prevention. We must as caregivers and product designers, do what we can to avoid friction on the skin in at-risk locations.

Strategic Friction Management

- A complementary tool
- Not a substitute for pressure management

Without Friction Management

Damaging Levels of Friction-Shear Exist when Patient is At Rest in chair or bed.

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I want to close by making sure to correct a common misconception. We all know that skin is at risk for damage whenever it slides across a supporting surface. However, a critical aspect of how friction-induced shear contributes to ulcer generation has been almost totally overlooked. The skin of virtually all wheelchair users and most bed patients is subjected to significant levels of friction when at rest..not moving in, out or across bed or chair. The friction develops as they “settle in” to their wheelchair or as the head of the bed is elevated. The resulting shear stresses are then present and operating continuously, along with pressure, to hasten pressure ulcer generation.

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