Deep Tissue Injury Research, Part I
Pressure Ulcers: A New Perspective

They’re not a new medical condition, and healthcare professionals have been dealing with them for so long that multiple terms have been coined for them. Bedsores. Decubitus ulcers. Pressure sores. Pressure ulcers.

But in research published in Mobility Management last year (June, August and September 2014 issues), Amit Gefen, Ph.D., shed important light on the hows, whys, whens and wheres of tissue deformation and how this internal deformation can cause Deep Tissue Injuries (DTI) that can be even more insidious than traditional pressure ulcers — because they’re typically harder to identify and observe in the usual ways.

This year, we start a new research series based on new conversations with Gefen as well as with his colleague Kara Kopplin, BSc, the Senior Director of Efficacy Research, Standards & Compliance for ROHO Inc. The series will explore the role of tissue deformation on skin and tissue health, and will extrapolate from last year’s research.*

A Different Background, a Different Approach
Gefen is a professor of biomedical engineering at Tel Aviv University. His Ph.D. and master’s degrees are in biomedical engineering, while his bachelor’s degree is in mechanical engineering.

That background resulted in Gefen adopting an unconventional, but very effective approach in trying to understand the forces within the body that lead ultimately to skin breakdown. While studying chronic wounds during his master’s research, Gefen investigated how the bones of the foot and the soft tissues within the foot interacted. He also noticed that the chronic wound field lacked the large bodies of research that one could easily find in other healthcare specialties, such as orthopaedics or cancer. “I decided I would focus on that and try to bring the tools that mechanical engineers use, like computational modeling,” Gefen said. “Mechanical engineers use a lot of computational tools, computer tools, to try to describe how complex structures behave."

Computer simulations offered a way “to look at how loads develop in tissues, not only on the surface of tissues, but also internally, where you can’t look,” Gefen explained. He also used laboratory-generated human tissue, subjecting that tissue to forces and loads that clinicians can expect to see in wheelchair users. Those tissues substituted for human subjects, thus circumventing a chronic challenge for researchers in the complex rehab industry: The relatively small number of clients to test and examine.

Gefen also called upon other tools common in the medical field, though not necessarily to the seating & wheeled mobility niche. One very helpful device was an “open” style of MRI machine, which enabled subjects to be scanned while sitting upright — first on a rubber tire, then directly on the flat MRI surface. When subjects sat on that surface, Gefen noted, “You can see that the muscle is deformed to at least 50 percent of its original thickness.”

Why Tissue Deformation Is Crucial to Pressure Ulcer Discussions
On this year’s series, Gefen said, “It all builds on the research that we discussed last year. If you remember what we discussed last year, it’s essentially the role of tissue deformation. And we covered the seating studies that we did with an MRI, looking at tissue deformation with the MRI being the tool to measure tissue deformation in human beings and how you extrapolate from these measurements of tissue deformation some measures of tissue tolerance by using, say, animal models or tissue engineering models — where you apply the same mechanical loads that you are observing in the MRI and then to approximate how the tissues respond to that and whether they stay viable or not.

“And then we went to the cellular level and looked at what exactly happens to the cells that kills them. We found that these deformations are basically compromising the control of transport through the plasma membrane of the cell so after certain times, the walls of the cell, the plasma membranes, become more permeable.”

That conclusion — that deformation eventually causes tissue damage that happens internally, where it’s difficult or impossible to detect using conventional observational methods such as checking for a change in skin color — sounds simple. But it potentially evolves how pressure ulcer formation and therefore prevention should be understood and approached.

“If you want to protect tissues, what you really need to do is to minimize tissue deformation,” Gefen said. “Minimize tissue deformation as opposed to minimizing interface pressures. It’s not the same thing. If you look at interface pressures, you basically look at just the skin. And you can’t really tell what’s going on in [the body].”

Taking Gefen’s findings into consideration, the commonly used term “skin breakdown” seems somewhat imprecise. Gefen suggested that “tissue breakdown” is a far more accurate term. But skin breakdown is really how the industry has come to think of pressure ulcer formation. HCPCS codes and related funding, for instance, describe wheelchair seat cushions as “skin protection” models. In reality, protecting skin doesn’t seem to even come close to ultimately understanding the entire picture.

As Kopplin pointed out, “Skin we can protect easily. But the internal damage...”●

*Editor’s Note: Stay tuned for part II of this year’s series. Download a free pdf containing all three of the 2014 research columns here: mobilitymgmt.com/14pu

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Last month, we reviewed pressure ulcer research from 2014 as discussed by Amit Gefen, Ph.D, professor of biomedical engineering at Tel Aviv University, and Kara Kopplin, BSc, the Senior Director of Efficacy Research, Standards & Compliance for ROHO Inc. A key take-away from last year’s research — and a point critical to this year’s follow-through — is how tissue deformation occurs within the body, how it can cause tissue damage, and why deep tissue injury (DTI) presents such a challenge to today’s healthcare providers, in particular professionals in seating & wheeled mobility.

Due to factors that can include long periods of sitting, lack of sensation, difficulty in performing regular and sufficient weight shifts, and changes occurring within their bodies (such as the incursion of additional fat into the muscle tissue of spinal cord injury patients), wheelchair users are at increased risk for developing pressure ulcers. That’s been understood in the seating & wheeled mobility niche for a long time, and it’s the reason that wheelchair users are told to perform regular skin checks, and healthcare professionals and caregivers are taught to look for telltale signs of pressure ulcers, such as changes in skin color, temperature and texture.

Getting Under Your Client's Skin
Structurally, healthy skin is similar across individuals; it’s composed of (starting at the surface and going deeper) epidermis, dermis and subcutaneous fat layers. But when discussing pressure ulcers with Mobility Management at this year’s International Seating Symposium in Nashville, Tenn., Gefen pointed out that beneath the skin, every person is different.

“You can look at the skin of Kara and myself,” Gefen said, referring to his colleague, “and get similar pressure maps. But internally, it would be different. Because her pelvis and her bones are shaped differently than mine, and I have more muscle mass and less fat mass or whatever, the internal anatomy can be essentially different.”

That’s an important point because compared to ischemia-caused pressure ulcers, which wheelchair users have traditionally been taught to watch for by looking for reddened skin, etc., DTIs can be much more difficult to detect as they are forming.

Once DTIs are detectable, critical damage may already have occurred.

“When you see [the DTI], it can also become a systemic problem,” Gefen said, “because the kidneys are overloaded with these muscle proteins that are going through the bloodstream. Everything now builds on this new knowledge, that tissue deformation is really the factor that you should look at.”

A Changing Conversation
Gefen added that the perspective on pressure ulcers is changing, thanks to a greater understanding of internal tissue deformation. He pointed to the National Pressure Ulcer Advisory Panel (NPUAP), headquartered in Washington, D.C., and the European Pressure Ulcer Advisory Panel.

“You could actually listen to a new conversation, with new terminology,” he said. “When I was in these meetings a few years ago, they were all talking about preventing ischemia and optimizing blood flow and looking at pressure maps and saying well, if the pressures are too high, then blood vessels are collapsing, and then you have ischemia, and that’s not good. The other side of it, which is really scary, is that they were saying some products work better than others, based only on the superficial information that they do decrease pressure.”

Gefen said research has shown that merely changing pressure at the skin/wheelchair cushion interface is not nearly enough to truly prevent the comprehensive damage caused by pressure ulcers.

And he said he realizes that recognizing the danger of DTI impacts so many existing processes and protocols, from HCPCS codes for skin-protection cushions to the funding attached to those codes, plus client risk assessment, design of future wheelchair cushions, the prescription of those cushions and efficacy evaluations.

“It’s changing already,” he said of pressure ulcer discussions. “I’m also the president of the European Pressure Ulcer Advisory Panel, and we’ve just launched, together with NPUAP, new guidelines for prevention and treatment, which were developed by an international group from Asia, the Americas and Europe. There’s a unified classification system now, and this classification system now includes DTIs worldwide.”

Gefen indicated this is one of the first steps in moving toward tackling a problem that can be so hard to predict and prevent because DTIs happen internally, and their formation is different for every patient. This means, for instance, that a long-term care facility’s practice of changing a resident’s position at regular intervals and checking for visual changes in the patient’s skin might not be enough — and that such facilities need to be educated appropriately.

“Sometimes you can’t see it,” Gefen says of DTIs. “You just break down. It’s all individual, so we have to rethink everything, basically, and this is a process which has started already.”

Coming Up: How deep tissue injuries form, and how that process could change the way tomorrow’s wheelchair seat cushions are designed and created.
Pressure ulcers are insidious, but traditional wisdom has said they could be prevented by diligently performing skin checks. At-risk populations and their families/caregivers have been advised to look for the changes in skin temperature, color and texture that can signal skin breakdown. Ischemia, the lack of adequate blood supply to skin under unrelieved pressure, was thought to typically be the cause of pressure ulcers, also known as pressure sores or bedsores.

But new research has pulled back the curtain on pressure ulcers to reveal additional causes and results that are much more difficult to detect. Deep tissue injuries (DTI) happen internally, and therefore don’t necessarily cause the reddened or warmer skin that has been a trademark of a developing pressure ulcer. With this evolution in understanding comes a critical question: What will clinicians, ATPs, seating manufacturers and other stakeholders do with this newly discovered information?

Deep Tissue Injury Formation

Recent and ongoing research by Amit Gefen, Ph.D., professor of biomedical engineering at Tel Aviv University, and Kara Kopplin, BSc, the Senior Director of Efficacy & Research for ROHO Inc., has focused on pressure-related deep tissue injuries (see Mobility Management, September 2015).

A mechanical engineer by training, Gefen approaches the problem of pressure ulcers via a different route than that commonly taken by seating professionals. When you talk with him, as Mobility Management did over breakfast for a second consecutive year at the 2015 International Seating Symposium in Nashville, Tenn., the conversation is full of mentions of forces and loads and structures.

“We know that exposures to tissue deformation are putting the tissue at risk, and since we know that the more serious pressure ulcers are deep tissue injuries that start from the inside, we know where to look,” he says. “The highest tissue loads are at the bone/soft tissue interface.”

Taking the ischial tuberosity (IT) as an example, Gefen mentions what has long been understood in the seating realm: When the IT presses down on the tissue and skin beneath it for unrelieved periods of time, damage can occur.

“It’s the sharpness of the bone which is deforming the tissues,” Gefen says of the rather pointed IT depressing the soft tissue of the buttock. During the discussion, with one hand he held a knife vertically as a visual aid and lightly pressed its point against the palm of his other hand. “It’s like taking this knife here and if I do this, I’ll be able to cut through. And the reason for that is the sharp tip of the knife is focusing all the force I’m delivering with my hand in one very small area.” In the case of the IT, he says, “You have the sharp tip of the bone which is compressing against a very small area of soft tissue, and that’s where you have these great forces.”

Kopplin says the traditional concern of a lack of bloodflow resulting in what’s been called “skin breakdown” is only part of the real issue — which has just recently begun to be understood. “Last year and two years ago, it was still all this talk about ischemia,” she says. “They were barking up the wrong tree. [DTI] is what is more critical.”

Gefen agrees: “Once you understand deformation, and you connect that with the clinical manifestation of DTIs, then you really understand what’s going on here.”

Applying New Knowledge

Having come to this new understanding of deep tissue injuries through research that used engineering principles, laboratory-grown tissue cells and computer extrapolations of what happened when those cells were subjected to loads, Gefen’s next question was how the knowledge could be applied to real-world situations. Working with Kopplin and with seating clinicians, Gefen decided next to focus on scar tissue, a too-common trait among wheelchair users.

Gefen and Kopplin referenced a sobering truth about pressure ulcers among wheelchair users: Once a client has one, it’s very difficult to prevent a recurrence.

“They never really heal,” Kopplin says. “We talk about healing from your pressure ulcer; that tissue’s never going to be the same.”

So seating professionals have to deal with the resulting scar tissue,
new discoveries

Deep Tissue Injury Research, Part III
DTIs, Scars & Ramifications

which lacks the elasticity and load-bearing abilities of healthy skin and tissue.

Gefen contends that proper immersion and envelopment in wheelchair cushions — and specifically, his studies focused on ROHO air-celled cushions — are paramount to protecting wheelchair users not just against ischemic pressure ulcers, but also against deformation-inflicted DTIs. So a logical next step was to determine whether immersion and envelopment strategies would also work for clients who already have scar tissue — “different types and shapes and sizes of scars that clinicians see in the real world,” Gefen says. “We know based on work that is conducted in Japan, for example, that with simple ultrasound scanning, basically anatomical mapping, you can identify scars, even internally.”

This gives clinicians the chance to not only identify whether a client has a scar, but also its shape and size — and to judge the scar’s attributes not just by what’s visible on the skin surface, but also far underneath it.

“If the scar tissue goes deeper, it concentrates mechanical loads and acts as an additional site for mechanical stress concentrations, much like the bone,” Gefen says. “So we decided we wanted to look at the different scar shapes, scar sizes and locations.”

Borrowing the names coined by Japanese researchers, Gefen says, “SW is sandwich, because [such a scar] has components on the surface and components internally, just like a sandwich. Hourglass (HG) is shaped like an hourglass.” In the cross-section diagram , you can see the whitish shape of the IT, the gluteus muscle directly around the IT, the surrounding fat (yellow) and the scar tissue (blue). In some cases (i.e., “Thin”), the scar tissue is on the surface of the skin. In the SW illustration, scar tissue is present near the IT as well as on the skin. In the HG example, scar tissue is present from the IT all the way through tissue layers to the skin, creating a column-like structure.

The next part of the series will discuss how different scars react differently to loads, how cushions react to those loads, and the importance of adjustability in the wheelchair seat cushion efficacy equation.

Editor’s Note: The first two parts of this series are in Mobility Management’s August and September 2015 issues, viewable at MobilityMgmt.com. Read “Computer simulations of efficacy of air-cell-based cushions in protecting against reoccurrence of pressure ulcers” by Gefen, Kopplin, and Ayelet Levy, in the Journal of Rehabilitation Research & Development (rehab.research.va.gov/jour/2014/518/jrrd-2014-02-0048.html) Mobility Management illustrations by Dudley Wakamatsu, based on research by Gefen, Kopplin and Levy.

new discoveries

Deep Tissue Injury Research, Part IV:
How Clients Change & What We’ve Learned

By Laurie Watanabe

In 2014, Mobility Management began a series on the pressure ulcer research of Amit Gefen, Ph.D., professor in biomedical engineering at Tel Aviv University. Gefen, immediate past president of the European Pressure Ulcer Advisory Panel, brought a new perspective and new tools — including laboratory-generated cells and tissues that could be tested, and those results then modeled and extrapolated via computer programs — to the task of better understanding what pressure ulcers are, why they form, and how they challenge seating & positioning professionals trying to keep wheelchair users safe.

That series of clinical articles led into a second research series in 2015, this time concentrating on deep tissue injuries (DTI).
new discoveries

Deep Tissue Injury Research, Part IV: How Clients Change & What We’ve Learned

The traditional view of pressure ulcers focuses on ischemia. Ulcers of that type were thought to be caused by inadequate blood flow, often as a result of prolonged pressure over a bony prominence, such as an ischial tuberosity (IT). Current clinical practices for reducing that sort of pressure ulcer risk include watching for changes in skin color and temperature. But Gefen’s research, as well as research by other notable scientists around the globe, indicated that ischemia is not the only way pressure ulcers form — and DTIs are not so easily identified by looking for changes in skin texture or color. In fact, DTIs are influenced by factors we’re only now starting to understand.

Gefen’s industry partner in this research has been Kara Kopplin, BSc, the Senior Director of Efficacy & Research for ROHO Inc. It’s an evolving area of study, one that will impact not just today’s wheelchair users, but tomorrow’s. Here we wrap up our series by discussing how wheelchair users’ changing bodies can affect their risk.

Differences in Scar Tissues

As discussed in November, Gefen’s research covered not just how healthy tissue responds to forces and distortions, but how compromised tissue does as well. DTIs are caused by sustained tissue deformations. Gefen wanted to determine whether the immersion and envelopment strategies advanced by ROHO’s air-celled cushions would succeed in those environments, including “different types and shapes and sizes of scars that clinicians see in the real world.”

Gefen explained that ultrasound scanning work and anatomical mapping done for example in Japan could identify existing scars by looking at deeper tissues as well as what was visible on the skin. “So if you see something, that can give you a hint that this patient had a pressure ulcer already,” he noted. He used the names that Japanese researchers created to differentiate the types of scars that seating specialists often see in their clients (see diagrams).

In the illustrations, the ischial tuberosity is white. The gluteus muscle is red and is seen directly around the IT. Surrounding fat tissue is yellow, and scar tissue is blue.

In the cross-sections, you’ll see the “Thin” example has scar tissue on the surface of the skin. “Deep” has scar tissue at the IT and gluteus muscle interface. The “Sandwich” (abbreviated “SW”) scar shows scar tissue both internally at the IT and on the surface of the skin. And the “Hourglass” scar (abbreviated “HG”) has scar tissue that traverses the distance from the IT to the surface of the skin.

Gefen pointed out that it’s important to understand how scar tissue differs from healthy tissue, and how it reacts differently to force. In the Sandwich scar, for instance, he noted, “You can see how the scar concentrates the mechanical forces. The forces are basically going through the scar. That’s a well-known principle in mechanical engineering: Forces will always tend to go through stiffer structures. They go all the way down through the scar. But the scar cannot deform much, so at the interface, the non-scar tissues are deforming, and they’re deforming a lot. They’re deforming for themselves and compensating for the tissue that can’t deform, which means that they deform excessively.”

Gefen said he found that if scar tissue is milder, the immersion and envelopment offered by the ROHO air-cell cushions he used did greatly compensate for it.

“If the scars are more mild, you actually get load values in the tissues that are similar to what you have in tissues and skin that are normal,” Gefen said. “The immersion and envelopment effect is so strong that it can mitigate not only the presence of force between the bone and the soft tissue, but also the presence of the [mild] scar. And we quantified that. In each and every case, we divided the value of the mechanical loading in the tissues where there is a scar by the volume of the mechanical loading as if there was no scar there.

“So ideally, you would want these values to be around 1 or lower than 1. On a ROHO cushion, in some of the [more severe] scars, you do get values above 1.”

But Gefen added that for less severe scars, “most of the time, it’s controllable. [The ROHO air-celled cushion] contains them.”

In other words, those immersion and envelopment strategies can significantly compensate for and manage those scar conditions.

Managing Scars as a Chronic Condition

This research suggests that even when scar tissue is already present, it can be possible to manage pressure ulcers and deep tissue injury risk safely, as a chronic condition — depending on the severity of the scarring as well as the intervention chosen.

Gefen visited long-term care facilities and rehab centers all over the world, and noticed that the most aggressive, significant seating interventions were often reserved for “patients in the worst condition.”

That means other patients thought to be at lower risk for pressure ulcers could be denied the most effective interventions until they deteriorate. That’s far from ideal, but Gefen pointed out that the reasoning has been that clinicians in those settings haven’t understood why those immersion and envelopment strategies work — thereby making them more difficult to justify.

In pointing out the importance of these research findings, Kopplin explained, “Now that we have the evidence, we can start those conversations with them, with research data instead of anecdotal or subjective information. That’s part of the broader plan with this research. We’ve never known why some people with scars can be managed, and some with scars can’t.”

“It all points to immersion and envelopment,” Gefen said. “And as you increase immersion and envelop-
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Deep Tissue Injury Research, Part IV: How Clients Change & What We’ve Learned

Client’s Bodies Change — Quickly
Another feature of the research to emerge is how quickly a client’s body can change, for example, after a spinal cord injury (SCI). Gefen’s research discussed how rapidly fat can encroach upon muscle in newly injured SCI patients. Intramuscular fat can increase significantly within the weeks post injury, thereby drastically changing the nature of the tissue that wheelchair seat cushions are trying to protect.

“Before the person breaks down, there are so many changes that are ongoing,” Gefen said. “That all takes place in weeks. Dramatic changes. In about 20 to 40 weeks, [newly injured SCI patients] lose 40 to 50 percent of their bone and muscle mass in the buttocks. In half a year.”

That’s a problem, Gefen pointed out, given that those clients continue to use the same seat cushions prescribed for them months before, when their bodies were much different.

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That’s a problem, Gefen pointed out, given that those clients continue to use the same seat cushions prescribed for them months before, when their bodies were much different.

“Here in the States, [funding sources and insurance companies] are pushing for a reimbursement factor of [one cushion] every fifth year. They’re thinking about the cushion. They’re thinking about the materials of the cushion — for instance, when the foam collapses. They’re not thinking about the patient. The cushion still hasn’t aged; it’s still brand new. But the person has gained a little bit of weight. If this is a non-adjustable, contoured foam cushion for example, it would not fit the shape of the buttocks after that weight gain. The buttocks are not sitting in the holes [of the cushion] any more.”

As intramuscular fat continues to develop, Gefen said, “It’s practically taking over, and if you wait long enough, there will be practically no muscle. You have stripes of fat in between muscle layers. These muscles internally slide against each other [on the cushion]. That will add even more shear internally in the tissues.”

So in addition to its ability to immerse and envelop the client’s shape when it’s prescribed, Gefen said a cushion needs to adjust to the client’s evolving body shape as long as he/she is using that cushion. This feature is called adjustability, and Gefen said it is a critical design feature of a good wheelchair cushion.

“So how well can the cushion adjust as the person changes?” Gefen asked. “What we find is that at the time of the fitting, you get shear deformation levels that are tolerable by themselves. A few weeks later, it’s tripled. The patient doesn’t even know that; it all happens internally. It’s not only the immersion and envelopment, but also the ability of the cushion to adjust to body changes.”

Kopplin said that when a person needs to function in their daily living environment, for example shifting in the chair, reaching for objects (and therefore changing sitting posture), or even changing clothes, the cushion needs to accommodate these movements to continue to protect the client. That’s the real-world interaction between the client and the cushion. They refer to this critical cushion function as adaptability, and it’s needed not just as a client changes over weeks, but even during a typical day.

“You shouldn’t have to constantly adjust your cushion every time you’re going to lean forward to work on your computer,” she said. “It needs to respond and adapt to you.”

Gefen referred to a study that Kopplin conducted at ROHO to look at the drastic postural changes that take place simply when a client changes from flat shoes to high-heeled ones.

“I can imagine what’s happening internally at that bone and in the soft tissues surrounding it, and what a great risk that person is at, just from changing their shoes,” Kopplin said.

The current understanding of deformation and DTI, along with these research studies of the effects of scar tissues, body changes, custom contoured cushions (which may no longer “fit” over time) and even daily movements and wardrobe changes, led Gefen to a conclusion about what seating clinicians, ATPs and cushion manufacturers should strive for.

“We can actually say here,” he noted, “that Envelopment + Adjustability + Adaptability = Safety.”