Support Surfaces:
Viscoelastic Expanded Urethane versus Conventional Foam

Conventional mattresses can create painful, high-pressure areas for patients. Is there a safer alternative, one that reduces pressure by increasing contact areas?

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The entire weight of a bed-ridden patient must be supported by the areas where the body is in contact with the mattress. Since body contours are not uniform, these contact areas are relatively small compared to the entire back, side, or front contour. For a conventional mattress, the prime contact areas are the bony prominences, such as the heels, trochanters, and scapulae. The pressure at any contact area is the portion of the patient's weight carried at that location, divided by that contact area. For instance, in the case of the heel, the weight of the foot and part of the lower leg is concentrated over the small contact area of the back of the heel. This leads to very high pressure at that location. A pressure ulcer will form at this location, if this pressure is uninterrupted or not reduced.

Pressure management support surfaces are mattresses, beds, overlays, and pads. They are used to either decrease the time of exposure to high pressure or reduce pressure over the use period. This article presents the principles of support surfaces that reduce pressure over the use period.

PRINCIPLE OF PRESSURE REDUCTION

There are 2 factors that determine the pressure at a location where the patient's body contacts

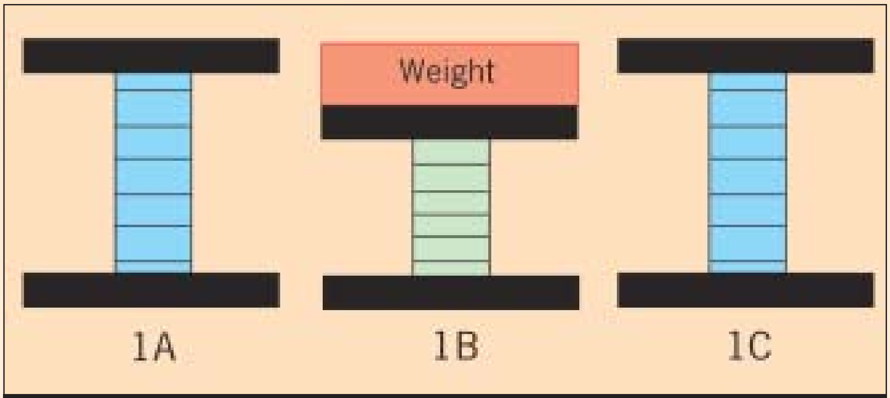

Figure 1. Elastic deformation.

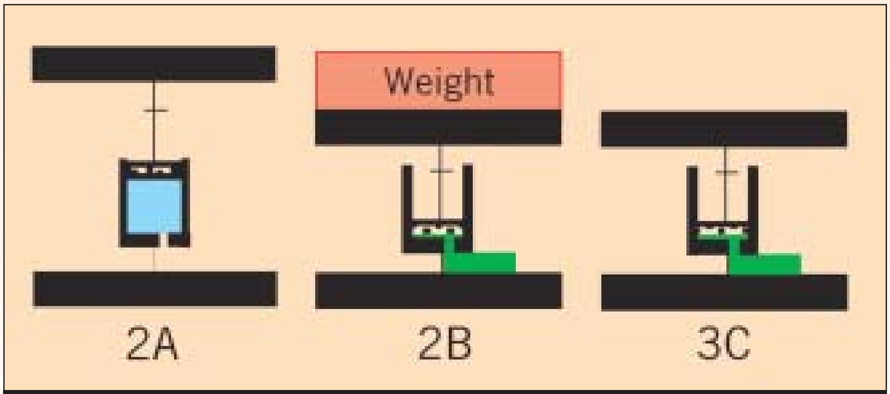

Figure 2. Viscous deformation.

the support surface. One is the portion of the patient's weight involved at this location; the other is the area of contact. The amount of pressure at this location is the weight divided by the contact area. In practice, the patient's weight cannot be altered. This means that pressure can only be changed by varying the contact area. To reduce pressure, the contact area must be increased. For example, if pressure at the heel is 50 millimeters of mercury (mm Hg), with a contact area of 10 cm^2, pressure will be reduced to 25 mm Hg if the contact area is increased to 20 cm^2. Effective support surfaces reduce pressure by increasing the contact area.

There are many approaches to this, and the makers of a number of commercially available support surfaces claim that they reduce contact pressure. These products include mattresses made from solid materials and those made from arrangements of solid and fluid materials.

MATTRESSES MADE FROM ARRANGEMENTS OF SOLID AND FLUID MATERIALS

The method of pressure reduction by mattresses made from arrangements of solid and fluid materials is reasonably well understood. At each contact area, the mattress is compressed by the patient's weight and deforms in response to this compression. The amount of deformation depends on the portion of the body weight and the performance of the mattress at that location. In general, mattress performance involves a combination of elastic and viscous deformation in response to the weight of the patient.

Elastic deformation. A good example of an elastic solid is a bedspring. Figure 1A represents a bedspring and shows how elastic deformation works. The elastic material is uncompressed. In Figure 1B, it is compressed by the weight. This causes the elastic material to deform, and as it deforms, it develops a back pressure. The elastic material continues to deform until the back pressure is equal to the weight divided by the contact area. When this happens, the elastic material stops deforming and remains compressed as long as the weight is maintained. In Figure 1C, the weight is removed, and the back pressure causes the elastic material to spring back to its original size.

Viscous deformation. A good example of a viscous material is honey. In Figure 2, the viscous material is placed inside the chamber. In Figure 2A, the material is uncompressed. In Figure 2B, the material is compressed by the weight and deforms. Unlike the elastic material, the viscous material does not develop a back pressure as it deforms. Instead, it flows out through the gap in the bottom of the chamber. In Figure 2C, the weight is removed, and the material remains at its compressed size.

In a mattress made with solid and fluid components, the solid parts generally have elastic characteristics, and the fluid parts usually display viscous behavior. Figure 3 shows how such a combination of elastic and viscous components works.

Figure 3A shows the combination before the patient is placed on the mattress. Both the elastic and viscous components are in their original uncompressed states. To be effective, the mattress needs sufficient elasticity to develop the back pressure required to support the patient without bottoming out. Figure 3B shows the elastic material developing this back pressure. To reduce the pressure, the mattress needs sufficient viscous behavior to increase the contact area. Figure 3B shows the viscous material flowing out to increase the contact area. To return to its unloaded dimensions when the patient is moved or repositioned, the mattress needs sufficient elasticity to return both the elastic and viscous components to the original size. This is shown in Figure 3C.

MATTRESSES MADE FROM SOLID MATERIALS

While they are widely used, there is an incomplete understanding of how products made from solid materials reduce pressure. To increase this knowledge, a

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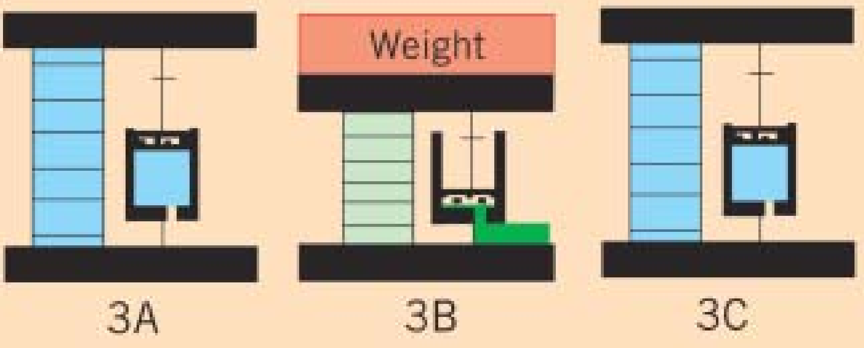

Figure 3. Elastic and viscous deformation.

Table 1. Heel Pressures on Materials

Material	Peak Pressure	Level Pressure	Pressure Reduction
Control	100%	96%	4%
VE	100%	82%	18%

study was conducted with 2 materials in this category: conventional polyurethane foam representing the most prevalent material in this group (control material) and a viscoelastic expanded urethane (VE material) supplied by Tempur-Pedic International, Inc. (Lexington, Ky).

As mentioned earlier, most pressure ulcers occur at bony prominences, such as the heels. At each of these locations, the greatest pressure concentration is at the boundary between the bone and soft tissue (B-ST). Studies have demonstrated that this is where true pressure ulcers originate.[1–4] However, this pressure cannot be measured in patients or human volunteers without invasive procedures. To overcome this situation, an instrument to measure the B-ST pressures was developed and validated against clinical studies. This instrument contains a full body model with skeleton, simulated soft tissue, and pressure sensors located at the boundary between the skeleton and soft tissue at the bony prominences. Since it is a frequent site of pressure ulcers and generally a high-pressure point, the heel was selected as the site for this study.

The heel was positioned over the material and uniformly lowered onto its surface. The B-ST pressure was measured continuously from the onset of loading. When the heel came into full contact with the material, an initial high pressure (peak pressure) was observed. As the heel sank into the material, the pressure dropped to a final, stabilized value (level pressure). The pressure reduction for each material is equal to the difference between the peak pressure and the level pressure. Each set of pressure measurements was repeated 3 times. Typical pressure recordings with the 2 materials are shown in Figures 4 and 5.

The average peak pressures, level pressures, and pressure reductions are presented in Table 1.

These results show that the pressure reduction obtained with the VE material was more than 4 times as much as that achieved with the control material. How did this happen? The weight did not change during the study, and the 2 materials had similar peak pressure values. Since pressure is equal to the weight divided by the contact area, this difference in pressure reduction must be due to a greater contact area with the VE than with the control material. The amount of increased contact area is the pressure reduction with the VE minus that with the control (14%).

To determine what caused this difference, it is helpful to discuss what happens as the heel sinks into the materials. Both materials are integral solids that deform as the heel sinks into them. This deformation is in 2 directions: vertical compression and lateral stretching. Lateral stretching is the equivalent of the "hammock effect." Figure 6 shows the process for the control material; Figure 7 shows it for the VE material.

Figure 6A shows the heel before contacting the control material; Figure 7A shows the heel before contacting the VE material.

Figures 6B and 7B show full weight contact before the material deforms: 6B shows the heel as it makes full contact with the control material. The red region indicates the location of the peak pressure and shows that it occurs over the smallest contact area; 7B shows the same for the VE material. This supports the observation that the peak pressures for the 2 materials are similar.

Figures 6C and 7C show the completion of compression and deformation. Figure 6C shows the heel when it has completed its movement into the control material. The heel has sunk into the material and stretched it laterally. It is now at the level pressure for the control material. The material has developed an elastic back pressure that is composed of both the compression and the lateral stretching. This occurs at a relatively small contact area and, therefore, at a higher level pressure. Figure 7C shows the heel when it has completed its movement into the VE material. It is now at the level pressure for the VE material. This response is quite different from that with the control material. The heel has sunk deeper and has produced a smaller amount of lateral stretching. By sinking deeper into the VE material, the contact area has increased over that with the control, and therefore, the level pressure with the VE material is lower.

Figures 6D and 7D are the cut-away drawings of Figures 6C and 7C. They show the differences in the contact areas more clearly.

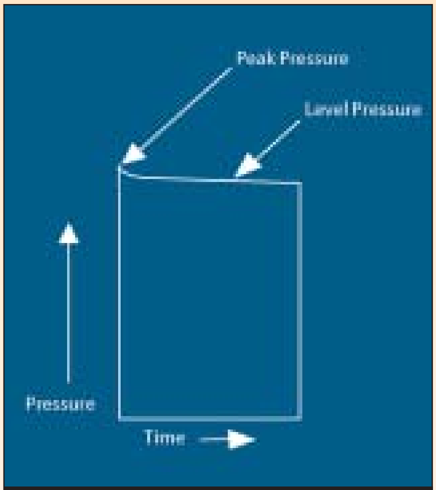

Figure 4. Pressure profile control material.

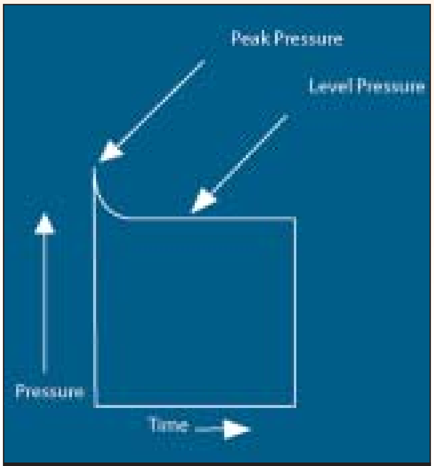

Figure 5. Pressure profile VE material.

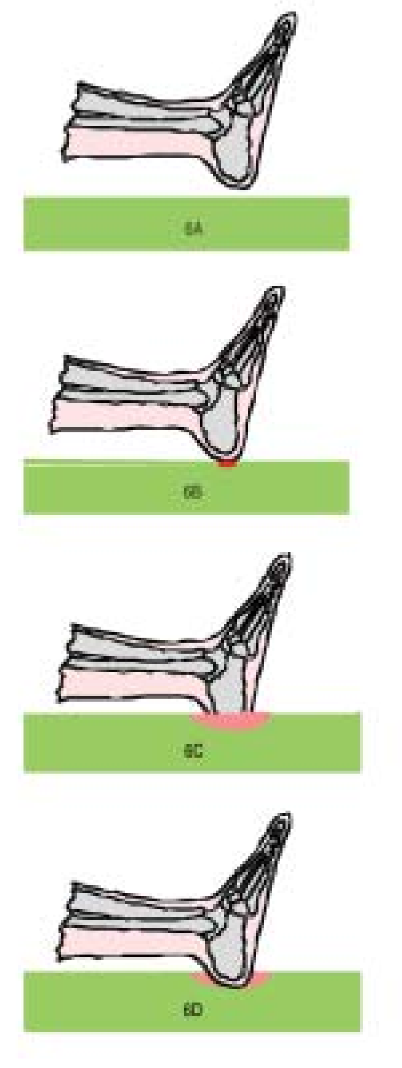

Figure 6. Compression by heel—control material.

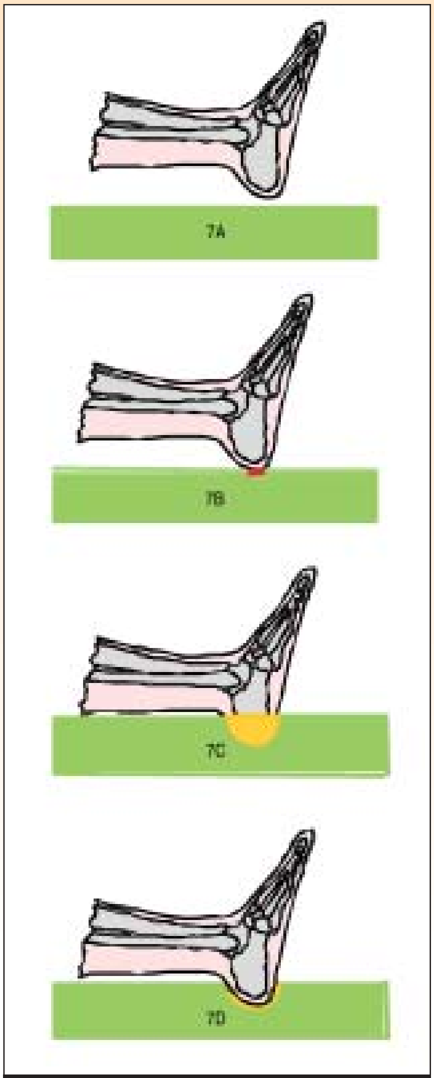

Figure 7. Compression by heel—VE material.

CONCLUSION

When we discussed mattresses made from arrangements of solid and fluid materials, we described their behaviors in terms of elastic and viscous deformation. It was noted that an effective mattress needs both components. The behavior of the VE material reflects a presence of both of these components in the same material. When it responds to the weight, the VE material first displays a fully elastic behavior quite similar to the control material. However, once deformation begins and the heel sinks into the VE material, the lateral stretching is noticeably reduced as the material appears to yield in a fluid-like manner. This reduces the back pressure due to elastic deformation, and the heel sinks further into the VE material. This process continues until the contact area has increased sufficiently to carry the weight. This increased contact area results in a lower level pressure.

When the weight is removed, both materials return to their original size. This indicates that the VE material has sufficient elastic behavior to return both the solid and fluid-like components to the material's original size. ■

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